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Distribution and behavior ecology of salmon (*Salmo salar* L.) in the North Atlantic – Report on Salmon DST tagging surveys in Icelandic waters the winter '02-'03

by

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Introduction

The present-day situation is declining status of Atlantic salmon stocks in general. Salmon stocks in freshwater are in many rivers/areas being endangered because of lower survival manly because of direct or indirect human activities. In the sea phase the survival rates are being reduced, due to environmental changes (climate>ocean>biota) affecting salmon but possibly also to some extent in certain areas due to increased fishing mortality of salmon because of the meant increased bycatch of salmon post-smolts in surface oriented pelagic fishery. Because of these circumstances it is important to improve our knowlegde on salmon ecology in the sea, especially in the oceanic areas. The Icelandic salmon DST tagging surveys are response to this situation. The research is basically enabled because of improved technology, both a new method to capture viable salmon fit for tagging and also because small enough DSTs are now available.

Salmon in Icelandic waters

The feeding Atlantic salmon (*Salmo salar* L.), including salmon of Icelandic origin, are widely dispersed in the N-Atlantic as reflected by recaptures of tagged fish (Hansen & Jacobsen 2000; Mills 2000; Gudjonsson 1988). Information is very scarce on distribution and ecology of salmon during their ocean migrations, but more information is available on salmon in the beginning and towards the end of their sea migrations in coastal waters. This is also the situation with salmon in Icelandic waters, where only a glimpse of information is available from the oceanic part, but detailed information is available on salmon migration and feeding in coastal waters west off Iceland.

The main migration pattern of Icelandic salmon in coastal waters has been described for post-smolts in the beginning of the feeding migration (Sturlaugsson 1994; Sturlaugsson & Thorisson 1995a & 1995b; Thorisson & Sturlaugsson 1995; Sturlaugsson 2000) and also for adults (1SW & 2SW) during spawning migration (Sturlaugsson 1995; Sturlaugsson & Thorisson 1997; Sturlaugsson *et al*.1997a & 1997b; Sturlaugsson 2000). These studies showed that post-smolts migrating oceanward spent most of their time very close to the sea surface (majority at < 3 meters depth) especially during night. During spawning migration adult salmon were also shown to spent most of their time very close to the sea surface and showed very strong tendency to migrate closely along shores. On the other hand their vertical distribution was showing the opposite of the post-smolt distribution, whereas they were at average staying deeper during night.

The food and feeding of salmon has also been mapped for this life phases in Icelandic coastal waters. The post-smolts most important prey types in estuaries and during their first days of oceanwards migration were decapods (crab larvae), amphipods, copepods, dipteras (imago/adult stage), euphausiids and fish larvae. The importance of some of the main prey types was area restricted e.g. dipteras and benthic amphipods (gammarids) were important in estuaries and near-shore area opposite to offshore areas where pelagic amphipods (hyperids) and fish larvae (sand eel) became the most important prey along with the crab larvae. Adult salmon finishing spawning migration in sea had overall largely ceased feeding, but those feeding had mostly low forage status, though extensive feeding was observed. These 1SW and 2SW salmon fed mostly on fish manly sand eel (Ammodytidae) and herring (*Clupea harengus* L.), but crustacean were also important prey in the northernmost parts of the West Coast.

The bits of information available on salmon from Icelandic oceanic areas are of two main sources. Firstly information on salmon as bycatch sampled from Icelandic fishermen (from fishing gear and indirectly from other fish stomachs), has given important indication of distribution of salmon and predation on salmon in Icelandic oceanic as well as coastal waters (Sturlaugsson unpubl.). On the other hand Icelandic direct research on salmon in oceanic areas is until now just based on oceanic transplanting releases of salmon tagged with data storage tags (DSTs) within their spawning migration phase (Sturlaugsson unpubl.). In general the pioneering use of DSTs on salmonids in Iceland to study their distribution and behavior ecology in sea, that started with DST tagging of salmon in 1993, have resulted in improved DSTs and given valuable methodological experience valuable for this study (Sturlaugsson 1995; Sturlaugsson and Johannsson 1996; Sturlaugsson and Gudbjornsson 1997; Sturlaugsson and Johannsson 1997; ICES 1997 &1998). Recent studies carried out by Faroe Islands and Norway have given valuable information on Atlantic salmon in the ocean (Jacobsen & Hansen 1998; Jacobsen 2000; Jacobsen *et al*. 2001; Holm *et al.* 2000). That work also resulted in new research equipment, the pelagic trawl equipped with the so called Fish-Lift, designed to catch salmon alive (Holst & Mcdonald 2000). Taken together these circumstances of new technique and corresponding experience enabled platform for the study revealed here.

Study on salmon in Icelandic oceanic waters

The Icelandic project "Mapping of distribution and behavior ecology of Atlantic salmon in oceanic areas around Iceland " was started in 2002. The project has a 3 year scheduled trawling survey activity and corresponding DST taggings into late winter ´04-´05, but analyses and reporting will be finished in 2006. In the first year of the project these Icelandic salmon tagging surveys have been carried out in co-operation of the Institute of Freshwater Fisheries and the Marine Research Institute (MRI) in Iceland in co-operation with the Institute of Marine Research (IMR) in Bergen Norway and the Fisheries Laboratory in the Faroe Islands. The IMR in Norway and the Faroese Fisheries Laboratory are carrying out same kind of research activity in Faroese and Norwegian waters and adjacent areas. All the projects are carried out within the same years and are a part of the multinational Nordic project "Distribution of salmon in relation to environmental parameters and origin in the North Atlantic - Capture, tagging and release of salmon with data storage tags (DSTs)". Before the end of the first year of research activity of the Icelandic ocean salmon DST tagging project (summer '02- summer '03), the research co-operation changed in such a way that the Institute of Freshwater Fisheries withdraw from the project, when they quit their activity in this field of research in the beginning of February 2003. Their participation was replaced by an Icelandic research company Laxfiskar (Salmon and Trout Research) that will in co-operation with MRI, IMR and the Fisheries Laboratory carry out the work of the Icelandic project and the corresponding Nordic overall project.

Study aims
Improvements of knowledge on salmon ecology in the sea is the main task in the Icelandic project as well as in the overall Nordic project on salmon in the sea. The new and detailed research methodology used in the study, enabled us a new research approach. The research work is carried out by following a group of ambitious main aims in order to investigate the temporal and spatial distribution of DST-tagged salmon in Icelandic waters and adjacent areas:

- Investigate the distribution (vertical & horizontal) and behaviour of salmon in relation to marine abiotic environmental factors (temperature & salinity) and biotic factors (information on distribution and abundance of prey, predators and competitors).
- Investigate the winter habitat of salmon
- Investigate the behaviour (temperature preference) of salmon at different age, sizes and stages of maturation
- Investigate relationships between environmental parameters and growth/mortality of salmon.
- Investigate to what extent salmon are taken as by-catch in pelagic fisheries with ref. to their distribution (vertical & horizontal)

These investigations along with the co-operating work with Faroese and Norwegian scientists are a likely starting point in improving information on salmon from oceanic areas. This is because information from the salmon's "in situ" mapping of their own environmental conditions experienced and corresponding behaviour in the sea, together with information on the marine migration routes involved and their general geographic distribution, will give new detailed and useful information. Finally increased size of such data sets will to some extent enable us to look into differences in distribution and behaviour between salmon of different age groups, wild & reared salmon and salmon originating from different areas.

The aim of the paper is to present the geographic distribution of salmon captured in pelagic trawl surveys carried out in the winter of 2002 - 2003 and the research methods used and the material collected.

Material and methods

Surveys and salmon surface trawling
In the winter of 2002 –2003 two salmon research surveys were conducted in Icelandic waters in co-operation of the Institute of Freshwater Fisheries and the Marine Research Institute through participation in routine cruises of R/V Arni Fridriksson (70 m research vessel fully equipped for high seas investigations) within the 200 miles economical Zone. These cruises were directed towards capelin (*Mallotus villosus* Müller) and herring stock abundance estimations and hydrographical measurements, but salmon trawling was as much as possible carried out parallel to that activity. These surveys were carried out November 8 – December 13 2002 and January 6-24 2003. Special pelagic salmon trawl, the "Oceanic Fish-Lift" (OFL), a live fish trawl sampler developed at the IMR was used to carry out survey trawling for salmon in the surface layer (down from 0 m depth). Holst & Mcdonald (2000) describe the design and size of the OFL, but details on the general trawling technology used, are given in Holm *et al*. (2000). The Ocean Fish Lift is equipped with 1 m^3 aluminum boat shaped "aquarium". The aquarium box is attached directly to the trawl, replacing the cod-end. Sorting grid frame is placed in the upper part of the aquarium box. Fish that does not pass through the gaps between the grids (19 mm intervals between grids), enters the lower part of the box that represent the aquarium container facility, where the fish stay protected in a non-turbulent sea during trawling. The trawl successfully captures post-smolts but also capture grilse though not effectively in general, but increased towing speed or/and lower temperature favour grilse captures.

In the Icelandic survey we used the salmon trawl and the OFL with 3.2 m^2 (400 kg) trawl doors and trawled at 3 – 4.5 knots. During day the trawl was towed in large arcs to keep the trawl out of the wake of the ship, but during darkness the surface trawl was for precautionary reasons towed in the wake because during that period it was impossible to follow it up visually. Because the trawlings for salmon reached up to the actual surface (two 120" bouys attached to the upper bridle/wing end & 3 fenders on the headline), they were only carried out when conditions allowed because of wind and waves. The work was also affected by tasks involving capelin or herring stock abundance estimations and hydrographical measurements. All trawling in November and December occurred or at least started when light conditions were daylight–dusk hours (Table 1). In the

January survey trawling occurred also during dark hours. Trawling usually was conducted for one hour (Table 1). In Table 1 the sites & dates of the surface trawling for salmon are listed. Data storage tag measuring depth (pressure) and temperature at 1 or 2 minutes intervals were fastened to the aquarium box and sometimes also to the headline in order to follow more closely up how the trawl worked, than was possible by visual check from the ship, also giving detailed data on temperature distribution (Fig. 4).

Sampling of hydrographical data

Temperature and salinity were sampled continuously from the ship at 5 m depth at 1 minute interval. This was directly comparable to the conditions in the layer trawled (0 - ca 10 m). Additionally a vertical CDT measurements (temperature & salinity) were taken at or near the trawling sites in most instances, usually down to bottom but in some cases just the uppermost 50 m (Table 2). The measurements carried out on temperature at 1-2 sites on the trawl, enabled us to look closer into the temperature distribution if needed. These measurements also enabled to detect possible variation in temperature and salinity at each trawling site, both vertically and horizontally (Figs. 3 & 4).

In order to have a further comparison in relation to salmon distribution, data on temperature and/or salinity were received from measurements on sea surface temperatures (SSTs) from satellites measurements (images), measurements from moored stations and from available hydrographical surveys. Estimation of salmon distribution will be done by simulation between the temperature data from salmon DSTs and the available information of sea temperature manly based on SSTs. This comparison is possible because the salmon mainly migrate trough the uppermost meters of the sea.

Study area, tagging and releases

Salmon trawling stations are shown in fig. 1. When salmon were captured they were transferred in sea water from the aquarium box to a holder tank with flowing sea, where they were kept for a short while until they were tagged. Following tagging the fish were kept in the holder tank for short time in order to ensure their recovery ("wake up period") following the tagging anesthesia. Fish were anaesthetized using controlled phenylethanol solution while tagged, measured (fork length and weight) and during counting of sea lices (*Lepheoptheirus salmonis* Krøyer). The salmon lice infestation rate of the captured salmon was checked and simultaneously they were sorted into groups of the largest individuals (adult females) and smaller individuals representing males and possibly others. Indication of reared origin was checked (fin condition etc). When each fish had been calm by anesthesia it was tagged with data storage tag by surgical implantation. The placement of the tag into the body cavity (intraperitoneal tagging) was based on a very small surgical incision (just enabling to implant the tag) that was located a little bit anterior to the pelvic fins. A hole was also made through the body wall posterior of the incision with a hollow needle, where soft plastic advertising spaghetti tube (1,5 mm in diameter, yellow or pink in color) that is fastened to the DST was threaded out through. The DST was carefully put into the abdomen in posterior direction and when the tag was in place a knot was made on the advertising plastic tube to ensure that the tube would stick out through body wall serving its purpose of advertising the DST inside. The incision was then closed with a synthetic absorbable suture that disappears in a few weeks. The fish was then injected with antibiotics and B vitamins. The incision was then covered with a fungicide (Aureomycin). For determination of age and growth history, 3-5 scales were sampled from each fish. For determining of country/stock origin by tissue analysis the adipose fin was cut off (part of pelvic fin was taken in case of microtagged fish were that fin had been removed). External numbered tag (Floy T-bar anchor type) was put uppermost in the back, into the base of the dorsal fin in order to follow up whether shedding of DSTs or the advertising tubes of the DSTs would occur. When the fish had recovered as shown by proper balance and activity, the fish were released after the ship had stopped. Release was carried out by lowering the fish in a small release tank down to sea level where they were released. Because of the OFL method the tagged fish were in especially good condition. That together with the fact that the time of tagging takes place when much of the post-smolt mortality has already taken place, gives us a reason to anticipate freshwater recapture rates of ca 10% from these DST salmon. In order to ensure enough data for analysis, the DST tagging in Icelandic waters as well as in Faroe Islands and Norwegian waters has been scheduled for three years. For the same reason data evaluation will partly being carried out by pooling together data from all the Nordic participants. Salmon tagged with DSTs will mostly be captured as grilse (1SW) but to much lesser extend as salmon (2SW).

Tag types, programming and data retrieval

Data storage tags are pre-programmed microprocessor-controlled data-logging tags that measure information in their surroundings and record it on internal (onboard) memory without any external recording devices. DSTs are not actively monitored but rely on the tag being found and returned in order to retrieve the stored information. The DSTs used were of the type “DSTmilli” from Star-Oddi. The amount of “DSTmilli” allocated for the tagging during the winter ´02-´03 were 150 tags, the tags not used within the period are added to the next tagging period. The size and features of these electronic tags together with information on how they were programmed for this study is listed in Table 3. The “DSTmilli” is a very small tag with cylindrical shaped housing made of ceramic (biocompatible). The miniature size enables tagging of relatively small fish like salmon post-smolts after they have reached certain minium size (Fig. 2.).

The “DSTmilli” measures in relation to given time two parameters, depth (pressure) and corresponding temperature, utilising a real time clock inside the tag. Communication and data transfer is wireless through a box connected to a PC. Therefore no need is for opening up of tags for direct plug-in when they are programmed or during uploading of data from retrieved DSTs. Prior to applying the tag to the fish, the starting time and sampling intervals are chosen. DSTs used in Icelandic waters were programmed to take the parallel temperature and depth measurements with two different time intervals within a total sampling period of 2 years. Most of the time the DSTs are measuring at 1 hour interval but at given days within the 1_{st} year they measure at 1 minute interval.

Information on where and how to return tags and on the reward are written on the tag houses (100$ reward is paid for returning DST). The attached advertising tube leads to the electronic tag and the written information on the housing make it both easy and interesting for the fisherman to return the tag. When DST is recovered the data is retrieved by uploading it via the upload box by using special Windows software. The time related information on the fish behavior and its environment are then available for evaluation.

Results and discussion

Trawling

The effort of salmon trawling in Icelandic waters in the winter 2002 – 2003 and the corresponding capture of salmon is presented in Figure 1 and Table 1. Although the cruises included surveys around Iceland and over long time periods the salmon trawling activity was less than scheduled, and the trawling site distribution did not represent satisfactory, the waters surveyed around Iceland (Fig.1 & Table 1). The reasons for lesser trawling activity than expected in relation to the total time of cruises are manly two. Firstly because of unusually bad weather that was interfering with the work during a large part of these cruises. Secondly the reduction intrawling activity was because of major difficulties in locating the capelin and herring schools, because those stock abundance estimations were the main task of the cruises along with the hydrographical measurements.

A total of 16 sites were trawled for salmon for ca 19 hours. Thereof the first two sites (# 522 & 523) represent nearly 4 hours of the total 19 hours, which were taken as an exercise in a sheltered fjord where salmon were not expected to be caught, where the research vessel was waiting because of adverse weather. Another examples of a trawl sites where expectancy of salmon capture was little but nevertheless interesting to look at, were trawl sites no. 560 (0.2-2°C temperature at 5m depth) and no. 617 (ineffective trawling due to critical weather/wave conditions) (Table 1 & 2). Taken this into account the chance to capture salmon was reasonable in 12 out of 16 trawl sites (in 13 hours of the 19 hours trawled). In 4 hauls of those 12, salmon post-smolts were captured, despite the fact that 2 of these trawlings were made in the wake of the ship because they were carried out during the dark hours (Table 1). The capture versus fishing effort shows both how efficient the trawl is and also indicates that the waters within the Iceland economic zone east off Iceland are winter habitat of post-smolts. Despite attempts to capture salmon in the waters west and northwest off Iceland they did not result in capture. The frequency of trawling in those areas is on the other hand too limited in number to postulate something. It is however, tempting to speculate whether this difference in catch between the waters surveyed in the eastern and western part of the economic zone are real indication of differences between these areas as winter habitats for salmon post-smolts.

Salmon captured by the surface trawling with the OFL were in good condition, as reflected by very little scale loss of these fish. The only exception of a salmon caught in the trawl , that could not be used for tagging, was when the trawl had twisted itself before trawling so that the fish captured during the trawling could not enter the aquarium container. Unfortunately that happened during the best salmon haul so instead of being able to DST tag those 16 salmon, their stomach samples were taken instead (Table 4). The stomach samples have not been analysed but pelagic amphipods were seen to be eaten in considerable amounts.

Salmon capture & distribution

A total of 28 salmon were captured during the salmon surface trawlings, whereof 11 were tagged with DSTs (Table 1 & 4). In addition other fish species were caught in the surface trawl, mainly the lumpsucker (*Cyclopterus Lumpu*s L.), but herring was also caught (Table 1). One microtagged salmon was recaptured and could therefore not be tagged, whereas the snout had to be taken to obtain the coded wire tag. Age of the salmon captured has not yet been verified by scale sample analysis. But based on the salmon size distribution these salmon are all representing the post-smolt phase, although the two largest fish captured in November (50 & 53 cm) may possibly be very small grilse going into their second year (Fig. 3. & Table 1). The limited number of salmon captured and the few trawling stations that gave salmon capture (4) means that the data is poorly representative for Icelandic waters as a whole, but these captures surely give interesting indication on post-smolt winter habitat in waters east off Iceland (Tables 1, 4 & 5). This data agrees with information obtained from fishermen that demonstrates that a few post-smolts have been captured in pelagic fishing on herring and capelin (Sturlaugsson unpublished).

Following recaptures of DST tagged salmon, the measurements on the fishes behavior (depth/temp. within a day-seasons/areas) and on its environment (temp./depth) will be used to map their behaviour. This information will also enable estimations on their geographical distribution including their distributional (vertical/horizontal) interaction with known abiotic (temperature & salinity) and biotic factors (prey, predators & competitors).

Salmon habitat

The salmon winter habitat that we found east of Iceland was ranging from coastal area (< 200 m bottom depth) just 50 km from nearest shore and out to 250 km east of that site where the easternmost trawling site was located in the oceanic area (Table 5). The temperature and salinity of the area where salmon were captured was especially interesting. Although the data is limited, the thermal range observed in this area gives interesting indication and the same is true for the salinity (Table 2 & 5 and Figs. 3 & 4). Due to shortage of such data from the mid-winter period this hydrographical data sampled parallel to salmon capture is already giving interesting information on the salmons temperature (sea type) preference during this time of the year in this area of the N-Atlantic. It is, for example interesting that the salmon captures in January were within 3.9-4.8 °C and salinity of 34.2-34.6 S, whereas in the warmer and more saline waters short distance away no salmon captches occurred. It will be interesting to receive temperature data from DSTs in order to be able to define the main thermal preferences for given life stage and season. In that context it will also be interesting to see if the salmon has tendency to take advantage of the thermal fronts e.g. in context of feeding and digestion, but these fronts are available both vertically (Fig. 3a) and horizontally (Fig. 4b).

Salmon size, condition, origin and growth

The few salmon captured in end of November showed large variation in size ranging from 36 to 53 cm in fork length (Table 1 & Fig. 5a). In January the size of the salmon captured was not as variable (Table 1 & Fig. 5b). The condition factor (Fultons) of the post-smolts (pre-grilse) ranged between 0.86 – 1,12 in November and between 0.89-1.03 in January (Fig. 6). No obvious relationship was found between condition factor of salmon and their salmon lice infestation rate.

The number and composition of salmon lice was possible to determine for the 12 fish that were captured via the fish lift aquarium (Fig. 7). It should though be noted that part of the salmon with lower rate of sea lice might have lost some sea lice during the trawling as indicated by one example where fish had “fresh” heavy skin lesions in the head region, but was at the same time nearly without sea lice. The infestation rate of salmon lice per individual salmon ranged from a total of 2 – 32 whereof maximum number of adult females sea lice was highest 24 sea lice. In November on the average 7 sea lice were attached to each salmon (SD = 6) and in January the mean number of salmon lice per individual was 14 (SD = 11). The number of salmon lice observed is of interest in the context that the amount of sea lice can affect both growth and survival of salmon as has been shown by experiments that also gave information on how infestation rates above certain limits are lethal for the fish (Finstad *et al*. 1994; Grimnes & Jacobsen 1995).

The origin of the salmon that were captured is not known, with one exception. That fish had been microtagged and was recaptured during trawling in the end of November at station no. 631. That salmon originated from W-Ireland, showing that fish from that area can stay at least a part of the winter in Icelandic waters (Table 4). A check on fin condition etc gave no indication that the captured salmon were derived from rearing. That issue will finally be checked by thorough scale analysis. That work will also give interesting information on the distribution of the smolt (river) age of the fish captured. Will the smolt age reflect the general trend found among Icelandic stocks? Or will we see salmon that has left their rivers as 1+ smolts and are therefore not of Icelandic origin but representing "overwintering" of salmon derived from "southern" stocks? Analysis of tissue has not been carried out, but it surely can also give interesting information.

When DSTs from tagged salmon from the feeding areas start to be recovered it gives a unique opportunity to look into the possible links between the growth of those fish (body & scale growth) from the time of their DST tagging and compare it to the temperature/depth experienced by the fish during that period (Sturlaugsson 1995). If that comparison would result in some main relationship being found between the temperature experienced and the scale growth patterns (number of growth rings, the distance between them etc.), it would most likely increase the use of the many massive scale collections that are available. Because scales from post-smolts in mid-winter are far from being common samples, it is now already interesting to analyse briefly the winter growth pattern status of the fish captured in Icelandic waters the winter '02-'03 (number of growth rings etc.).

One of the positive output of the 3 years tagging in Icelandic waters and in the overall Nordic project, will be new information on the winter environmental condition of salmon. Those are derived both from hydrographical measurements carried out during the winter research captures parallel to tagging. But later on from the detailed "in situ" measurements that will be retrieved from recovered DSTs from these tagging. These information together will obviously be valuable input in order to improve the model based on pre-fishery abundance prediction (size of stocks vs size of winter habitat based on corresponding optimal sea thermal range) to provide catch advice on North American and European salmon.

Concluding remarks

The Icelandic DST tagging survey and the co-sponsored DST tagging surveys in Faroese, Norwegian and adjacent waters have established a successful salmon research technology by combining use of new small data storage tags and new capture method for oceanic tagging. The Icelandic project has already given valuable information on the distribution of salmon in Icelandic waters obtained from winter captures and tagging, thereby enabling new insight to the conditions of salmon in mid-winter, the period of the year where shortage of direct ecological data on salmon in the sea is critical. This information and the detailed "in situ" information on salmon sea migrations to be retrieved from recaptured DSTs from all the 3 years of tagging, will be a good starting point in using this methodology to help us to map the main patterns in salmon behaviour ecology in the N-Atlantic. Such improvements of knowledge on the distribution of salmon and the corresponding behavior and growth of the individuals, are really needed in order to improve understanding on salmon survival in the sea and thereby salmon management, conservation and of course further research on salmon in the N-Atlantic.

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Figures and tables

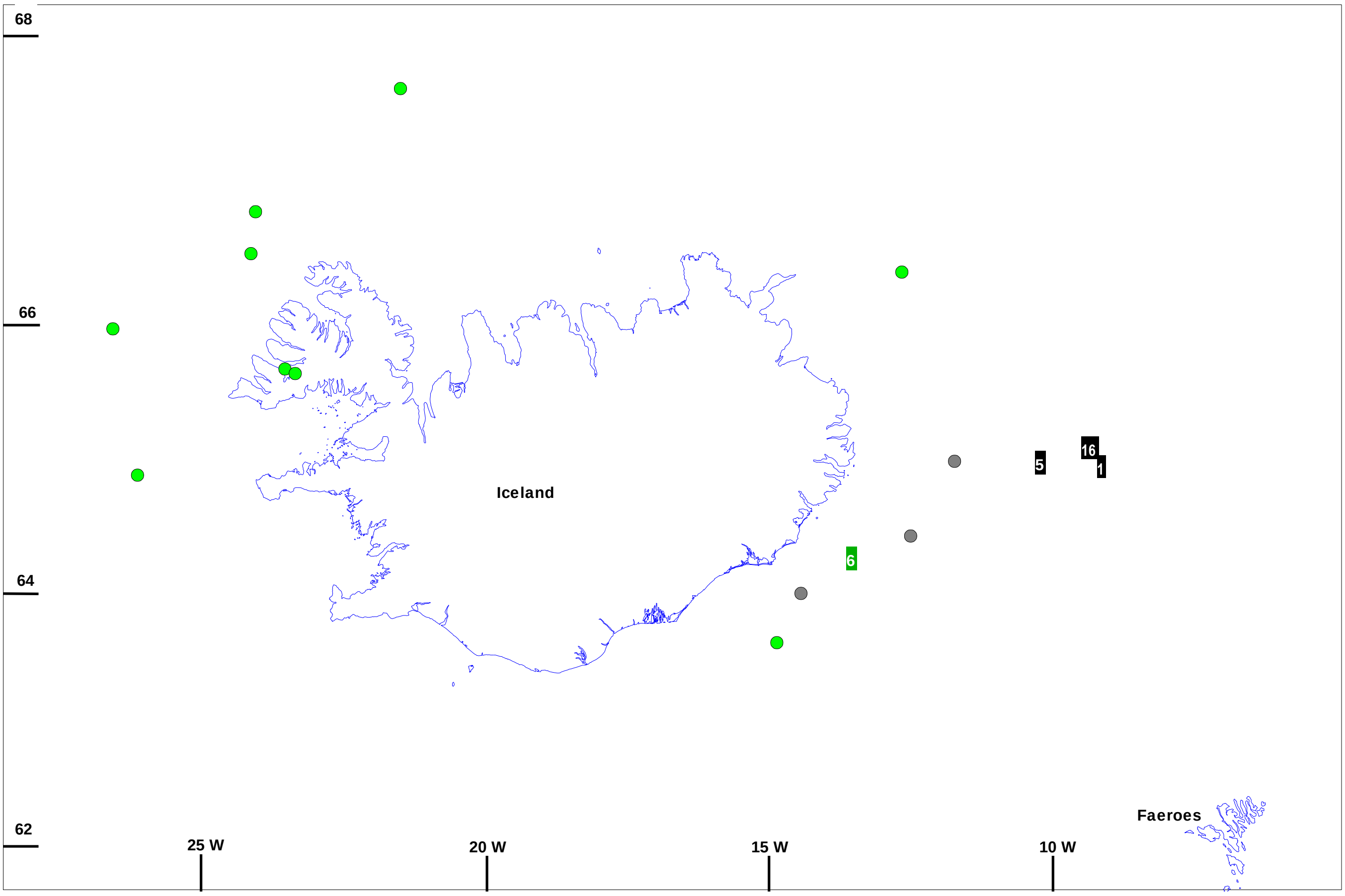


Figure 1. Locasion of trawl sites in Icelandic waters where surface trawling was conducted for salmon in November ´02 – Januar ’03, during surveys on the research vessel Arni Fridriksson. The trawling sites are indicated with circles if there are no salmon captured, but squares indicate if salmon were captured. Green color stands for trawling in November and December 2002, but black/grey color stands for trawling in January 2003. Number of captured salmon in given haul are given in the symbols where salmon were captured.

Table 1. Sites were salmon surface trawl were used for sampling during combined capelin/herring/salmon surveys carried out in Icelandic waters within the time interval Nov. ´02 – Jan ´03 and informations on corresponding capture. Number of trawl sites are given, their position, bottomn depth and the time of the trawling. The capture is listed in relation to the fish species involved, the catch per unit (CPU, given as no./1hour) and in relation to the fish size, both length and weight (mean, along with standard deviation and max & min).

Trawling sites							Capture										
										Fish length				Fish weight			
No.	**Position - start of haul (°N °W)**	**Position - end of haul (°N °W)**	**Bott-om depth (m)**	**Date ´02 (Nov-Dec) '03 (Jan)**	**Time of day**	**Haul time (min)**	**Fish species**	**No. of fish**	**CPU (no./ hour)**	**Mean length (cm)**	**SD**	**Min**	**Max**	**Mean weight (g)**	**SD**	**Min**	**Max**
522	65°42´0 23°33´0	65°46´4 23°45´4	100 - 100	12/11	7:14 - 8:59	105	Herring	193	110	9,6	1,5	8	15				
523	65°40´0 23°22´2	65°43´0 23°36´1	84 - 98	12/11	12:30 - 13:30	120	Herring	23	12	9,3	1,5	8	14				
529	66°31´5 24°09´0	66°35´4 23°57´8	106 - 228	13/11	14:40 - 16:10	90	Lump-sucker	16	11	18,0	11,7	9	42				
530	66°49´1 24°04´1	66°56´6 24°11´8	147 - 340	13/11	18:03 - 20:03	120	Lump-sucker	159	80	13,0	6,1	7	39				
560	67°39´6 21°30´8	67°38´7 21°21´9	710 - 740	16/11	15:23 - 16:23	60	Lump-sucker	5	5	22,3	7,9	14	31				
617	66°23´7 12°40´2	66°25´0 12°37´0	198 - 276	25/11	15:50 - 16:40	50											
631	64°16´5 13°32´1	64°18´1 13°39´0	165 - 170	30/11	12:25 - 13:25	60	**Salmon**	6	6	46,6	7,0	35,8	53,4	1085	448	396	1590
-	-	-	-	-	-	-	Lump-sucker	13	13	20,6	6,5	13	31				
637	63°37´9 14°52´5	63°40´3 14°49´6	142 - 217	1/12	10:25 - 11:25	60											
652	64°55´0 26°09´0	64°57´9 26°09´3	183 - 178	7/12	13:25 - 14:25	60	Lump-sucker	1	1	21,6							
659	65°59´4 26°35´0	65°58´7 26°27´9	284 - 291	9/12	13:13 - 14:13	60											
20	65°05´6 9°19´8	65°07´3 9°10´8	818-883	10/1	15:15 - 16:15	60	**Salmon**	16	16	43,4	2,0	39,0	45,6	791	108	538	878
22	65°00´0 9°03´8	65°00´0 9°12´2	1255-1100	10/1	19:00 - 20:00	60	**Salmon**	1	1	44,7				857			
-	-	-	-	-	-	-	Lump-sucker	1	1	15,5							
24	65°00´0 10°12´3	65°01´5 10°20´7	502 - 451	10-11 /1	23:47 - 00:47	60	**Salmon**	5	5	44,8	3,1	40,8	49,3	863	148	681	1087
-	-	-	-	-	-	-	Lump-sucker	6	6	22,2	10,0	7,2	35,5				
27	65°01´2 11°44´5	65°03´4 11°50´7	212 - 236	11/1	05:55 - 06:55	60	Lump-sucker	1	1	18,6							
32	64°01´0 14°27´0	63°57´4 14°24´5	135 - 117	11/1	19:12 - 20:12	60											
67	64°27´4 12°31´0	64°24´2 12°34´1	166 - 168	22-23 /1	23:11 - 00:11	60	Lump-sucker	7	7	21	6,3	15,8	33,0				
-	-	-	-	-	-	-	Herring	8	8	34,0	4,2	26,3	39,7				

Table 2. Sea temperature and salinity at surface trawl sites during salmon DST tagging survey during Nov. ´02 – Jan. ´03. Measurements given here were carried out during each trawling at 5 m depth with 1 minute measuring interval (mean, standard deviation, max & min). Vertical sections of temperature and salinity were also measured with CDT at/near trawling stations (positions of the CDT sections are given). (S = ‰).

Trawl sites	**Salinity (5 m depth)**				**Temperature (5 m depth)**				**Salinity and temperature (from vertical CDT measurements)**				
Number (no. is bold if salmon caught)	**Mean (S)**	**SD**	**Max (S)**	**Min (S)**	**Mean (°C)**	**SD**	**Max (°C)**	**Min (°C)**	**5 m depth** Salinity (S)	**5 m depth** Temp. (°C)	**50 m depth** Salinity (S)	**50 m depth** Temp. (°C)	**Position of CDT sections (°N °W)**
522					7	0,74	8,2	6,4	34,38	6,5	34,38	6,5	65°42´54 23°35´30
523					6,4	0,01	6,5	6,1	-	-	-	-	-
529	35,0	0,02	35,0	34,9	7,0	0,08	7,1	6,8	34,91	7,3	34,92	7,3	66°24´12 24°37´82
530	34,5	0,38	34,9	33,7	6,8	0,11	6,9	6,6	34,31	3,4	34,39	3,9	67°05´12 24°22´90
									34,86	6,7	34,86	6,7	66°41´10 23°08´96
560	33,9	0,12	34,2	33,6	0,8	0,62	2,1	0,2	34,12	2,2	34,31	3,6	67°39´95 21°34´87
617	34,4	0,04	34,4	34,3	4,9	0,14	5,0	4,6	34,51	5,1	34,50	5,1	66°21´94 13°00´17
631	34,6	0,06	34,8	34,5	6,8	0,21	7,2	6,5	34,51	5,9	34,90	7,5	64°18´13 13°22´37
637	35,1	0,01	35,1	35,1	8,1	0,03	8,2	8,1	35,17	8,5	35,17	8,5	63°40´77 14°48´46
652	34,9	0,03	35,0	34,9	7,6	0,03	7,6	7,6					
659	34,9	0,03	35,0	34,9	7,6	0,03	7,6	7,6					
20	34,5	0,01	34,5	34,4	4,1	0,07	4,2	4,0	34,56	4,4	34,59	4,5	64°59´96 08°59´99
22	34,4	0,09	34,3	34,5	4,1	0,13	4,4	3,9	34,50	3,9	34,53	3,9	65°00´01 10°06´71
24	34,5	0,09	34,6	34,2	4,6	0,12	4,8	4,3	34,48	3,6	34,49	3,6	65°00´21 11°17´21
									34,49	4,2	34,67	4,5	64°59´97 11°39´83
27	34,5	0,09	34,5	34,5	4,2	0,03	4,3	4,2	34,58	4,5	34,60	4,6	64°59´97 12°48´89
									34,39	4,2	34,39	4,2	65°00´02 13°29´97
32	34,7	0,09	35,0	34,3	7,7	0,18	8,1	7,3	34,92	7,2	34,93	7,1	64°02´00 14°28´16
									35,07	7,7	35,08	7,7	63°51´90 14°07´86
67					5,0	0,68	6,5	4,3					

Table 3. DSTmilli size, weight, technical features and programming.

Size (diameter x length)	12.5 mm x 38.4 mm
Weight (in air/in water)	9.6g / 5g
Temperature range (measuring interval)	(-1) - (+21°C)
Depth range (measuring interval)	0 - 500 m
Memory capacity	43476 measurements 21738 measurements/parameter
Temperature - resolution	0,032°C
Depth - resolution	0,15 m (0,025% of the max of the mesuring interval)
Temperature - accuracy	+/- 0,1 °C
Depth - accuracy	+/- 2,0 m
Measuring intervals	1 hour interval and 1 minute interval for given days inbetween. Tot. meas. interval = 2 years.
Data retention	25 years
Clock	Real time clock. Accuracy +/-1 min/month
Batteries - lifetime	24 months (minium)

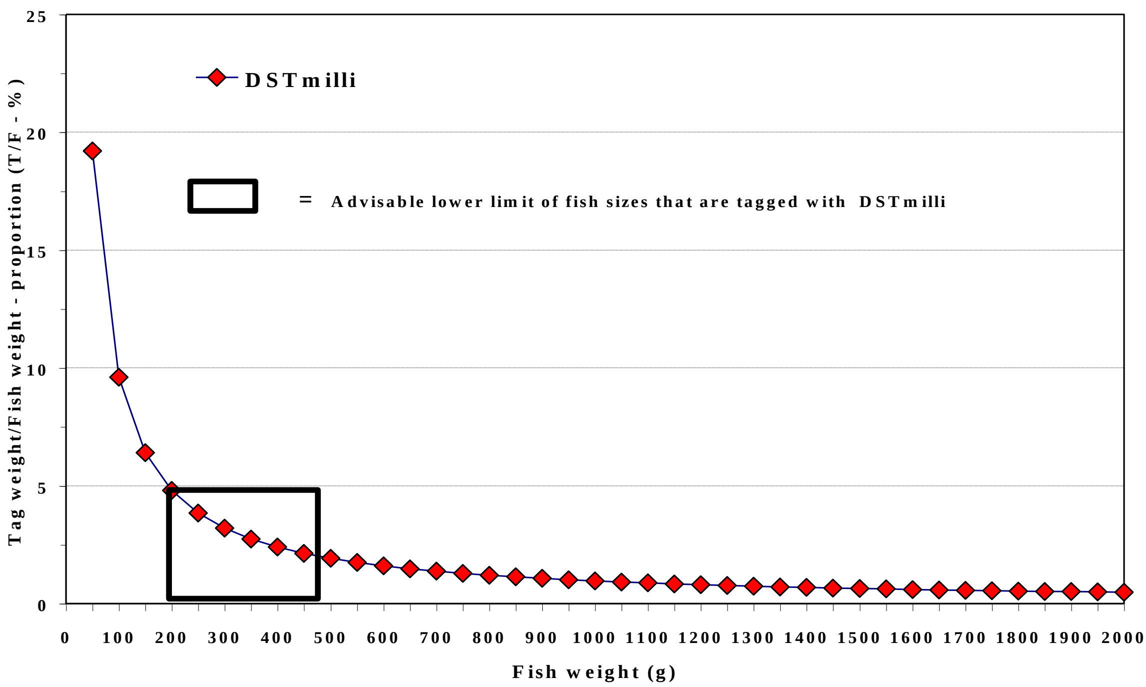


Figure 2. The weight of the data storage tag DSTmilli (9,6 g) shown as proportion (%) of fish weight for given weight interval of fish. Length interval of fish within this weight interval (200-2000g) would be ranging from ca 25-28cm up to ca 55-60cm. The black frame enclosure the advisable lower limit in fish size to be tagged with DSTmicro and DSTmilli according to the thumb rule that maximum values of T/F weight ratio should be in the interval 2-5%. Here it must be kept in mind how fast salmon is growing during the sea (feeding) migration, so their T/F weight ratio is lowering rapidly during the feeding migration.

Table 4. Overview of capture of salmon and corresponding tagging, sampling and recaptures of tags.

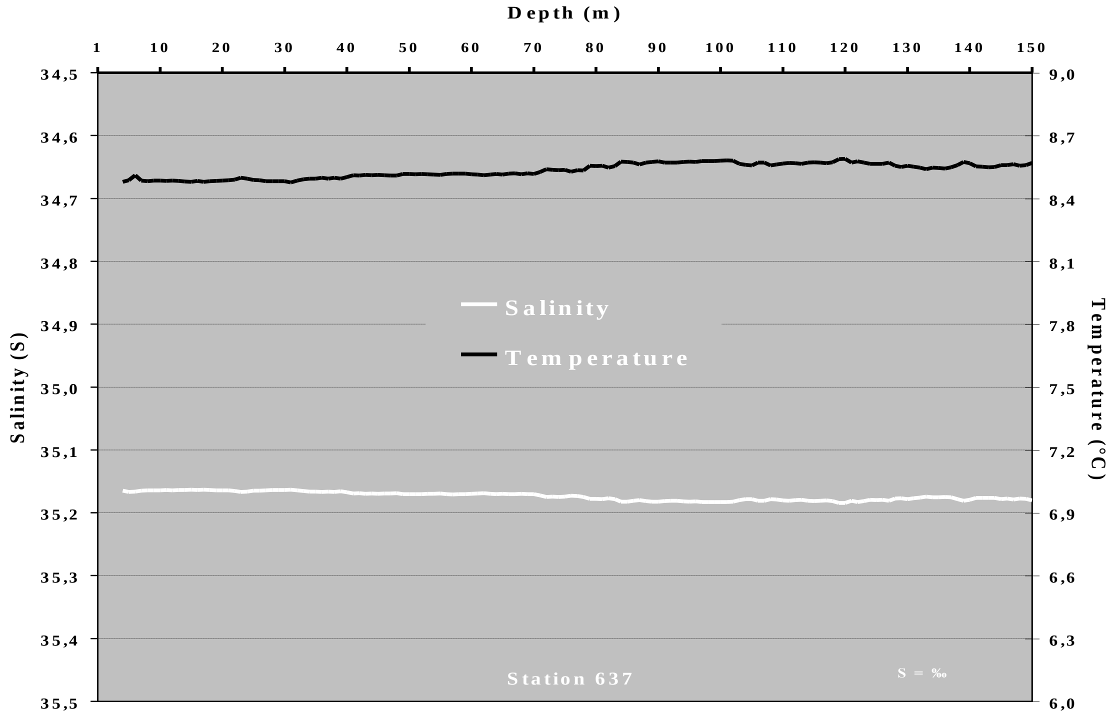
Salmon captures & corresponding tagging and/or sampling from captured fish

Time period of surveys (months)	Capture (no.)	Tagged with DSTs (no.)	Stomach samples (no.)	Recaptured coded wire tags (no.)	Origin of recaptured tagged salmon	Sampling of scales for growth /age /origin analysis (no.)	Sampling of adipose fin (tissue) for analysis on origin with ref. to country/stock (no.)
Nov. - Dec. 2002	6	5		1	Ireland	6	6
January 2002	22	6	16			22	22
Total (Nov ´02 -Jan ´03)	28	11	16	1		28	28

Table 5. Information on the outlines of areas and conditions involved in the salmon tagging surveys in Icelandic waters during the winter ´02-´03, in relation to survey periods and salmon capture, (S = ‰).

Location & Conditions of areas surveyed for salmon in relation to survey periods and capture

Time period of surveys (months)	Area of survey interval (°N-°N & °W-°W)	Area of survey including salmon capture interval (°N-°N & °W-°W)	Bottom depth surveyed - interval (m)	Bottom depth involving salmon capture - interval (m)	Temperature intervals of trawled routes at 5 m depth (°C)	Temperature intervals of trawled routes at 5 m depth where salmon captured (°C)	Salinity intervals of trawled routes at 5 m depth (S)	Salinity intervals of trawled routes at 5 m depth where salmon captured (S)
Nov. - Dec. 2002	63°38´ - 67°40´ N 12°37´ - 26°35´ W	64°17´ - 64°18´ N 13°32´ - 13°39´ W	84 - 740	165 - 170	0.2 - 8.2	6.5 - 7.2	33.6 - 35.1	34.5 - 34.8
January 2002	63°57´ - 65°07´ N 9°04´ - 14°27´ W	65°00´ - 65°07´ N 9°04´ - 10°21´ W	117 - 1255	451 - 1255	3.9 - 8.2	3.9 - 4.8	34.2 - 35.0	34.2 - 34.6
Total (Nov ´02 -Jan ´03)	63°38´ - 67°40´ N 9°04´ - 26°35´ W	64°17´ - 65°07´ N 9°04´ - 13°39´ W	84 - 1255	165 - 1255	0.2 - 8.2	3.9 - 7.2	33.6 - 35.1	34.2 - 34.8



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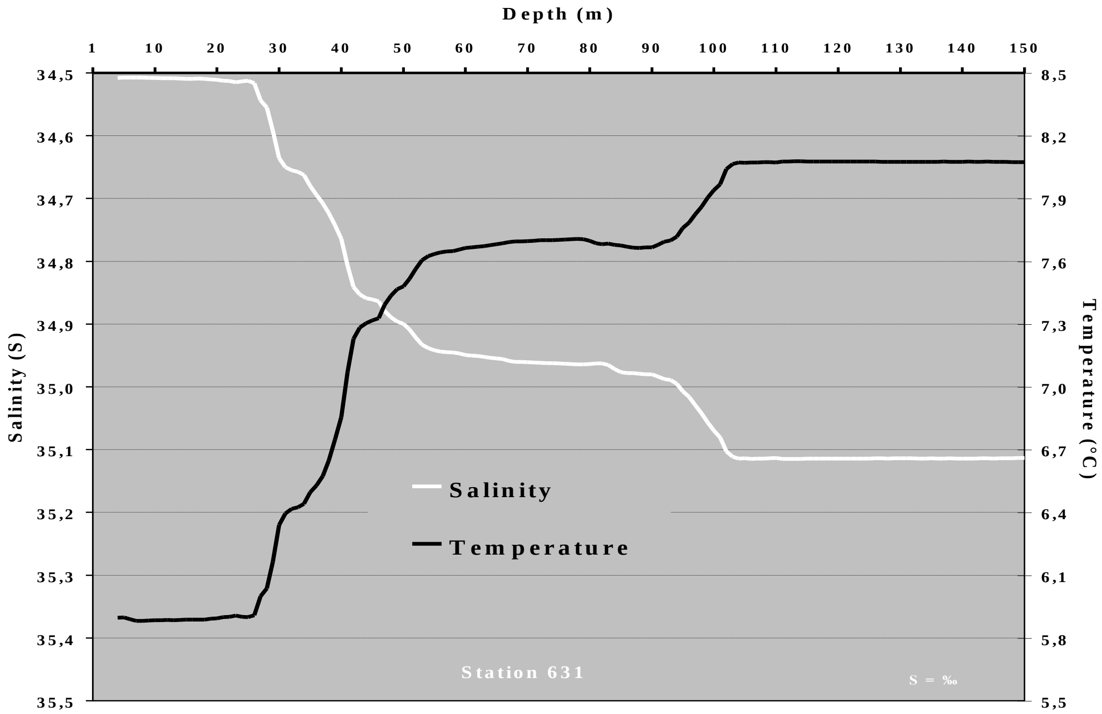
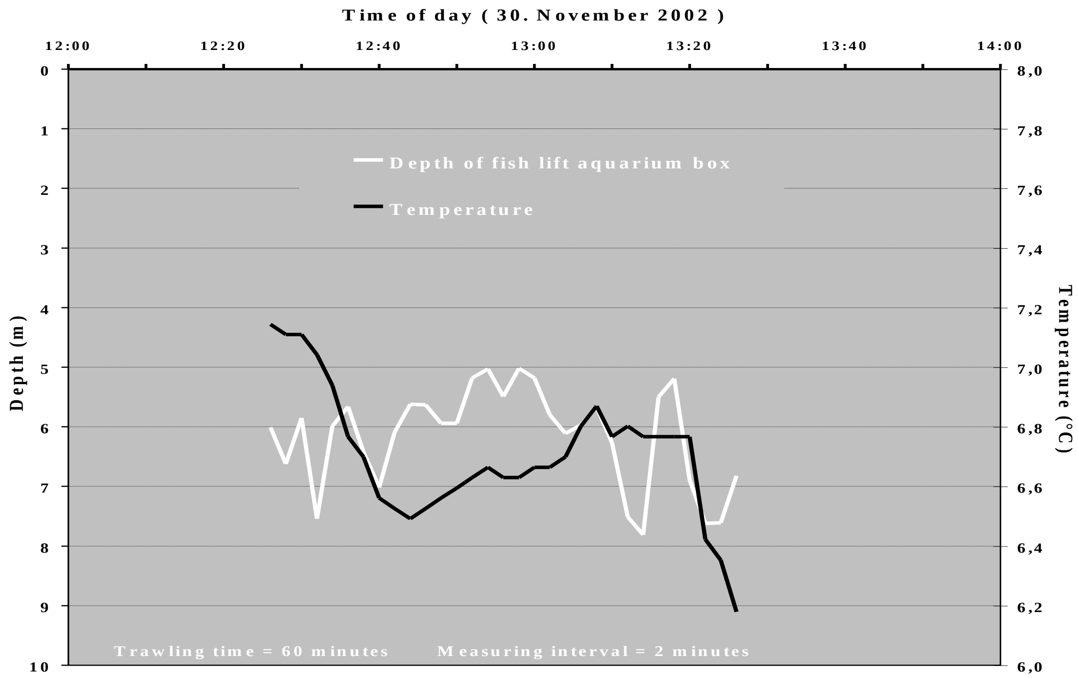


B.

Figure 3. Salinity and temperature vertical sections (150 uppermost meters profiles) at station 637 (**A**) and at station 631 (**B**). Sampling with surface salmon trawl at these stations gave salmon and lump sucker capture at station no. 631 (30. Nov. ´02), but non capture when trawling at station no 637 (1. Dec. ´02) .



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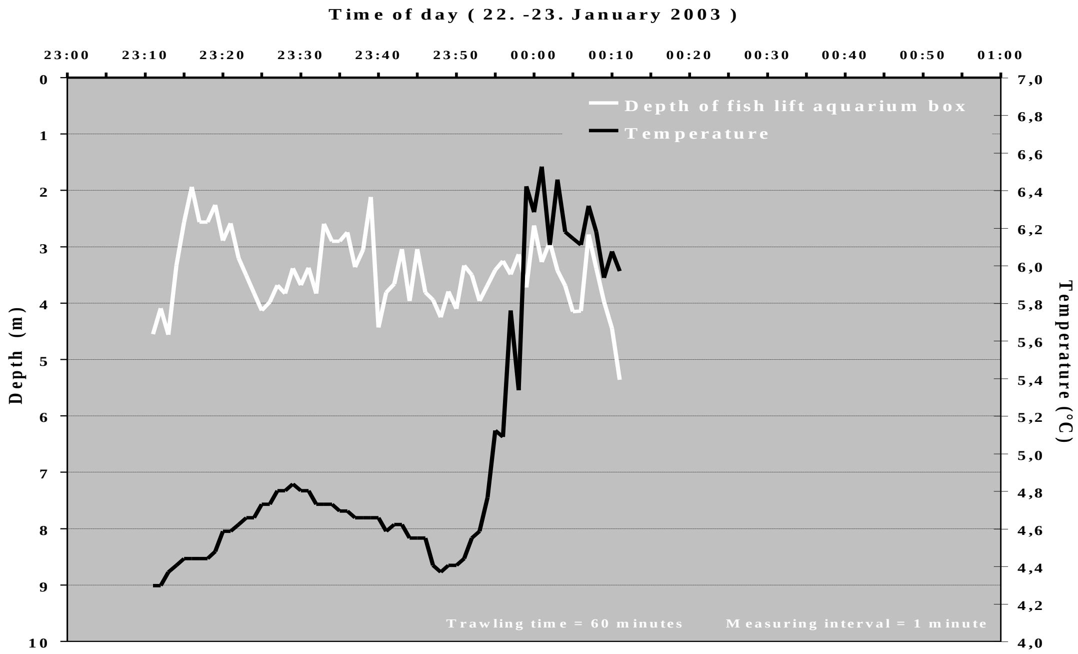
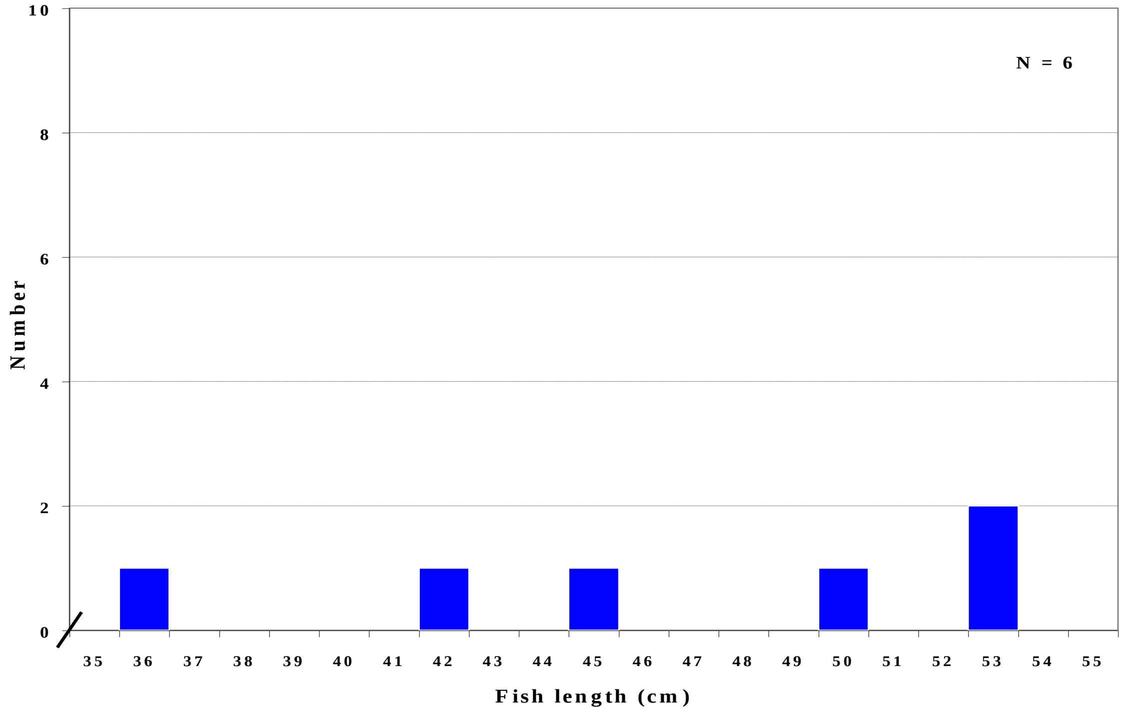


B.

Figure 4. Tracks of fish lift aquarium box (tank) during two hauls (figs. 4A and 4B) with salmon surface trawl, in relation to the depth of the box and corresponding sea temperature. The tank is "replacing" the cod end of the trawl that is fishing from the surface down to ca. 10 meters. The proportionally large variation in temperature shown here within same depth layer in short distance measured (1 hour haul at 4 knots) reflects temperature front. That shear zone of this two sea types is extremely clear in fig 3.B. The steepest vertical movements of the tank during this haul are reflecting the steepest turns of the research vessel during towing, that are due to zic-zac towing in order to place the trawl as much as possible out of the wake of the ship.



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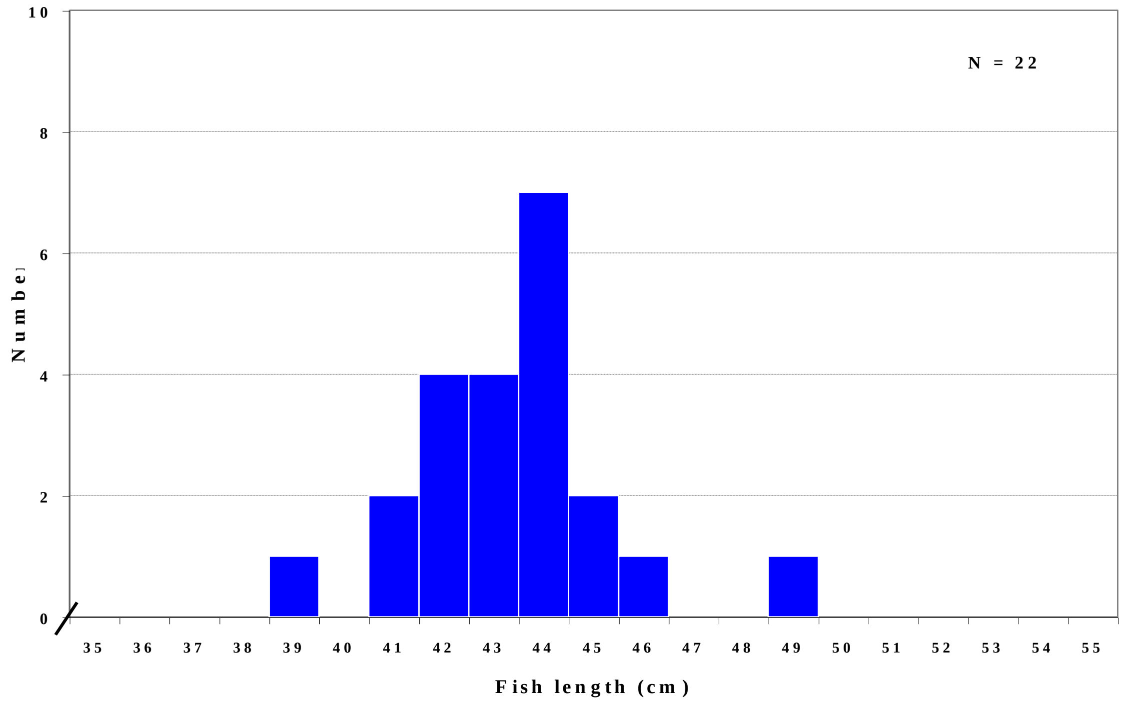
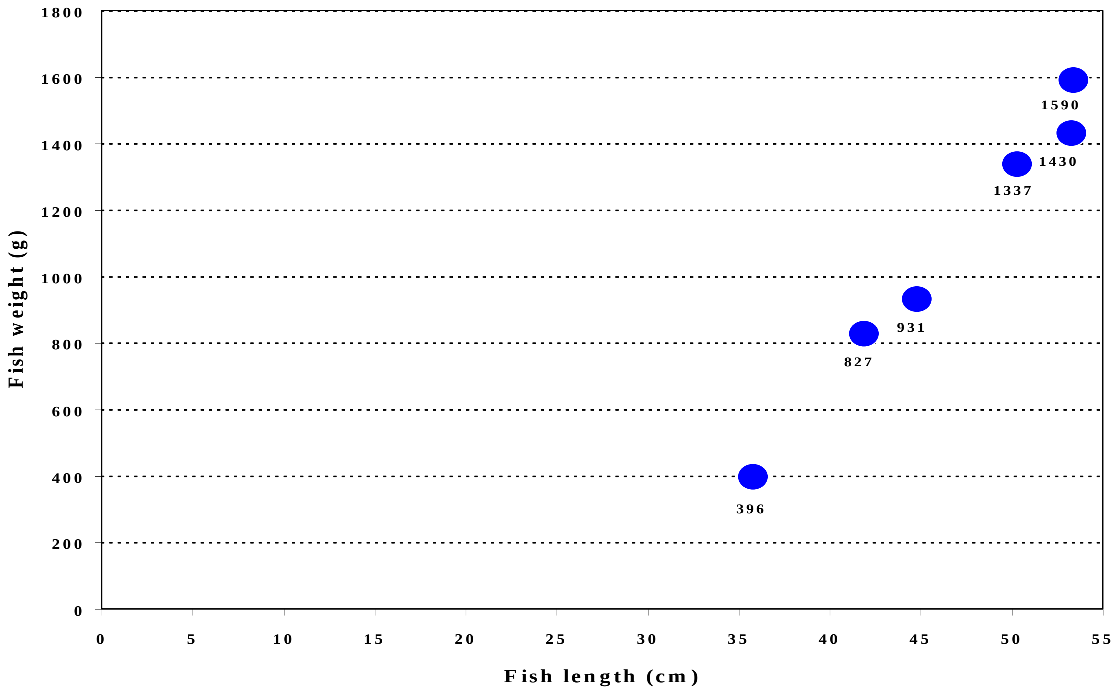


B.

Figure 5. Size of salmon that were captured in salmon surface trawl east off Iceland, during the salmon fishing during Nov.´02 – Jan.´03. Figure **5A.** shows length of salmon captured at station no. 631, 30. November 2002 at Berufjardardypi. The latter figure (**5B**) shows the length of salmon captured 10-11 January 2003 (at stations no. 20, 22 og 24). Total number (N) of salmon captured are given.



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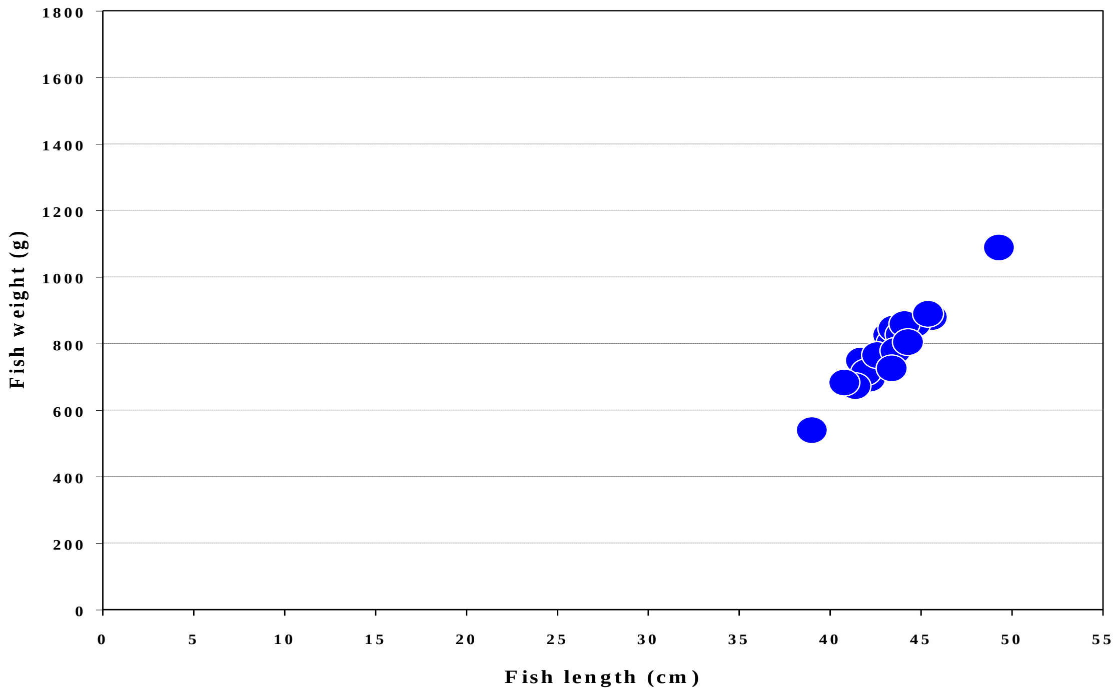
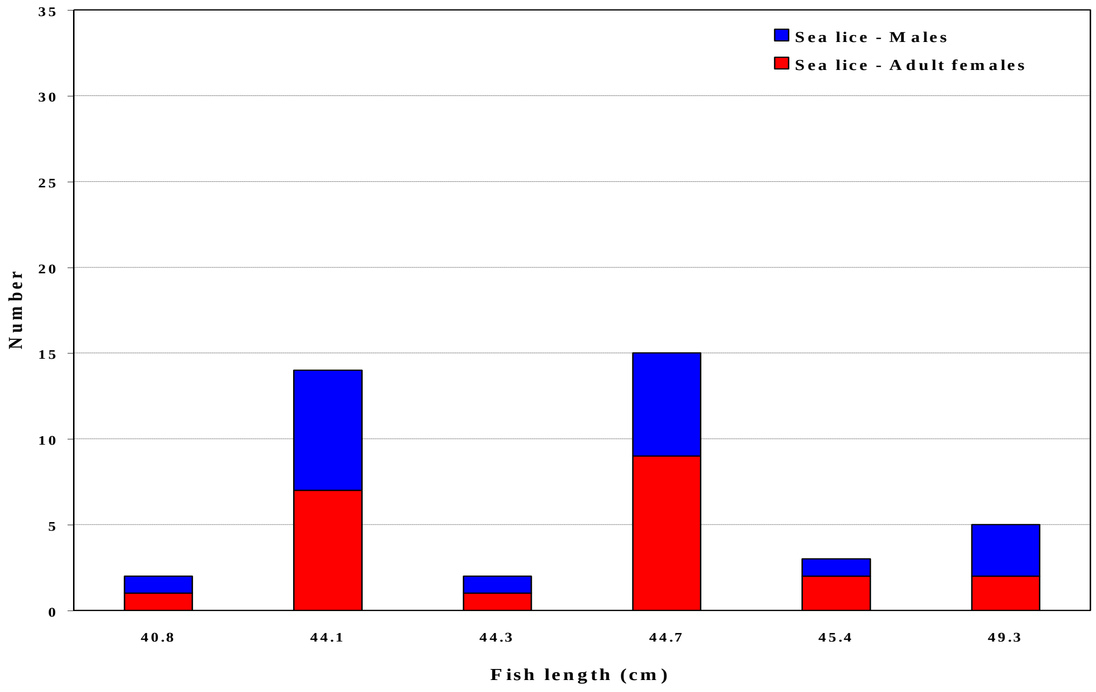
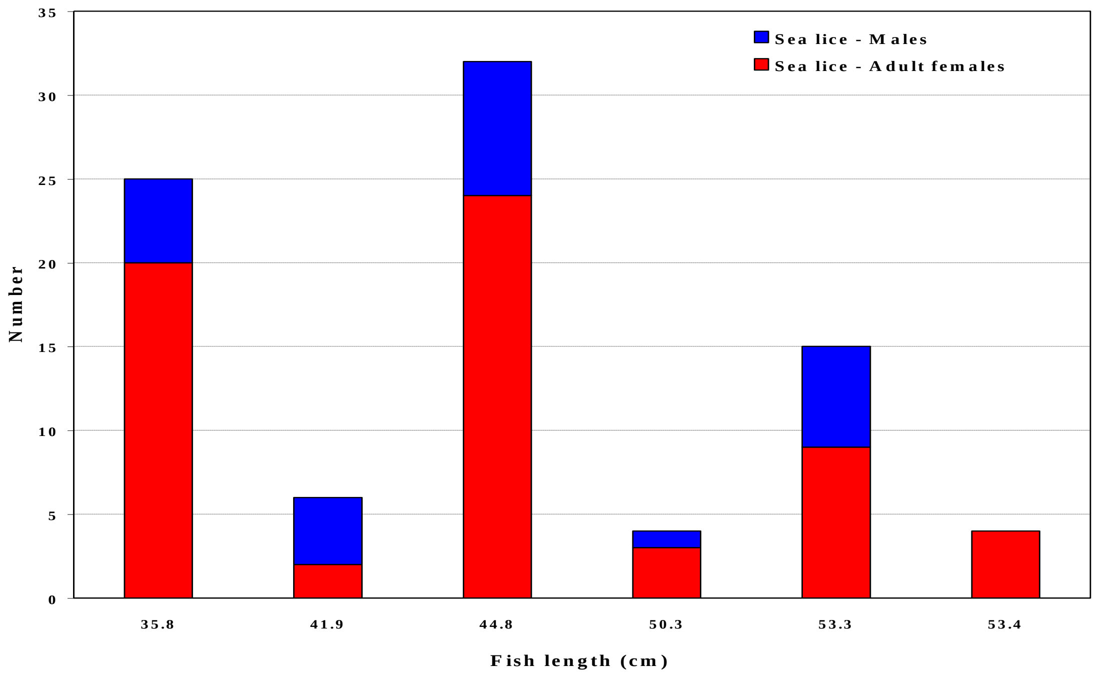


B.

Figure 6. Relationship between length and weight of salmon captured in surface trawl east off Iceland in November 2002 – January 2003. Figure **6A.** shows length & weight of salmon captured at station no. 631, 30. November 2002 at Berufjardardypi. The latter figure (**6 B**) shows the length & weight of salmon captured 10-11 January 2003 (stations no. 20, 22 og 24).



A.



B.

Figure 7. Number of salmon lice found on salmon that were captured in salmon surface trawl east off Iceland in Nov. 2003 – Jan. 2003. Length of captured salmons are given (cm) and for each of them the number of salmon lice found on them. That number is divided in relation to whether the sea lice are large female, or smaller individuals (males & others). Figure **7A.** shows number of salmon lice on salmon captured at station no. 631, 30. November 2002 at Berufjardardypi. The latter figure (**7 B**) shows number of salmon lice on salmon salmon captured 10-11 January 2003 (stations no. 20, 22 & 24).