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Some Effects of Diurnal Variation in the Catches upon Estimates of Abundance of Plaice and Sole

by

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1. Introduction

It is a well-known fact that the catches of many species of fish may vary with the time of the day. Thus, abundance estimates obtained from a limited number of hauls may be affected by the time of the day at which the hauls have been made. This can be the case in research vessel investigations, for instance those carried out to study the distribution and abundance of young fish. But also the data of abundance of adult fish estimated from catch per unit effort data of commercial vessels and based on a large number of hauls may be influenced by the diurnal variation in catches.

Although the way in which diurnal variation may affect the abundance estimates is often obvious, very little is known of the magnitude of these effects. This paper gives some examples derived from the Netherlands' sole and plaice investigations.

2. The magnitude of the diurnal variation in the catches of plaice and sole

With the former Netherlands' research vessel "Antoni van Leeuwenhoek" investigations have been carried out on the distribution and abundance of young plaice and sole in the area along the Dutch coast, in the years 1949-55. In these investigations hauls were made with a light Dutch trawl with 4 cm meshes in the cod-end, at stations situated along three lines more or less perpendicular to the coast. For various reasons each "line" was fished in as short a period as possible, with the result that some hauls were carried out at night, others in the daytime. Because it was expected that diurnal variation might affect the numbers of fish caught, and in order to obtain information on the magnitude of this variation, it had been decided in the first years of these investigations to make series of 3-hour hauls in one area of about 10 x 4 miles, in the close vicinity of each "line" for at least 24 hours in succession, and that immediately after completion of that "line". All plaice and sole caught were weighed, counted and all, or a representative sample, were measured.

In the years 1949-52 18 of such 24-hour stations were completed. For each separate experiment the average catch of plaice (by numbers) per night haul has been expressed in percentage of the average catch per haul carried out between sunrise and sunset. The data (Table 1) show great variation, but in the majority of the experiments the average catch at night was greater than the average catch during daylight. In most experiments the graph of the numbers caught in the successive hauls was fairly regular, which suggests that the difference between the experiments is not due to random variation only. It has not been possible, however, to assign the differences between the results of the experiments to differences in fishing ground, season, or to tidal effects.

No difference was observed between the average size of the plaice caught at night and those captured during daylight hours. These results differ from those of Woodhead (1960), who reported greater catches of plaice during the day than in the dark.

De Groot (1963) analysed a great number of data of plaice from commercial vessels. He found, as in the Netherlands' research vessel investigations mentioned above, a very great variation in the results of separate 24 hour periods within the same month and area. His figures indicated that the average catch at night was about 75-85% of the catch during daylight. This is similar to Woodhead's results. De Groot also showed that in the area off Hook of Holland, the diurnal pattern is reversed in January-February, showing greater catches during the night, and suggests that this is related with the spawning behaviour.

Table 1. Average number of plaice caught per 3 hours haul during the night, expressed as percentage of the average number caught during daylight.

Fishing ground	53°1o'N 4°E	52°4o'N 4°E	52°2o'N 4°5'E
Date			
April-May 1949		295	
June-July 1949		13o,91	
August-Sept. 1949	85	1o2, 127,148	
October-Nov. 1949			129
Dec.1949-Jan.195o		154	
April-May 195o		15o	68
June-July 195o			87
Dec.195o-Jan.1951		157	
June-July 1951			116
Oct.-Nov. 1951		155	2o1
April-May 1952			37
June-July 1952		154	

The data on the diurnal variation in the catches of sole obtained in the above-mentioned Netherlands' research vessel investigations have been studied by Stam (1952). He too recorded rather great differences between the results of the individual 24 hour periods. His average graphs are reproduced in Figure 1. These indicate that the average catches of sole around midnight are about 1o times as high as those at midday. He mentioned that he did not find essential differences between the diurnal patterns in the catches of soles of different length categories, but did not study the length data in detail.

3. Effects of diurnal variation upon abundance estimates based on research vessel sampling

The abundance of plaice and sole, and in particular in plaice the age-composition also, varies with the distance from the coast. The diurnal variation may lead to a distorted picture of the distribution pattern and of the abundance of the year-class of these species in case they are obtained from investigations such as the Netherlands' "line" investigations.

The best way to study the magnitude of this distortion would be to compare the data on the distribution and abundance of the fish obtained from the usual way of fishing the "lines" with those obtained when fishing all stations at about the same hour of successive days, or with the results of a second fishery of the "line" immediately following the first, and at which the stations were fished at other hours of the day. These experiments, however, have not been possible.

But some idea of the mis representation caused by the diurnal variation can be obtained by comparing the original data with those obtained when a correction factor for this variation has been applied to the catches of each haul separately.

In the case of plaice the differences between the day and night catches are usually rather small, hence corrections for diurnal variation cannot be expected to have a very great effect. Furthermore, the variability in the night - day difference in the catches, as mentioned above, is such that it is hard to determine exactly what correction factor should be applied in each special case. It can, therefore, be understood that application of correction factors, obtained for each line separately from the data on diurnal variation of the 24 hour station closest by in space and time, did not lead to any notable decrease in the variation of the abundance estimates of the year-classes of plaice which were obtained from the "lines" in successive periods.

However, application of correction factors for diurnal variation to the data on the distribution of soles gives more striking results. Figure 2 gives graphs of the numbers of sole caught per hour fishing at the stations along one of the lines, and also of the numbers caught multiplied by a correction factor obtained from Stam's average graphs of diurnal variation given in Figure 1. The difference between the two lines in each graph demonstrates the great effect which diurnal variation can have on the picture of the distribution of soles.

It will be clear that under such circumstances, and taking into account the great difference in real abundance of this fish along the "line", the figure obtained for the total abundance of soles along the "lines", depends very much upon the time of the day or night at which in particular the stations with the greatest abundance of sole are fished. Thus the diurnal variation can add a considerable source of variation to the estimate of abundance.

However, the effect on the estimate of the % age-composition of the sole along the "lines" is less marked, as can be derived from a comparison of age-compositions based on numbers caught and on those numbers corrected for diurnal variation (Figure 3). This is due to the fact that all investigated age-groups of sole (except the very young ones 0 and I) showed approximately the same distribution, and are therefore more or less equally affected by the diurnal variation.

The results indicate that in a fishery along sections or "lines", for a study of distribution and abundance of a fish species with an important diurnal variation in the catches such as sole, this variation should be allowed for. This could be done by applying correction factors in the way as it has been carried out above, provided that sufficiently representative and reliable data on this diurnal variation can be obtained. It should be realised that such a treatment is not very satisfactory from a statistical point of view. For this reason it seems advisable that no hauls are carried out during the daily period of the lowest catches.

In the case of plaice, however, there seems to be no satisfactory method to reduce the variation in abundance estimates caused by this phenomenon until much more is known about its diurnal behaviour.

4. Effects of diurnal variation upon abundance estimates obtained from commercial landings

Although it cannot be expected that in general the diurnal variation in the catches will greatly affect the estimates of changes and trends in abundance when these estimates are based on a large number of data on catch per effort of commercial vessels, still some aspects are worth while to be considered.

Kruuk (1963) showed that the diurnal variation in the catches of sole is governed by light. Soles become active and are caught mainly when the light falls below a certain level. This is the reason why in winter the catches of sole remain high during the many hours of darkness, and drop to a low level only during relatively few hours around midday, whereas in summer the high peak at night is relatively narrow with a long period of low catches during the daylight hours, as is illustrated in Figure 1.

From the curves in Figure 1 it can be calculated that with identical midnight catches of sole, and assuming that fishing is carried out throughout the whole day, the average catch per day in May-July is 2o% below the average catch per day in January-February. Or, in other words, one hour fishing in May-July is on the average 2o% less efficient than one hour fishing in January-February. These estimates are derived from research vessel catches. In order to investigate whether this phenomenon can also be observed in the commercial fishery, use could be made of data on the catch per haul of commercial vessels collected by the Netherlands' Fisheries Inspection, and covering the years 1954 and 1955. For our purpose two fishing areas were studied separately, in both of which vessels reporting their catch per haul had been fishing the whole year round. To Area A belonged the fishing grounds between 53°o' and 53°4o'N and between 3°2o' and 4°4o'E, to Area B those between 52°o' and 52°4o'N and 3°o' and 4°o'E. For each month and area the average catch of sole per hour fishing has been calculated from all hauls, and also from those hauls which were carried out during the night only (between sunset and sunrise). The data obtained from all hauls have then been expressed as percentages of the values found for the night hauls only. These percentages, which will be called the "diurnal efficiency factors", have been plotted in Figure 4. The graphs show that, as in the estimates from the curves in Figure 1, the"diurnal efficiency factors" change in the course of the years, being lowest in the summer months. Table 2 gives the same data, calculated for 2 periods of 4 months, viz. summer (May-August included) and winter (January, February, November, December).

Table 2. "Diurnal efficiency factors" by area and season.

	Summer (May-August)			Winter (Jan.,Febr.,Nov.,Dec.)		
	Fishing hours		Diurnal efficiency factor	Fishing hours		Diurnal efficiency factor
	Night hauls	All hauls		Night hauls	All hauls	
Area A						
1954	9o7	2183	7o	745	1o85	95
1955	874	2271	71	5o6	761	87
Area B						
1954	4o6	1o97	7o	257	393	8o
1955	41o	1193	64	629	999	78

Here again, the differences between summer and winter are clear. In summer, the average catch per 24 hours is about 69% of the catch during the night, in winter about 85%. This means that with identical catches during the night, the average catch per hour of all hauls is in summer $\frac{85-69}{85} \times 1oo = 19\%$ lower than in winter. This figure is in close agreement with the figure of 2o% calculated above from research vessel data.

Both Figure 4 and Table 2 indicate that the "diurnal efficiency factors" in Area B are nearly always lower than those of Area A. Table 3 shows that this is partly due to differences between the areas in the proportion of the fishing hours made at day and night, but also to real differences in the diurnal variation of the catches between the two grounds.

Table 3. Difference in proportion of night and day hauls, and of diurnal variation, between Area A and B.

	No. of hours fishing at night in % of total fishing hours		Catch per hour fishing in daylight, in % of catch per hour fishing at night	
	summer	winter	summer	winter
Area A				
1954	42	69	49	85
1955	39	66	53	61
Area B				
1954	37	65	52	43
1955	34	63	45	39

No data are available to analyse whether this difference in diurnal variation is due to differences in fish behaviour or to different fishing tactics, although it is known that the uneven bottom in Area B requires especially adapted trawls and ways of fishing.

It follows from these results that the average catch per unit effort does not give the same measure of abundance in the various seasons and areas, for those species in which an important diurnal variation in the catches is governed by light and perhaps by other factors too. And also, one hour fishing does mean a different effort in the various seasons and areas for these species.

As long as the distribution of the fishing effort remains equal in time and space in successive years, the changes and trends in the data on abundance estimated from the normal catch per unit effort figures over these years still give the correct picture. But, in practice, changes in abundance are often accompanied by changes in the fishery. When the abundance decreases, many ships change to other fisheries in the poorest months. It is known that sometimes the diurnal variation is such that the ships stop fishing for soles during day-time. This also happened in the newly developed Dutch double-rigged beam-trawl fishery. In this fishery so many bottom invertebrates are caught, that only short hauls can be made. In order to get some rest many boats stop fishing during midday. All such factors, together with the effects of diurnal variation, may cause errors in abundance estimates, and thus on mortality estimates obtained from them. In sole, in which the total mortality is rather low, such errors could be serious.

It seems possible that application of correction factors for "diurnal efficiency", together with information from the industry on eventual discontinuation of the fishery during part of the day, might lead to less variable abundance estimates. Exceptional circumstances, such as reported by Woodhead (1963) on the effects of the cold winter, or by de Veen (1963), who describes that in some months so many soles swim at the surface at night that sometimes the diurnal periodicity in the trawl catches is reversed, should be duly taken into account.

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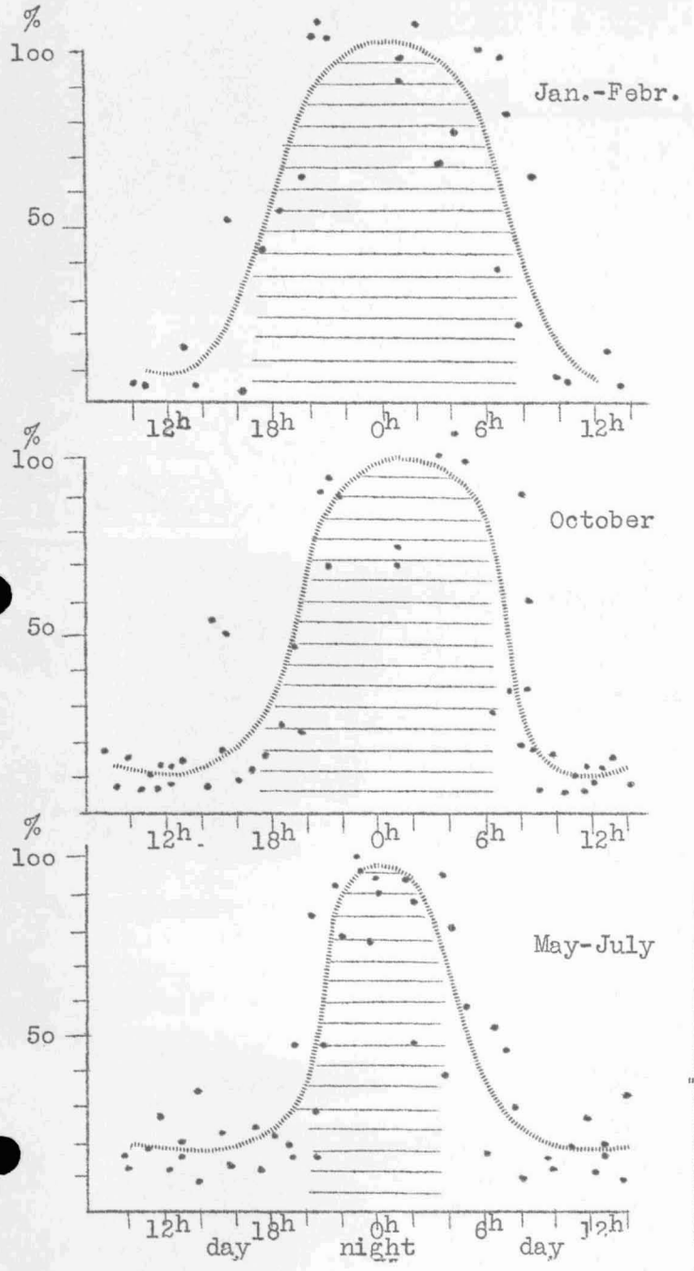
Figure 1. Diurnal variation in trawlcatches of sole (from Stam, 1952)



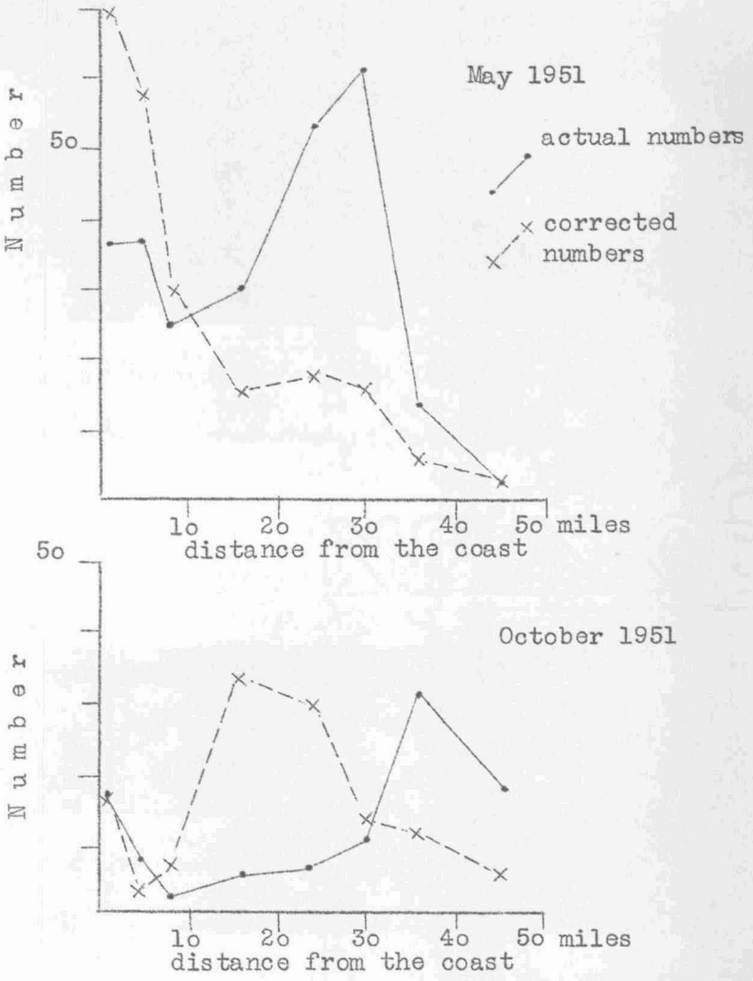
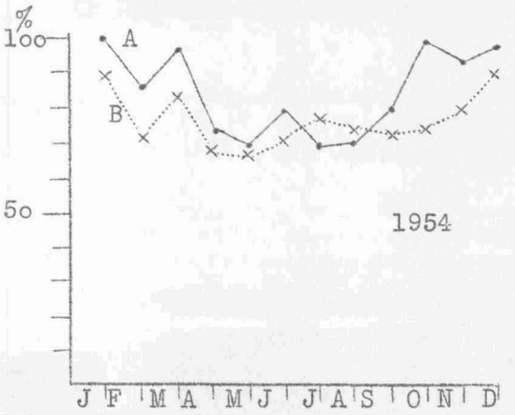
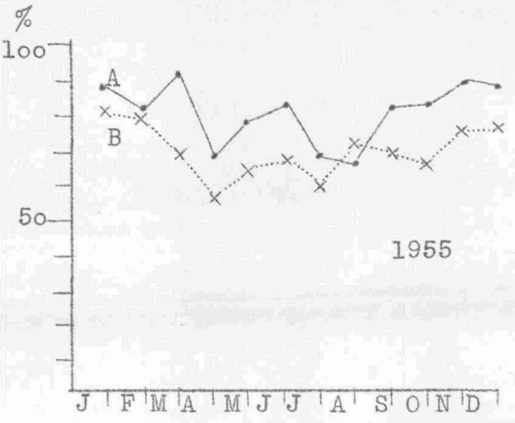


Figure 2. Distribution of sole along a line perpendicular to the Dutch coast, according to actual nos. caught, and to nos. corrected for diurnal variation.

Figure 4. Explanation - see text





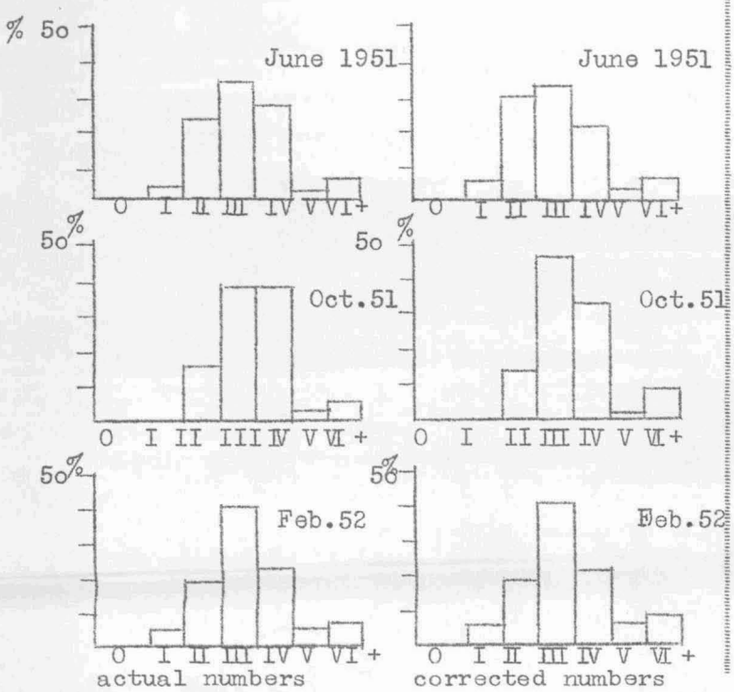


Figure 3. Age composition of sole determined from actual nos. caught along a line perpendicular to the Dutch coast, and from nos. corrected for diurnal variation.