International Council for the
Exploration of the Sea

C.M. 1984/K : 3
Shellfish Committee

Diurnal variations in CPUE and length composition of the catches in a Nephrops directed fishery in the Central North Sea

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Abstract.

The report describes the Belgian *Nephrops* directed fishery in the Central North Sea (Botney Gut - Silver Pit area) and analyzes the diurnal variations in CPUE and catch composition of several commercial *Nephrops* trawlers operating in this area. Peak CPUE-values were generally obtained after dawn and before dusk. Some anomalies however did occur. These are discussed in relation to the natural variations in light intensity on the sea floor and the food requirements of *Nephrops*. There was no evidence of significant changes in the length composition of *Nephrops* taken at different times of the day. The data even suggest that all size groups of *Nephrops* respond in the same way to changes in light intensity.

Résumé.

Le rapport décrit la pêche langoustinière belge dans la Mer du Nord centrale (région du Botney Gut et du Silver Pit). Il analyse les variations journalières dans les taux de capture par unité d'effort et la composition des captures de plusieurs langoustiniers opérant dans cette région. En général les captures par unité d'effort atteignaient leur maximum après l'aube et avant le crépuscule. Pourtant certaines anomalies se sont manifestées. Celles-ci ont été envisagées par rapport aux variations naturelles dans l'intensité lumineuse au fond marin et par rapport aux besoins nutritifs des *Nephrops*. Il n'y avait pas de variations d'importance dans la taille des langoustines prises à différentes heures du jour. Les données suggèrent même que toutes les *Nephrops*, de quelle longueur qu'elles soient, réagissent de la même façon aux changements de l'intensité lumineuse.

This study was subsidized by the Institute for Scientific Research in Industry and Agriculture, Brussels, Belgium.

1. Introduction.

Our present knowledge on the diurnal activity rhythm of Nephrops norvegicus is well documented by field studies and by experiments on captive animals (for extensive reviews see FARMER, 1974 ; ARECHIGA and ATKINSON, 1975 ; NAYLOR and ATKINSON, 1976 ; CHAPMAN, 1979 ; CHAPMAN and HOWARD, 1979 ; OAKLEY, 1979 ; ARECHIGA et al., 1980 ; MOLLER and NAYLOR, 1980).

In a recent review CHAPMAN showed that the emergence of Nephrops from their burrows is related to the intensity of light reaching the sea floor (CHAPMAN, 1979). Peak catches are generally obtained around dawn and dusk, but with increasing depth the two peaks shift towards midday. The periods of peak emergence at different depths however correspond to the same range of light intensities at the sea bed (CHAPMAN et al., 1975 ; CHAPMAN, 1979).

The present paper discusses the diurnal variations in CPUE and catch composition of several commercial Nephrops trawlers fishing in the Botney Gut - Silver Pit area (Central North Sea), at depths between 50 and 70 meters. The programme was originally designed as a comparative study to evaluate the effects of a possible mesh change (this is why the vessels fished with different mesh sizes), but afterwards the data files were reworked to extract data on the diurnal changes in CPUE and length composition of the Nephrops catches.

2. Description of the fishery.

Since 1973 the bulk of the Nephrops landed by Belgian trawlers comes from the Central North Sea. The yearly landings from this area increased from the mid-sixties to the mid-seventies to a level of between 450 and 650 metric tons (Table 1).

Prior to 1968 however the landings from the waters around Iceland equalled or even outnumbered those from the North Sea, but after a sharp decline in the period 1966-1974 the Belgian fishery for Nephrops around Iceland completely ceased in 1975. The landings from other areas, such as the Irish Sea, the Celtic Sea and the English Channel hardly exceeded 60 metric tons and mostly were less than 5 metric tons per year (Table 1).

The Belgian Nephrops directed fishery in the Central North Sea is concentrated around the Botney Gut and the Silver Pit. It is prosecuted by 10-15 vessels during summer and by 3-5 vessels during winter. Most Nephrops trawlers are mid-class vessels with 200-375 HP and 50-100 GRT. Fishing trips usually last 7-10 days, during which 40-70 hauls of about 3 hours each are made. The Nephrops are stored in huge quantities of ice and are marketed fresh, uncooked. The landed by-catch consists mainly of cod, whiting and plaice, together with smaller quantities of edible crab, scallop, whelk, dogfish, gurnard, turbot, dab, lemon sole, sole and monk.

Nephrops landings, total effort and CPUE show a remarkable seasonal evolution, with maxima during summer and early autumn (May-October) and minima during winter and early spring (December-March) (Figure 1). Between 60 and 70 % of the fishing effort is concentrated in the main Nephrops season (May-October), yielding between 75 and 85 % of the landings. During this season the trawlers catch, on average, 10-25 kg of marketable Nephrops (i.e. larger than 80 mm total length) per hour fishing. During wintertime CPUE's usually drop below 5 kg Nephrops per hour fishing (Figure 1).

3. Diurnal variations in CPUE.

3.1. Material and methods.

Data on the diurnal variations in CPUE were gathered from special forms completed by the skippers of four Nephrops trawlers regularly operating in the Botney Gut - Silver Pit area. These forms contained the following information on each haul : Decca position of the vessel when shooting and hauling the gear, duration of the haul, weather conditions and kilogrammes of marketable Nephrops and by-catch fish caught. The data were collected during the main Nephrops season, from mid-June to mid-September 1978 (Table 2).

These data were used to calculate haul per haul CPUE-values (expressed in kilogrammes of marketable Nephrops per hour fishing). The CPUE-values were plotted on a time scale versus the natural light-dark regime.

3.2. Results and discussion.

Some representative examples of the diurnal variations in CPUE are given in Figure 2. Solid lines connect CPUE-values of consecutive hauls on a same track or in a same very small area ; dotted lines connect CPUE-values of hauls on different tracks (e.g. late evening and early morning hauls "on *Nephrops*" alternated by midnight hauls "on fish") or scattered over a wider area (e.g. when the vessel shifts from one area to another in search of other or richer *Nephrops* grounds). This distinction was made to avoid mixing of hauls in different albeit small areas, possibly with different densities and/or size compositions of *Nephrops* (see e.g. Anon., 1982, section 5.4.2.), which might obscure the natural rhythm of the picture. On the other hand this rigorous restriction makes sure that the observed fluctuations in CPUE with the time of the day can be considered as a reflection of the diurnal emergence rhythm of *Nephrops*.

Even within these confines 55 complete 24-hour cycles could be extracted from the available data, covering about 50 % of the hauls made during the fishing trips under investigation.

The CPUE-values of consecutive hauls on a same track or in a same area mostly show a clear rhythm, with maxima after dawn (between 0 and 5 hours after sunrise) and before dusk (between 6 and ½ hours before sunset) (Figure 2). In the late forenoon the CPUE's decrease somewhat but remain fairly high throughout the day. They rise to a high level again in the (late) afternoon. Shortly after sunset the CPUE's decrease rapidly and approximately around midnight they are at their lowest level. CPUE-values of forenoon and afternoon peak hauls are 2-40 (on average 9) times those of the midnight hauls preceding or following them.

These findings are in general agreement with the results of similar investigations in areas with comparable depths, viz. in the Irish Sea, the North Sea (off North Shields), the Swedish, Scottish and Irish coastal waters (O'RIORDAN, 1961 ; SIMPSON, 1965 ; HÖGLUND and DYBERN, 1965 ; FARMER, 1974 ; HILLIS, 1971 ; ARECHIGA and ATKINSON, 1975 ; CHAPMAN and HOWARD, 1979 ; OAKLEY, 1979 ; MOLLER and NAYLOR, 1980).

Attention should be drawn to some peculiarities and anomalies in these 24-hour cycles :

(a) The relative importance of the forenoon and afternoon peaks is not always the same and may change from one day to another (see e.g. Figure 2c, days 3 and 4). In an extreme situation one of the peaks may be strongly reduced (see e.g. Figure 2a, days 7 and 8) or even disappear (see e.g. Figure 2b, day 11).

(b) In some cases the "afternoon" peak shifts to midday hours, 7-8 hours before sunset (see e.g. Figure 2b, day 10).

(c) During periods of heavy weather the peaks tend to converge or to level out completely (see e.g. Figure 2d, days 7 and 8).

The importance of light intensity on the sea floor in establishing the diurnal emergence pattern of Nephrops has been emphasized by several authors (CHAPMAN and RICE, 1971 ; HILLIS, 1971 ; CHAPMAN et al., 1972 ; ARECHIGA and ATKINSON, 1975 ; ATKINSON and NAYLOR, 1976). The emergence of Nephrops is generally confined to the range of light intensities from 10^{-5} to 1 meter candles (CHAPMAN, 1979). At depths between 50 and 70 meters (such as in the area under investigation) this optimum light intensity normally occurs around sunrise and sunset. However, local and temporal conditions, such as cloudiness or increased turbidity (due to tidal currents or stormy weather) may reduce the amount of light reaching the sea floor, effectively meaning that the periods of optimum light intensity may occur at other times of the day than around sunrise and sunset or, in an extreme situation, may even not occur at all. This could account, at least partly, for the variability described above, although in the last case reduced efficiency of the gear could also play an important rôle.

Another factor which may contribute to the observed variability are the food requirements of Nephrops (OAKLEY, 1979 ; MOLLER and NAYLOR, 1980). Hunger state and food availability may cause variations in the numbers of Nephrops emerging from their burrows - a feature already observed by CHAPMAN (1979) - or may even drive them to leave their burrows during periods of below or above optimum light intensity. The importance of hunger state and food availability was recently recognized by MOLLER and NAYLOR who suggested that "diel variations in trawl catches result from a combination of behavioural activities which at present appear to include an endogenous nocturnal activity rhythm and a labile emergence pattern determined by hunger state and food availability" (MOLLER and NAYLOR, 1980, pag. 112).

4. Diurnal variations in length composition of the Nephrops catch.

4.1. Material and methods.

Nephrops length frequency data from individual hauls were collected throughout the day by technicians of the Fisheries Research Station accompanying the Nephrops trawlers already mentioned in the previous section. Samples of 50-550 (on average 200) individuals of the unsorted Nephrops catch were measured to the nearest 0.5 cm total length, from the tip of the rostrum to the distal edge of the uropods (this size interval corresponds to a size interval of about 1 mm carapace length). Details on the samples taken are given in Table 2.

Only length frequency data from hauls on a same track or in a same very small area were used to investigate diurnal variations in length composition. This restriction was introduced to make sure that all the data were from the same part of the population or, in other words, to exclude variations due to differences in the size composition of different parts of the population (see e.g. Anon., 1982, section 5.4.2.).

Two types of comparisons between length frequency distributions were made. The first type, called "within day" comparison, involved the length distributions of consecutive forenoon, midday, afternoon and midnight hauls, corresponding to the daily minima (midday and midnight) and maxima (fore- and afternoon) in CPUE. The second type, called "between days" comparison, involved hauls at the same time of the day but on consecutive days.

4.2. Results and discussion.

Examples of "within day" and "between days" comparisons are given in Figures 3 and 4. Absolute frequency distributions were transformed into cumulative relative frequency distributions to visualize more neatly the possible fluctuations in the length composition of the Nephrops catch.

The "within day" comparisons reveal some shifts in the length distribution of the Nephrops catch with the time of the day, but these shifts show no common trend. In some cases the biggest Nephrops were caught during night-time and the smallest ones during day-time (see e.g. Figure 3b) ; in other cases the opposite was observed (see e.g. Figure 3d). Mostly the shifts are rather small, 1-1.5 cm total length between the extremes (corresponding to 2-3 mm carapace length).

There is no clear and general evidence of size related differences in the diurnal activity pattern of Nephrops. The observed variations in the length composition of the catches seem to be rather casual, and are probably due to sampling variations. This is demonstrated even more convincingly by the "between days" comparisons. Figure 4 shows that the differences between the length compositions of Nephrops taken at the same time on consecutive days at least equal and sometimes even outrange the differences between the length compositions of Nephrops taken at different times of the day.

The literature on the size related differences in behaviour of Nephrops is limited and somewhat contradictory. ANDERSEN (1962), JENSEN (1965) and CHAPMAN and HOWARD (1979) reported that Nephrops catches taken during the day comprise larger individuals than those caught at night. JENSEN (1965) however compared day-catches to night-catches taken in different years, thus completely overlooking possible long-term changes in the length composition of the population. FROGLIA (1972) and FARMER (1974) recorded the opposite, with the biggest Nephrops taken during night-time. MOLLER and NAYLOR (1980), finally, found that the largest individuals were caught at the times of peak catches, in their case a few hours after dawn and before dusk.

The present results do not confirm one of these findings, neither do they support ANDERSEN's hypothesis that large Nephrops are less sensitive to light than the smaller ones (ANDERSEN, 1962). The data even suggest that, at least in the Central North Sea, all size or age groups of Nephrops respond in the same way to changes in light intensity on the sea floor.

5. References.

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Table 1 - Belgian Nephrops landings, by area, 1964-1983.

Year	Botney Gut Silver Pit	Iceland	Other areas	Year	Botney Gut Silver Pit	Iceland	Other areas
1964	125	586	54	1974	418	6	2
65	95	409	29	75	433	-	1
66	135	546	20	76	426	-	4
67	264	208	3	77	454	-	+
68	295	157	2	78	574	-	+
1969	264	180	5	1979	299	-	+
70	336	114	7	80	569	-	1
71	212	149	1	81	526	-	62
72	207	79	+	82	449 *	-	+
73	372	5	+	83	633 *	-	+

* Provisional figures.

Table 2 - Review of sampling data, June-September 1978.

Vessel	HP	GRT	Date	Number of days on grounds	Mesh size	Number of hauls	Number of hauls sampled	Number of *Nephrops* measured
A	240	67	13.6 - 23.6.78	7 ½	70 mm	45	29	4965
B	240	89	15.6 - 26.6.78	9	50 mm	54	42	6534
A	240	67	26.6 - 6.7.78	7	70 mm	45	-	-
B	240	89	29.6 - 11.7.78	10	80 mm	60	47	8031
A	240	67	10.7 - 20.7.78	8	70 mm	48	7	2015
B	240	89	15.7 - 26.7.78	9	80 mm	53	12	3116
B	240	89	29.7 - 7.8.78	7	80 mm	45	-	-
C	300	99	1.8 - 14.8.78	11	80 mm	70	9	2885
D	220	70	4.8 - 14.8.78	8	80 mm	53	13	3576
B	240	89	11.8 - 20.8.78	6 ½	50/70 mm	44	16	2200
C	300	99	17.8 - 28.8.78	9	80 mm	56	-	-
D	220	70	18.8 - 29.8.78	9	80 mm	56	-	-
C	300	99	1.9 - 12.9.78	9	80 mm	52	7	2888
D	220	70	3.9 - 14.9.78	9	80 mm	52	10	3002

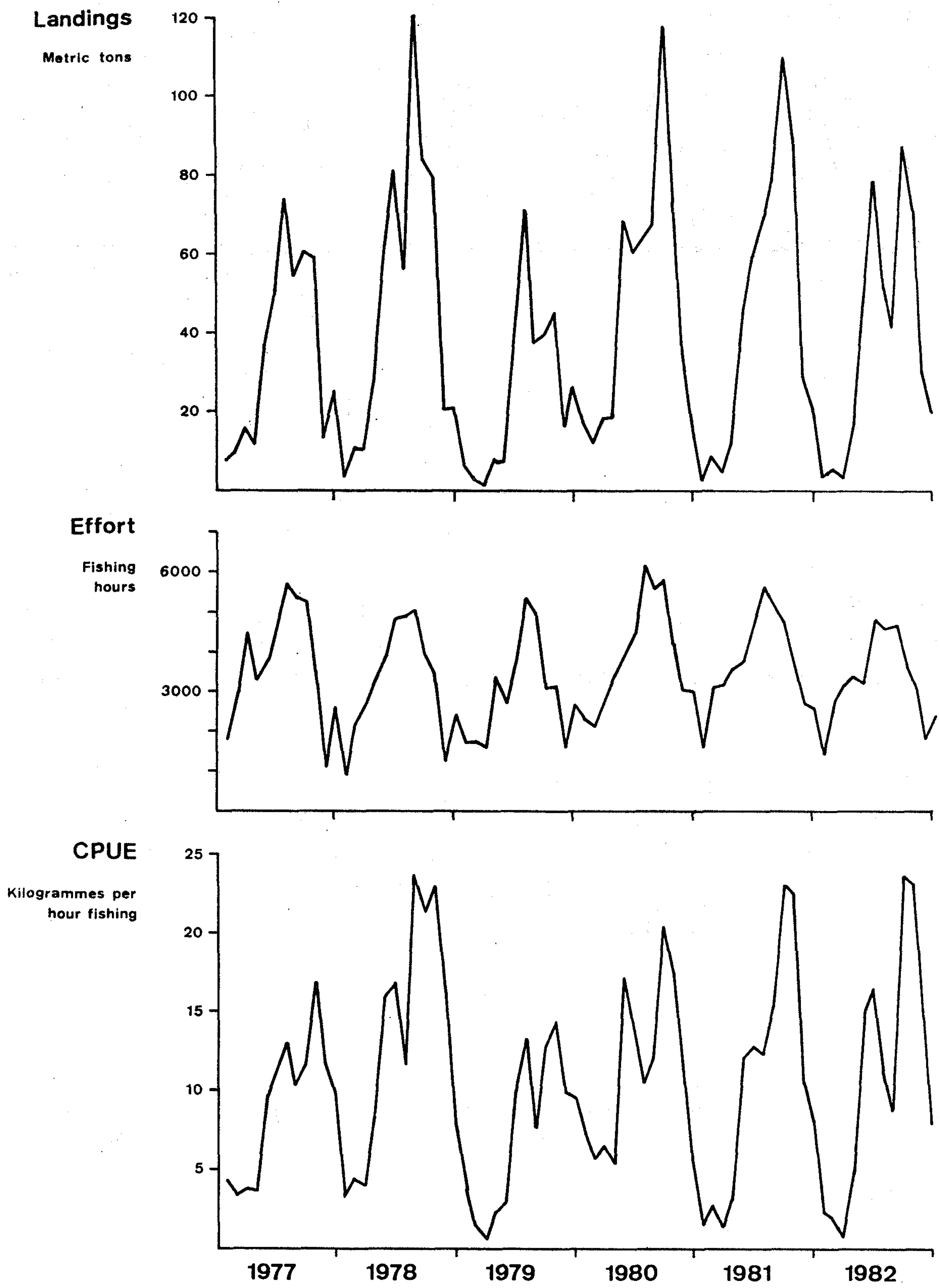

Figure 1 - Landings, fishing effort and catch per unit effort of the Belgian *Nephrops* directed fishery in the Central North Sea, by month, 1977-1982.

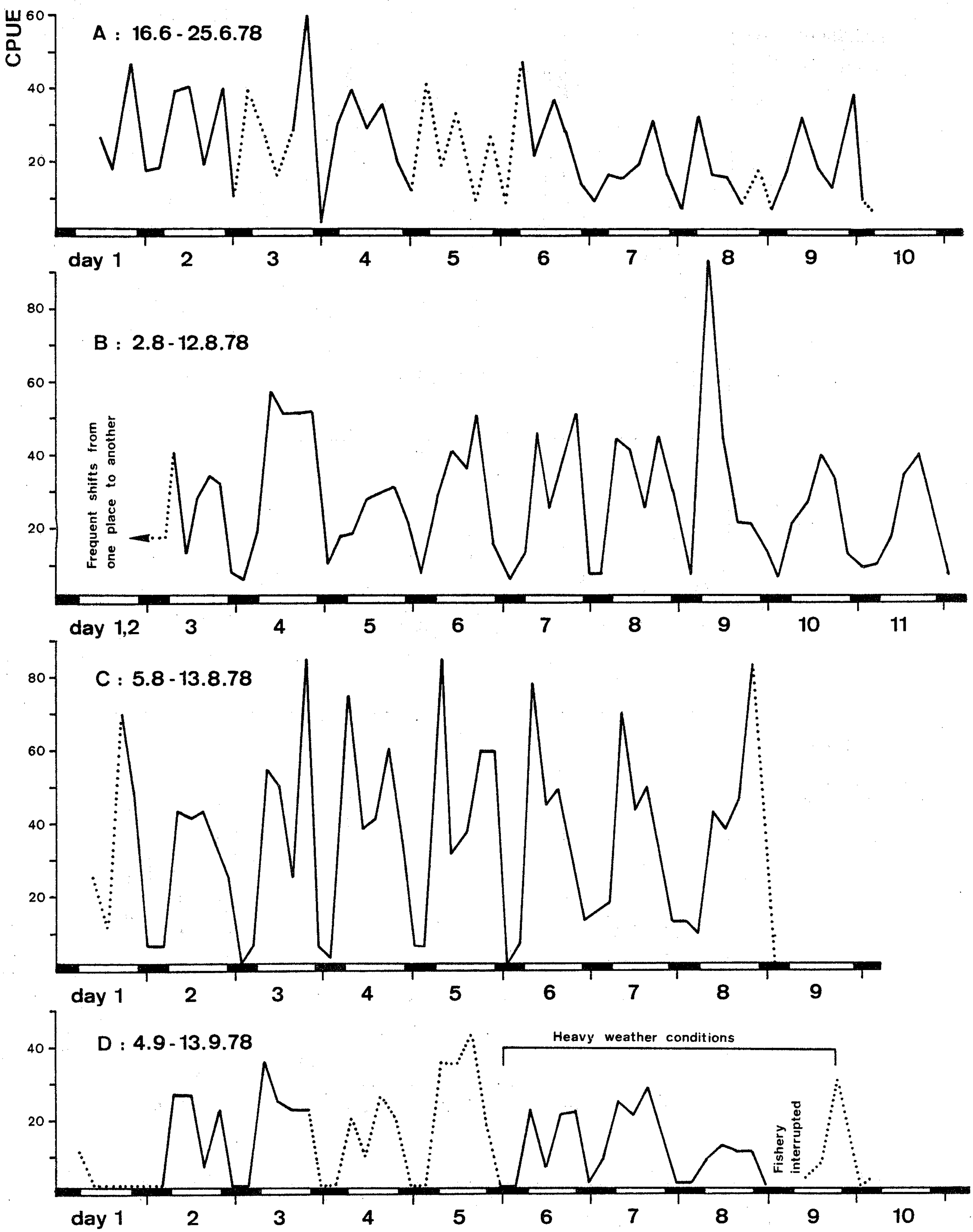

Figure 2 - Diurnal variations in CPUE (in kilogrammes of marketable <u>Nephrops</u> per hour fishing) of the <u>Nephrops</u> directed fishery in the Central North Sea versus the natural light-dark regime, summer 1978.

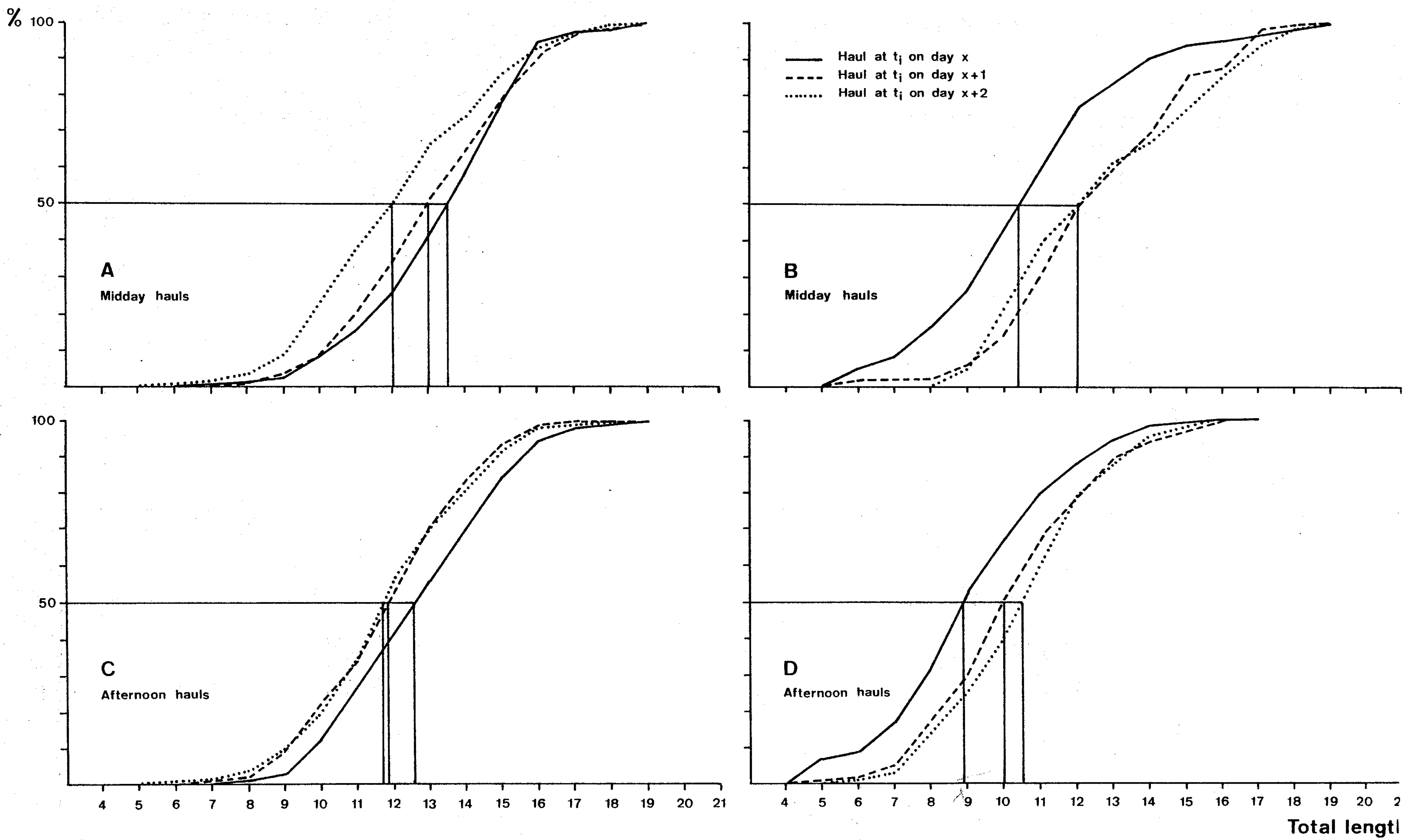

Figure 4 - Comparison of cumulative length (= total length in cm) frequency distributions of Nephrops taken at the same time of the day on consecutive days, summer 1978.

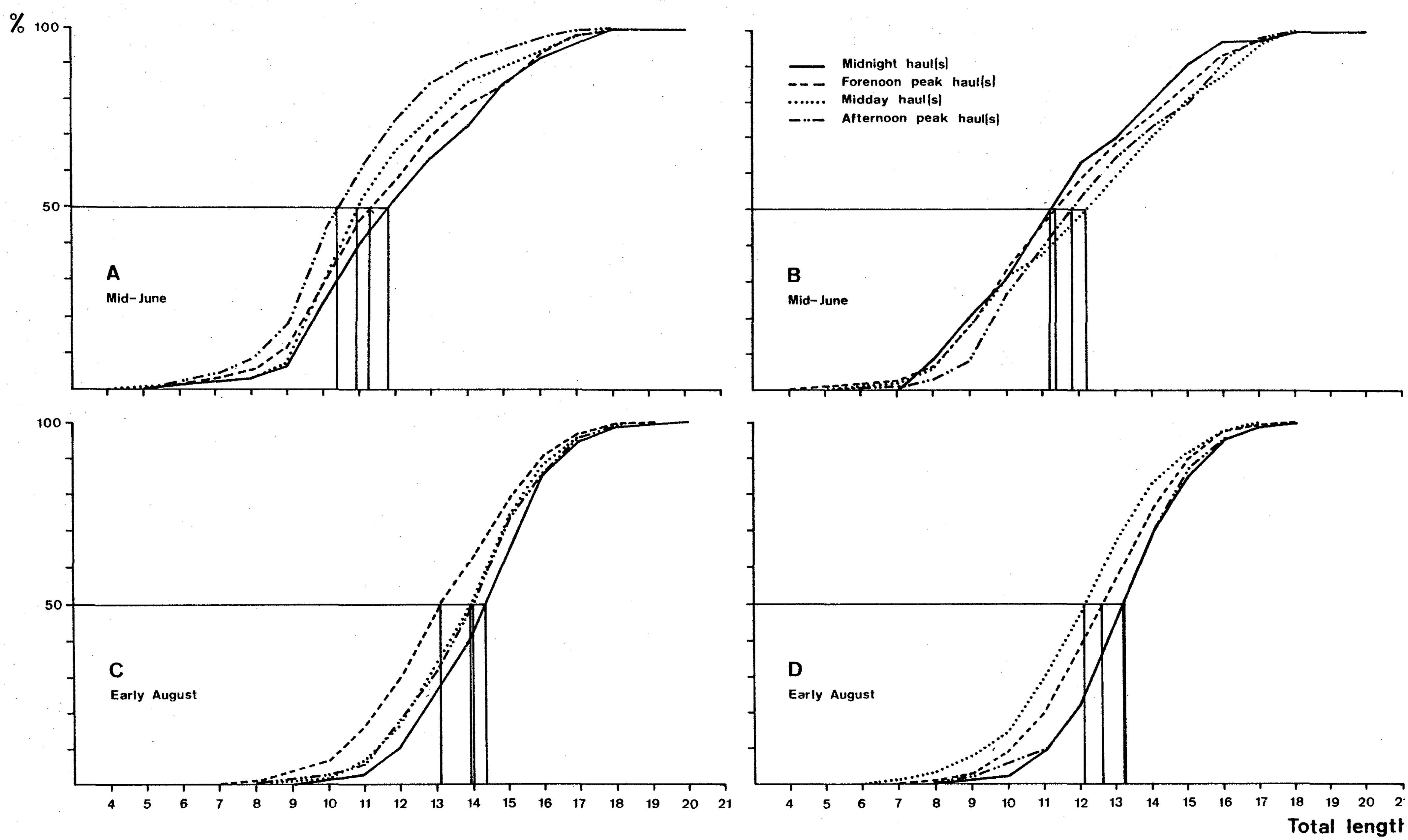

Figure 3 - Comparison of cumulative length (= total length in cm) frequency distributions of _Nephrops_ taken at different times of the day, summer 1978.

E

E.5. Management of exploited stocks

E.5.1. General considerations, overfishing

025 - 058 - 059 - 061 - 062 - 068 - 069 - 072 - 081 - 082 - 093
216 - 240 - 263 - 264 - 278 - 280 - 303 - 306 - 359 - 400 - 409
436 - 494

E.5.2. Selectivity of trawls

025 - 042 - 074 - 097 - 111 - 215 - 263 - 264 - 266 - 289 - 303
350 - 436 - 505

E.5.3. Shrimp sieves

025 - 065 - 068 - 071 - 072 - 074 - 075 - 089 - 090 - 094 - 129
130 - 202 - 263 - 264 - 273 - 274 - 340 - 502 - 527

C

C. CULTURE

C.1. Rearing and culture

Larvae : 141 - 426 - 530
Adults : 015 - 138 - 141 - 334 - 336 - 411 - 416 - 510