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SURFACE ACTIVITY OF ATLANTIC SALMON (SALMO SALAR) IN NET PENS

by

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ABSTRACT

An important feature of the behaviour of salmon is the leaping and rolling activity. These surface activities were studied in fish in net pens in relation to environmental factors and operational procedures. Data were collected manually and automatically by different sensors.

Daily changes of surface activity were observed. Effects of stressors were also demonstrated. The importance of surfacing in salmon fish farming is discussed.

INTRODUCTION

The surface activity of salmon is expressed in two main forms. The fish, from time to time, jump (or leap) with the whole body clear of the water, or surfacing by only parts of the body breaking the surface. Further there is a variation in the vertical position; the fish are sometimes close to the surface, and are now and then creating turbulences.

In salmonid fish farming, fish behaviour studies including surface activity have been paid less attention than operational and physiological investigations. This study is part of a program where the behavioural, physiological, and growth response of Atlantic salmon to changes in the physical environment is applied in order to improve production results. The surface activity is studied mainly in two net pens, one of them covered to reduce the light intensity.

The surface activity has been studied during a one year period. The aim of this study was to describe variations in surface activity over time with regard to age, season and time of day. The influence of environmental factors and operational routines on the surface activity was also studied.

MATERIALS AND METHODS

The experiment was carried out at the pen rearing facilities of Austevoll Marine Aquacultue station. In this study two net pens where used, one of them covered with a fine mesh black polyethylene cover, giving a light reduction of 70%. The covered and uncovered net pen are referred to as M12 and M13, respectively, being part of the total shading experiment. The pens were of standard size (12x12x6 m) with approximately 3000 salmon in each pen (Huse et al., 1988). In addition two other pens were investigated, where small and large salmon were compared. This study focus on the period from October 1986 to September 1987. The behaviour studies were supported by an extensive environmental monitoring, i.e. hydrography and meteorology (Bjordal et al. 1986).

Definition of leap, pen wall leap and roll:

Leap: The fish breaks the surface with most of its body clear of the water.

Pen wall leap: A leap where the fish hits the pen wall above the surface.

Roll: The fish partly and quietly breaks the surface.

Surface activity was recorded manually each day around 1 a.m. In addition morning, evening and night recordings were done in restricted periods. Each observation lasted 5 minutes, and the number of events were combined with the total number of fish in the pen, and averaged over a 24 hour period, giving a daily leaping frequency per fish. In addition, an infrared transmitter and receiver placed at each side of the pen were used to automatically register leaping each time the beam was broken, but the equipment was, however, quite sensitive to operational- and wave disturbance, and therefore the data are scarse.

Underwater studies were performed with two TV-cameras. One was mounted on a pan and tilt unit (SIT OE 1321) and placed between the two pens. The other camera, Osprey Electrons (OE 1336), was moved to different positions in M12 and M13. Visual surface studies were done frequently. The information from the TV-cameras was taped on a video recorder.

To further study the rolling activity related to environmental factors and operational routines, an intensive registration over a two weeks period was performed.

Together with all the environmental data, the biological data were fed into a Hewlett Packard HP 1000 computer (Bjordal et al., 1986).

RESULTS

Leaping

A leaping cycle starts at varying depths in the pen. A typical leap starts with the fish swimming horisontally, and then accelerating and pointing the body towards the surface. The angle with the perpendicular was often between 30 and 45°. The speed increases several times from the normal cruising speed before the fish break the surface. The fish accelerate often half the pen width before the actual leap. The whole leap cycle seems quite uncontrolled. The fish land on one side or the other, take a few strong tail beats, and mix with the shoal again. Fish have also been observed taking more than one leap after each other. From time to time fish accelerate and seem to be preparing for a leap, but change behaviour and retain normal speed again. It can also be seen that the fish accelerate, slow down and accelerate again without leaping, but during this behaviour the fish seem to have a more horizontal direction. Leaping was also studied in a pen with a superstructure that eliminated light. Nearly all available light would penetrate through the surrounding water. Very low leaping activity was registrated under these conditions, but the fish seemed to prepare for leaping by accelerating. The fish could speed up several times, but this rarely ended with a leap.

Figure 1 shows the leaping frequency from October 1986 to September 1987 for M12 and M13. The leaping activity was significantly higher in the unshaded pen ($P=0.0000$, Wilcoxon matched pairs signed-ranks test). Leaping activity in the two pens are closely correlated ($r=0.85$, $P=0.0000$). De-lousing occured in December, July, August and September, indicated by the letter D in Figure 1. After each treatment the leaping activity decreased significantly. Figure 2 illustrates leaping the day before and after de-lousing for the four treatments. Louse countings, taken 6 times during the period (Huse et al., 1988), are correlated to leap frequency at the same time (r=0.82 and P=0.042).

Figure 3 shows leaping activity related to light intensity for a 3 days period.

The average percentage of leaping salmon hitting the pen wall was 5,9 and 6.6 for M12 and M13, respectively. The two pens were positively correlated (r=0.34, p=0.0000) and not significantly different (P=0.13).

Leaping frequency of small and large salmon was compared (Fig. 4). The leaping activity in the two pens was positively correlated (r=0.66, p=0.0002). However, a significant difference was found between the two sizegroups (p=0.0000, Wilcoxon matched pairs signed-ranks test).

Rolling

Starting a rolling cycle the fish usually swim slowly towards the surface. The fish may ascend from varying depths. The actual roll could be compared to the breathing of whales. After rolling the fish swim normally with the shoal again. In UTV observations the fish can be seen swimming downwards after a roll, with air bubbles escaping from the mouth area or gill openings.

Frequently, ultrasonic tags were inoperated. The tags were placed in the body cavity after the fish had been anaesthetized (Furevik, 1987). When the fish had been placed in the pen again, it normally sunk to the bottom and later rised 5-7 times against the surface.

From time to time the fish just break the surface with the dorsal fins and part of the back, swimming quite slowly. This behaviour is not always clearly seperated from rolling, and it could have some connection with aggregation of zooplankton in the upper layer.

Rolling frequencies during the whole period for M12 and M13 are shown in Figure 5 ($r=0.36$, $p=0.0000$, Wilcoxon matched pairs signed-ranks test $p=0.22$).

During a two weeks period rolling was studied intensively, and important operational factors as feeding, measurement, de-lousing and boat activity were recorded. De-lousing had a dramatic effect on rolling activity, and it increased to a maximum of 44.2 30 minutes after the treatment was ended. Nearly two hours after the treatment, rolling frequencies were still fairly high (9.4). Also a routine operation, like cleaning the pen for dead fish, seems to influence the rolling frequency, as it increased from 5 to 10 rolls. Normally the values lie between 0 and 2 (Fig. 5).

DISCUSSION

Surface activities, like leaping- and rolling behaviour are typical for salmon and some other salmonid species. However, little knowledge exists on the functional reasons for this type of behaviour. To our knowledge, surface activity of salmon in sea water (both in the wild and in culture) is not described, while laboratory- and field studies have been done in fresh water (Stuart, 1962; Falkus, 1985).

Leap observations of wild salmon in the fjords and coastal waters (authors' observations) could suggest similarities with leaps in net pens. The leap is usually longer than 1 m, and the salmon often land on one side or the other. As for the net pen situation, these leaps also seem to be at least partly uncontrolled.

The adaptive significance of leaping behaviour in sea water is unclear. Several explanations have been proposed; the fish try to get rid of debris on the gills, louse or other parasites on the skin, training for river rapids, and filling of the swimbladder (Bjordal et al., 1986). In addition, the degree of leaping and rolling is dependent on environmental factors, operational routines and fish size.

Leaping behaviour in fresh water has been described by Stuart (1962) and Falkus (1985). In fresh water, the salmon are confronted with falls and obstructions, and a leap has to be orientated if the salmon shall proceed up the river without wasting energy. From extensive laboratory experiments Stuart (1962) describes the orientated leap. The fish visually examined the obstructions and leaped just enough to reach the crest of the weir. A leap starts just below the surface with a strong tailbeat, the fish keep on moving the tail while in the air, and hit the water surface with the ventral part of the body.

Leaping behaviour in fresh and sea water is quite different. The leap in a net pen seems quite different from the orientated leap in a river, and it could be asked if the salmon in the net pen leap completely at random, or if they are to some extent aware of the pen wall. From the results above it can not be concluded whether the fish leap at random or not, but the study from the "barrack pen" could indicate that the salmon need a "reference area" at the surface where there is a contrast between water and air. In the shaded pen (M12) the surface light is supressed, and there is significantly less leaps than in the unshaded pen (M13).

From the annual leap cycle (Fig. 1) it can be seen that the salmon are leaping throughout the year, but the activity is much less in winter time and early spring. Symons (1978) reports less leaping with lower temperature, and Fernø et al. (1988) found a correlation coefficient of 0.68 between leaping and sea water temperature for a period of 5 months (from December to April). Figure 3 shows that leaping activity also varies over a 24 hours period, with more leaping morning and evening.

Figure 3 and correlation data between louse category and leaping indicate that leaping increases with increased louse infection. Figure 2, which shows the leaping frequency the day before and after de-lousing, could support this assumption, but the strongly reduced leaping frequency could also be explained by the influence the chemical medicament (Neguevon) has on the fish, and not because the parasites are removed. Nevertheless, as one moves from coastal areas into the fjords where the salinity is reduced, fish farmers claim that the leaping activity is quite low. At Jakta salmon farm in Osterfjorden, no parasite treatment was needed. The fish were not completely free of parasites, but the infestation level was quite low.

Combining the average pen wall leaps for M13 and average leap frequencies, each fish will hit the pen wall 0.21 times every day, or once in a 5 days period. During the rearing period, the salmon will hit the pen wall hundred of times. For some fish this would cause extravasitation and skin damage, which could influence the market quality and increase the possibility for infection.

The daily registration of rolls over nearly one year shows no seasonal variation. No particular environmental factor seemed to have any influence (Fernø et al. 1988).

The present study shows that the rolling activity increases after different kinds of handling and environmental disturbances. It has been observed that the fish release gas during a stress situation. This has to be compensated afterwards, creating more rolls.

An experiment with a pen lowered below the surface (Fosseidengen et al. 1982) showed that salmon and rainbow trout were injured and had a much greater mortality and less growth than the control group. The fish swam against the roof of the pen, trying to reach the surface.

It should be emphasized how close the two pens are correlated in behaviour categories like leaping, rolling, group structure and tail beat frequencies (Fernø et al. 1988). The same accounts for small and large salmon in the earlier experiments, where the leaping acitity is closely correlated. This should indicate that there are common factors which influence the surface activity, though the degree of reaction differs.

Surface activity is an important part of the Atlantic salmon´s behavioural pattern, and this paper has indicated some factors which has an impact on this activity. From a practical point of view, fish farmers can, by studying surface activity, get supplementary information about the state of the fish. It must, however, be emphasized that there probably are additional factors and/or combinations of factors which influence the surface activity, and to get more information about surface behaviour, biological, environmental and operational parameters have to be studied intensively and simultaneously.

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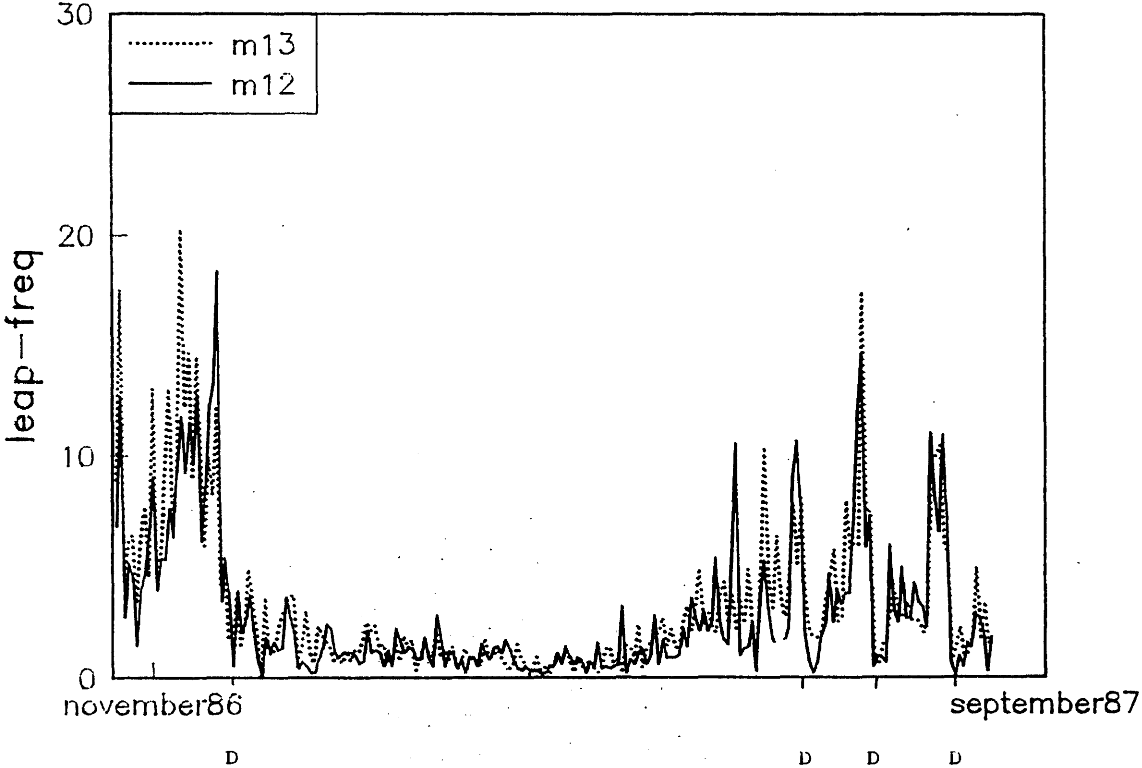

Figure 1. Annual leaping frequencies for M 12 and M 13 from October -86 to October 87
The letter D indicates periods of de-lousing

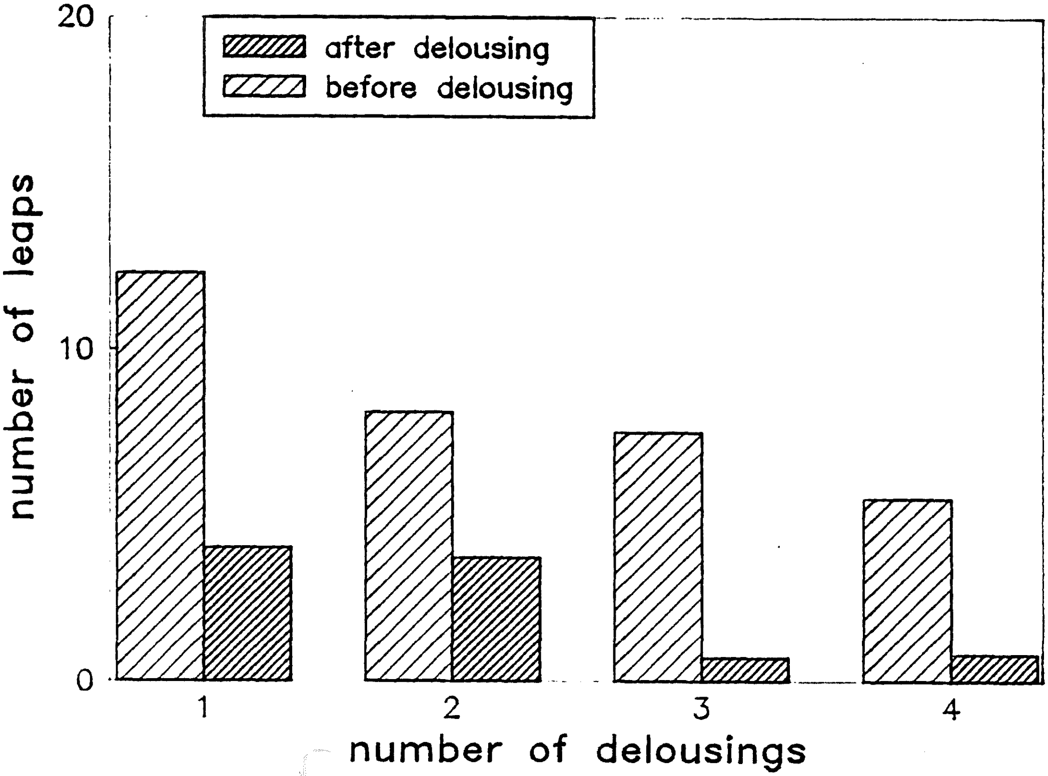

Figure 2. Leaping frequencies in M 13 just before and just after delousing

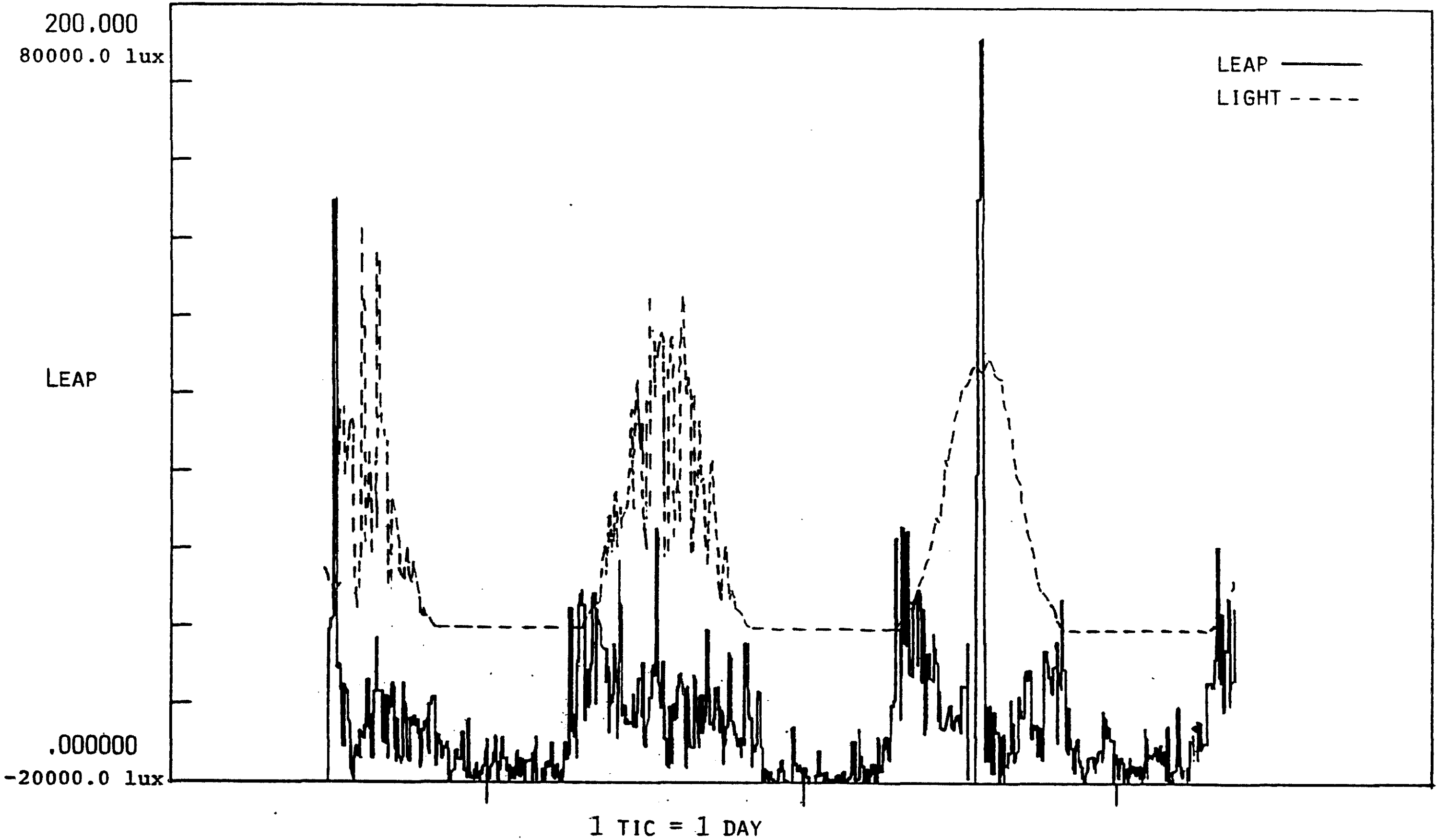

Figure 3. Automatic leap and light level registration for 3 days in M 13.

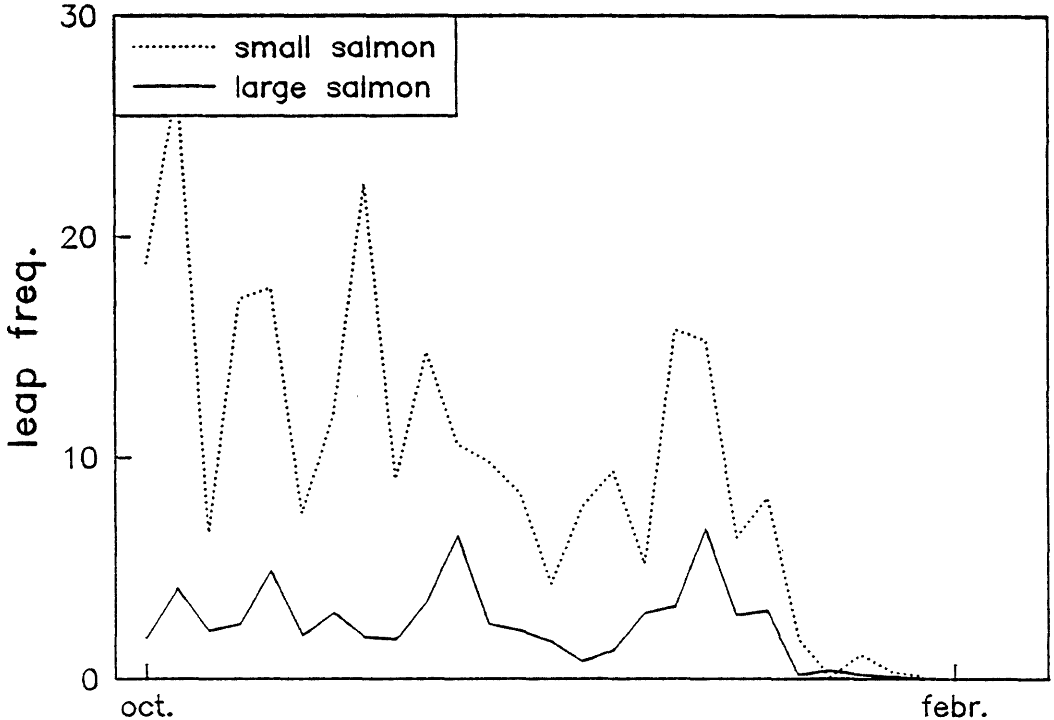

Figure 4. Leap frequencies for large and small salmon taken over a four months iod. The registrations were done at noon ch day.

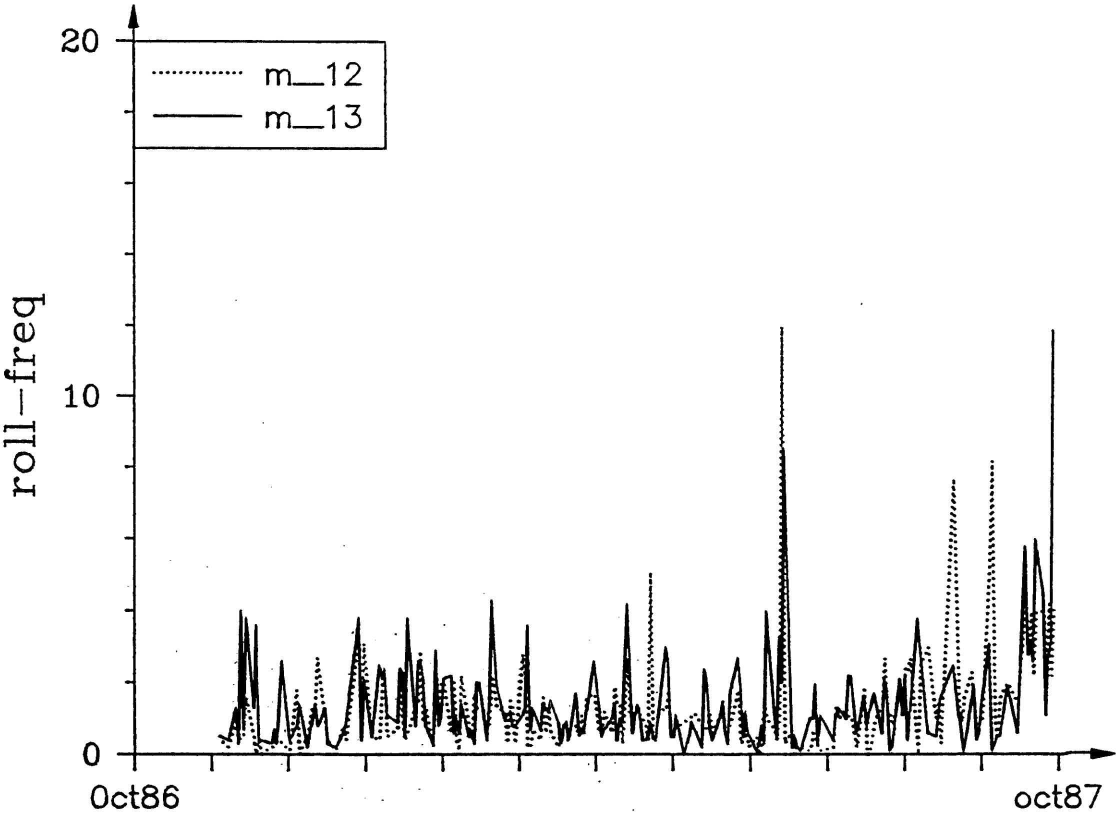

Figure 5. Annual rolling frequencies for M12 and M13. The registrations were done at noon each day.