INTERNATIONAL COUNCIL FOR THE
EXPLORATION OF THE SEA

C.M. 1977/K: 4
Shellfish & Benthos Committee

STOCK SIZE AND FISHING MORTALITY RATES OF A BROWN SHRIMP (CRANGON CRANGON) POPULATION ALONG THE DUTCH COAST IN THE YEARS 1973-1975.

by

R. Boddeke and H. B. Becker

Netherlands Institute for Fishery Investigations
P.O. Box 68, Ymuiden – The Netherlands

This paper not to be cited without prior reference to the authors

International Council for the Exploration of the Sea

C.M. 1977/K:4.

STOCK SIZE AND FISHING MORTALITY RATES OF A BROWN SHRIMP (CRANGON CRANGON) POPULATION ALONG THE DUTCH COAST IN THE YEARS 1973-1975.

by

R. Boddeke and H.B. Becker
Netherlands Institute for Fishery Investigations
Ymuiden, the Netherlands.

ABSTRACT

In this paper, the fishing mortality rate has been calculated for a stock of brown shrimp (Crangon crangon) in a central part of the Dutch coastal area. These calculations were based on three time series of data, concerning biological parameters of the shrimps, catch per effort and number of fishing days. On these data a modified Leslie method was applied. Variations of the fishing mortality could be explained satisfactorily by fluctuations of fishing days and environmental influences.

INTRODUCTION

In a previous paper (Boddeke and Becker, 1976) a quantitative picture of the reproduction cycle of the brown shrimp was obtained, by correlating the number of ripe eggs and the recruitment of consumption shrimps (longer than 52 mm), for the fishing grounds of Den Oever (ICES rectangles 3304, and 5210). These fishing grounds are a central part of the coastal area and Den Oever is the largest shrimp harbour in the Netherlands. This study was based on three sets of data, monthly series of catch per fishing day and number of fishing days, the number of shrimps per kilogram and a weekly sampling of the landings in which programme the bodylength of the shrimps was measured and the sex was defined. In the case of females (practically 100% of these shrimps longer than 50 mm) also the stage of development of the eggs was estimated. Dark coloured eggs were considered to be ripe or practically ripe. Between the number of eggs of a berried female shrimp and the body length is a strong relation. (Havinga, 1930). Combining of these data gave a quantitative picture of the monthly production of ripe eggs over a period of six years. By calculating the cross correlation function of the time series of the production of practically ripe eggs and the recruitment of consumption shrimps, a very constant ratio between the number of ripe eggs in the months January - August and the recruitment of consumption shrimps four months later was found. In this paper an attempt is done to calculate the fishing mortality per month of the brown shrimp stock in the already mentioned ICES rectangles 3304 and 5210.

Methods and Materials.

In this area a fast increase in the percentage of berried females with ripe eggs takes place (after a mild winter) in March. On these eggs the recruitment of consumption shrimps in July is based. After July the percentage of berried females with ripe eggs decreases quickly, but quantitatively this decrease is compensated during August by the increase of the shrimp stock in these months.
Although berried females are relatively scarce only during September and October (Tiews 1954) the period in which berried females with ripe eggs are scarce from September to March, due to to the long incubation time of shrimp eggs during winter.
Taking into account the period of four months the shrimps need to grow from ripe egg to recruiting size we get a period of six months with a high and rather regular recruitment (July-December) and six months (January-June) with practically no recruitment. For this reason the years dealt with were separated in these two periods of six months.
Forthese calculations the years 1973, 1974 and 1975 were chosen because by two publications on migration and distribution of the brown shrimp (Boddeke 1975 and 1976) much additional information on the shrimp stock in this area in this period was available. Another reason was the similarity of these years concerning various factors influencing the shrimp stock. In 1973 the shrimp stock recovered from the abnormal high natural mortality in 1971-1972 caused by the strong year classes of cod 1969 and 1970. The yearclasses of cod 1971, 1972 and 1973 were of moderate strength. (Boddeke 1975b).
Another factor influencing the shrimp stock is the sea water temperature in winter especially in February. If the landings give a realistic reflection of the stock, a negative correlation exists between the water temperature in February and the landings in autumn (Boddeke, 1975b). For these three years the average sea water temperatures measured at the lightship Texel in February were respectively 5.8, 6.0 and 5.7 °C. which differences must be considered too small to cause any significant difference to the shrimp stock in these years. Also the total landings from this area did not differ much in these years, with the exception of the first half of 1973.
In the first six months of 1973-1975 the total landings from these ICES rectangles were: 226, 630 and 491 tons respectively. For the second halves of these years, these figures were: 877, 854 and 946 tons.
The density of the shrimp stock in the coastal area of the

Netherlands is estimated biyearly by surveys in April and October. The results of these surveys in 1973-1975 for the coastal area north and south of Den Oever are shown in figure 1 and 2, table 1 and 2.
On the sets of data on the shrimp in these years in this area, Leslie's method adjusted to this special case was applied (Leslie and Davis, 1939).

Modeling

We considered that R recruits enter the catchable stock at a steady absolute rate throughout the last six months of the year (1 July - 1 January). A further assumption was that during the first six months of the year the number of shrimps recruiting to the catchable stock will be negligible. Hence the situation in the two half year periods are completely different.
The following symbols are used:

t designates the t^{th} month (a period of one month has been taken as unit of time).

N_t = size of the stock at the beginning of month t

$\bar{N}_t$ = average stock in month t

Z = instantaneous rate of total mortality

C_t = number of shrimps caught in month t

K_t = cummulative catch to the start of month t plus half of that in month t

q = fraction of the average stock taken by 1 unit of fishing effort (catchability)

f_t = fishing effort in month t (i.e. number of fishing days).

It is also assumed that the catchability q is constant from month to month (in the first half year as well as for the second half year period).

Period 1 July - 1 January.

R recruits enter the catchable stock at a steady absolute rate over this period of six months. The overall balance of recruiting and total mortality of the stock during a small period of time Δt is given by:

$$\Delta N_t = -ZN_t \Delta t + R \Delta t$$

or

$$\frac{dN_t}{dt} = -ZN_t + R$$

The solution of this differential equation is:

$$N_t = \frac{R}{Z} + Ke^{-Zt}$$ in which K is an integration constant.

At time t=0, $N_t = N_0$. From this follows: $K = N_0 - \frac{R}{Z}$, and

$$N_t = N_0 e^{-Zt} + \frac{R}{Z}(1-e^{-Zt})$$

The first term on the right hand side of this equation represents the part of the stock present at time t=0 which survived the period (0,t). The second term represents the number of surviving recruits at time t. The average stock in month t is

$$\bar{N}_t = \int_t^{t+1} N_t dt$$

Because of the increase in catch per unit of effort let

$$\frac{R}{Z} > N_0$$

i.e. N_t (and also $\bar{N}_t$) is an increasing function of t.

Assume there exists a constant (N), such that

$$\bar{N}_t = N + K_t \text{ for each month.}$$

This assumption seems to be reasonable because K_t is a reflection of the cumulative supply of recruitment to the catchable stock. With these assumptions we can use Leslie's method, starting from

$$\frac{C_t}{f_t} = q\bar{N}_t = q(N + K_t) = qN + qK_t$$

Plotting of catch per fishing day against cumulative catch for each month yields astraight line with intercept qN and slope q, from which N and thus $\bar{N}_t$ can be calculated.

Period 1 January - 1 July

In this period recruitment is negligible, so

$$\frac{dN_t}{dt} = -ZN_t$$

or

$$N_t = N_0 e^{-Zt}$$

which is the catchable stock at the beginning of month t.

$$\bar{N}_t = \int_t^{t+1} N_0 e^{-Zt} dt$$

Now $\bar{N}_t$ is a decreasing function of t.

We assume that analogous to the second half year period, there exists a constant (N), such that

$$\tilde{N}_t = N - K_t$$

It follows

$$\frac{C_t}{f_t} = q\bar{N}_t = qN - qK_t$$

Again, as the assumptions hold, a plot of catch per fishing day against the cumulative catch for each month yields a straight line with intercept qN and slope -q.

Results

The calculations have been carried out for the years 1973, 1974 and 1975, for reasons explained in the introduction.
The basic data used are given in table 3 and table 4. The calculated linear regression lines using the method of least squares become:

1st half year period

1973: $\frac{C_t}{f_t} = 120519 - 0.00038K_t$ $r = -0.47$

1974: $\frac{C_t}{f_t} = 197306 - 0.00037K_t$ $r = -0.78$

1975: $\frac{C_t}{f_t} = 226054 - 0.00077K_t$ $r = -0.91$

2nd half year period

1973: $\frac{C_t}{f_t} = 210239 + 0.00042K_t$ $r = 0.63$

1974: $\frac{C_t}{f_t} = 163993 + 0.00025K_t$ $r = 0.36$

1975: $\frac{C_t}{f_t} = 132235 + 0.00036K_t$ $r = 0.55$

In general the regression lines show a good fit. The estimates of the fishing mortality in percentages and N are given in table 3.

The estimated average stocks in the middle $(N-K_t)$ and at the end $(N+K_t)$ of these years are found to be

$\bar{N}$ (x 10^{-9})	middle	end
1973	0.2	0.9
1974	0.3	0.9
1975	0.1	0.6

Discussion

During these three years, the monthly fishing mortality fluctuated considerably, (table 5). A main reason for this fluctuation is the large variation in fishing effort, (tables 3 and 4), although also environmental factors will play a role.
Brown shrimps become highly vulnerable to beam trawl fishing in October when the sexually mature shrimps (of which the females are consumption shrimps) gather in tidal gullies, just outside the area dominated by tidal flats. This is the beginning of the autumn-winter migration toward open sea, which is a highlyflexible process in time, duration, distance and participation (Boddeke, 1976). Another vulnerable period occurs direct after the spring migration, when sexually mature shrimps are concentrated in the shore zone. The spring migration occurs in February - May, depending on the severity of the previous winter. During summer months, the brown shrimps in the western Wadden Sea get a considerable protection against trawl fishing from the mass development of algae (particularly Ulva lactuca) in shallow parts of this area. These sea weeds clog the nets. During July - September a considerable part of the stock of consumption shrimps in this area is found in these shallow inshore waters. Here, sea weeds abound, especially in a calm sunny summer, because light and thus also the clarity of the water favours the development of sea weeds.
On basis of this general information, it is possible to explain why the fishing mortality is not strictly related to the number of fishing days.

First six months

In the first halves of 1973 and especially 1974 the shrimp fishing in the ICES rectangles 3304 and 5210 was influenced by the regular seaward migration in the last months of 1972 and 1973. By this migration, the mass of consumption shrimps moves gradually farther off shore, and becomes less concentrated. This in combination with the comparatively low number of fishing days explains the moderate and regular fishing mortality.
In the first half year of 1975 the shrimp fishing in this area was favoured by the very mild winter 1974-1975 in which no night frost occured till February 1975. Due to this, practically no seaward migration to full sea (through the Marsdiep) took place and the shrimps stayed concentrated in deep, inshore gullies for a long period and could be easily caught there. This phenomenon, in combination with the high number of fishing days lead to trebling of the mean fishing mortality in comparison with the first half of 1974 but the total number of shrimps caught increased only with 21%.

Second six months

Catches in the second half year do not depend only on the size of the shrimp stock but are also influenced by the autumn-winter migration toward sea, which migration is tiggered by temperature fluctuations of the sea water. Especially night frost in

autumn causes an accelaration of the migration as was the case in the first days of November 1973, resulting in a high fishing mortality in this month and a very high total catch. However, in the winter of 1973-1974 the shrimps did not migrate far off shore due to a relatively short period of decreasing water temperatures. In December 1973 shrimpfishing mainly took place at a distance of 4 miles off shore.
In the second half of 1974, no night frost occurred in this area. Migration through the Marsdiep did not occur and the largest concentrations of consumption shrimps were found inside the Waddensea where fishing is difficult for the larger shrimpboats. This could be a reason for the rather low number of fishing days and the modest fishing mortality in this period.
Also in November - December 1975 the air temperature was mild and no night frost occurred before January 1976, a situation very similar to those in the previous year. The somewhat higher mean fishing mortality in July - December 1975, must be considered mainly as a result of the higher number of fishing days (1436, versus 1232 in the second half of 1974).

References

Boddeke, R., 1975a. - Autumn migration and vertical distribution of the Brown Shrimp (Crangon crangon L.) in relation to environmental conditions. Proc. 9th Europ. mar. biol. Symp. Harold Barnes, Editot. Aberdeen University Press. pp. 483-494

Boddeke, R., 1975b. - Changes in the stock of Brown Shrimp (Crangon crangon L.) in the coastal area of the Netherlands. ICES, Symposium on the changes in the North Sea Fish Stocks and their causes. No. 37.

Boddeke, R., 1976. - The seasonal migration of the Brown Shrimp (Crangon crangon).

Boddeke, R., and H.B. Becker, 1976 - A quantitative study of the fluctuations of the stock of Brown Shrimp (Crangon crangon) along the coast of the Netherlands. ICES, Special Meeting on Population Assessments of Shellfish Stocks. No. 58

Havinga, B., 1930. - Der Granat (Crangon vulgaris Fabr.) in den Holländischen Gewässern. J.Cons.perm.int.Explor.Mer. 5:57-87.

Leslie, P.H., and D.H.S. Davis, 1939 - An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8 : 94-113.

Tiews, K., 1954. - Die biologischen Grundlagen der Büsumer Garnalenfischerei. Ber.Dtsch.Wiss.Komm. Meeresforsch. 12 (3) 235-269.

COASTAL AREA NORTH OF TERSCHELLING AND AMELAND.

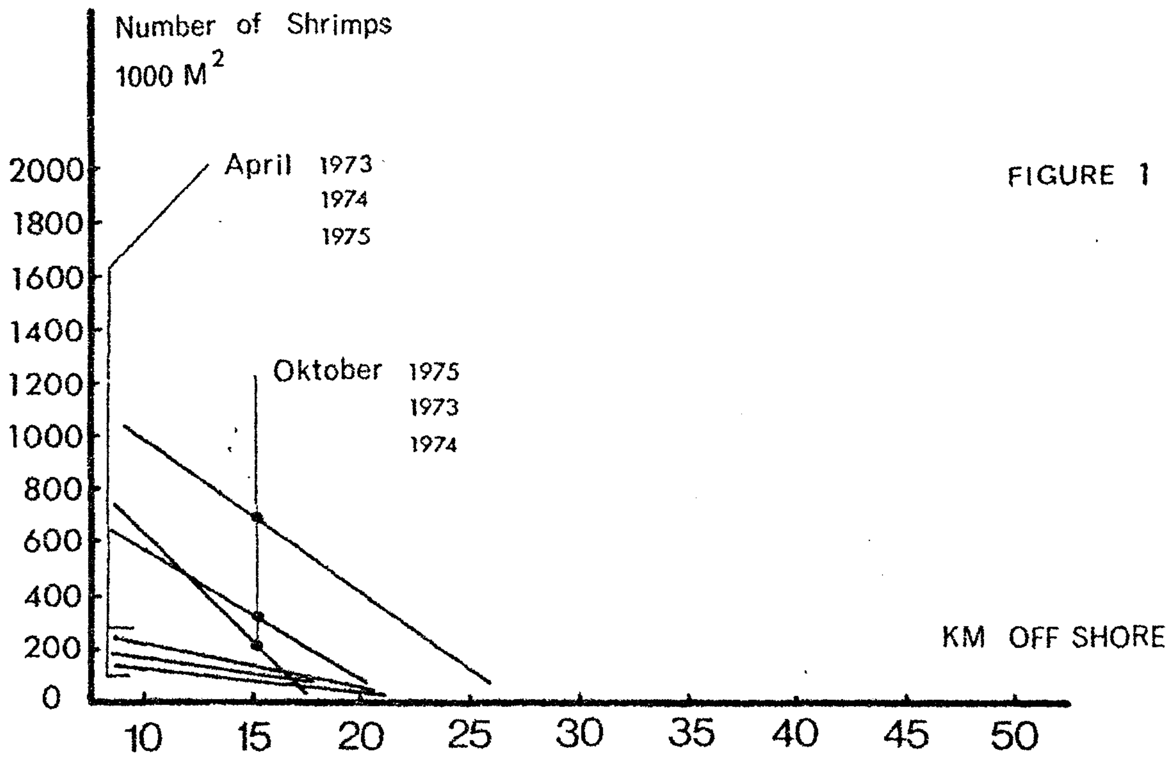

FIGURE 1

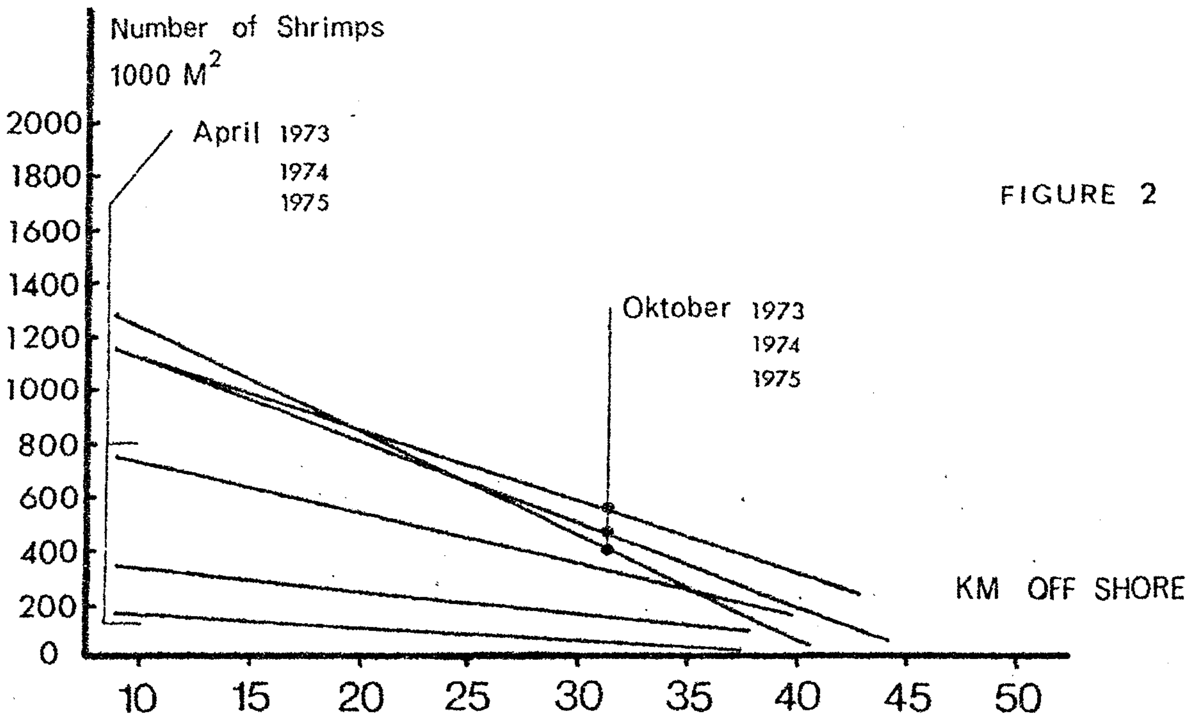

FIGURE 2

COASTAL AREA BETWEEN GOEDEREEDE AND DEN HELDER.

TABLE 1 - (belongs to figure 1) Coastal area north of Terschelling and Ameland.

APRIL	regression equation	r	n
1973	Y = 352.3 - 15.2 X	- 0.576	15
1974	Y = 293.4 - 12.3 X	- 0.483	21
1975	Y = 231.7 - 9.4 X	- 0.312	24
OCTOBER			
1973	Y = 1067.9 - 48.8 X	- 0.484	20
1974	Y = 1410.0 - 77.9 X	- 0.577	31
1975	Y = 1572.0 - 57.9 X	- 0.407	25

TABLE 2 - (belongs to figure 2) Coastal area between Goedereede and Den Helder.

APRIL			
1973	Y = 939.2 - 20.0 X	- 0.635	31
1974	Y = 422.1 - 8.5 X	- 0.490	38
1975	Y = 218.6 - 5.1 X	- 0.542	39
OCTOBER			
1973	Y = 1406.2 - 27.5 X	- 0.498	36
1974	Y = 1452.2 - 31.4 X	- 0.407	46
1975	Y = 1607.8 - 38.2 X	- 0.537	39

TABLE 3 - Catch (in numbers) and effort data for the first six months of the years 1973-1975.

1973	number of fishing days	catch per fishing day	total catch (in numbers)	K_t
Jan	278	135 578	37 690 776	18 845 388
Febr	219	95 660	20 949 582	48 165 567
March	214	73 627	15 756 120	66 518 418
April	82	74 877	6 139 922	77 466 439
May	154	78 588	12 102 600	86 587 700
June	247	122 947	27 897 942	106 587 971
	1194 total			
1974				
Jan	208	201 993	42 014 548	21 007 274
Febr	164	168 416	27 620 280	55 824 688
March	214	168 269	36 009 669	87 639 662
April	133	136 331	18 132 000	114 710 496
May	195	134 300	26 188 428	136 870 710
June	151	159396	24 068 772	161 999 310
	1065 total			
1975				
Jan	425	187 516	79 694 490	39 847 245
Febr	289	178 220	51 505 545	105 447 262
March	175	100 792	17 638 528	139 772 071
April	238	84 081	20 011 158	158 844 142
May	241	85 420	20 586 024	179 142 733
June	254	85 484	21 712 992	200 292 241
	1622 total			

TABLE 4 - Catch(in numbers) and effort data for the last months of the years 1973-1975.

1973	number of fishing days	catch per fishing day	total catch (in numbers)	K_t
July	180	202 814	36 506 604	18 253 302
Aug	293	189 746	55 595 705	64 304 456
Sept	161	227 531	36 632 520	110 418 568
Oct	171	393 418	69 635 043	163 552 349
Nov	359	357 853	128 469 144	262 604 443
Dec	248	302 479	75 014 694	364 346 362
	1412 total			
1974				
July	111	134 840	14 967 239	7 483 619
Aug	70	96 877	6 781 360	18 357 919
Sept	199	235 394	46 843 467	45 170 332
Oct	306	264 443	80 919 696	109 051 913
Nov	305	239 882	73 164 104	186 093 813
Dec	241	163 309	39 357 408	242 354 569
	1232 total			
1975				
July	222	107 940	23 962 680	11 981 340
Aug	159	146 635	23 315 040	35 620 200
Sept	212	122 723	26 017 354	60 286 397
Oct	287	261 465	75 040 590	110 815 369
Nov	281	207 927	58 427 551	177 549 439
Dec	275	173 301	47 657 792	230 592 010
	1436 total			

TABLE 5 - Estimates of the fishing mortality per month of the years 1973-1975.

F (%)	1973	1974	1975
Jan	10	7	28
Feb	8	6	20
March	8	8	12
April	3	5	15
May	6	7	17
June	9	5	18
$\bar{F}$, N	7, 0.3 10^9	7, 0.5 10^9	19, 0.3 10^9
July	7	3	8
Aug	11	2	6
Sept	6	5	8
Oct	7	8	7
Nov	14	8	10
Dec	10	6	10
$\bar{F}$, N	9, 0.5 10^9	5, 0.7 10^9	8, 0.4 10^9