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ENHANCEMENT OF THE PRODUCTION OF COCKLES (CERASTODERMA EDULE L.) BY THINNING OUT A DENSE NATURAL BED AND RESEEDING, OOSTERSCHELDE, SW NETHERLANDS

by

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Abstract

Cockle fishing in the Dutch coastal waters is mostly carried out on 2-3 year old cockles, generally dredged on intertidal sand flats. Re-seeding of cockles is practised on an experimental scale since 1980. Small cockles are fished on locations with bad conditions for growth and seeded on plots in areas where growth conditions are favourable. Cockles on natural beds can have such high population densities that growth is impaired and a part of the individuals is pushed out of the sediment and subsequently dies. In the spring of 1980 about half of the population on an experimental plot was fished up and re-seeded on an empty plot. Growth, density and biomass of the cockles of all these groups were followed over a period of 6 months. On a natural bed situated nearby, growth, density and biomass of the cockles were followed during 1980 and 1981 on locations with different densities.

Probably because the population density on the unfished bed was about the same as that on the fished plot, growth rate of the cockles on the fished plot did not differ from that on the surrounding unfished bed. 54% of the re-seeded cockles disappeared directly after seeding. Growth of the re-seeded cockles was faster than on the original bed. Per saldo, biomass on the thinned plus the re-seeded plot amounted to 11.1 kg fresh weight per square meter, compared with 7.5 kg per square meter on the original unfished part of the bed. It could be concluded that, despite considerable seeding losses, there is an advantage in thinning out very dense natural cockle beds. A considerable part of the seeding losses can, to the opinion of the authors, be avoided. The advantage of re-seeding appears to lie mainly in the "saving" of those cockles which would otherwise have disappeared from the bed. Also the better growth on the location of re-seeding than on the original bed has contributed to the increase in production. The thinning out appeared to have had no influence on the growth of the cockles on the original bed. On the nearby natural bed, however, growth appeared clearly density-dependent.

Thinning out did not have a significant influence on the growth rate of the cockles which had remained on the fished plot.

Resumé

AUGMENTATION DE LA PRODUCTION DE LA COQUE (Cerastoderma edule L.) EN ECLAIRCISSANT UNE DENSE POPULATION ET EN RE-SEMANT DANS LE OOSTERSCHELDE, S.O. DES PAYS-BAS.

La pêche aux coques (Cerastoderma edule L.) dans les eaux côtieres des Pays-Bas est généralement pratiquée aux animaux de 2-3 ans, draguées sur les bancs découvrants. Les engins normalement usés sont la drague aspirante ou la drague commune, tous les deux munies d'un jet d'eau pour dégager les cocques du sediment.

La re-semencement des coques se fait à une échelle experimentale dès 1980. Des petites coques sont pêchees dans des endroits où les conditions pour la pousse sont pauvres et sont re-semées dans des endroits où ces conditions sont meilleures.

Les coques dans les bancs naturels peuvent vivre dans des densités de

--population tellement élevées, que plus de croissance causerait qu'elles se pousseraient hors du sol et moureraient. Dans le printemps de 1980 autour de la moitié de la population dans une parcelle experimentale fut draguée et les coques furent re-semées dans une parcelle vide aux mêmes dimensions. La croissance, la densité et la biomasse des coques de toutes les catégories furent suivis durant une periode de 6 mois.
Dans un gisement de coques proche, la croissance, la densité et la biomasse des coques furent suivis dans des endroits à haute et à relativement baisse densité de population pendant 1980 et 1981.

Probablement comme la densité de population dans le gisement non-pêché se révêlait égale à laquelle dans la parcelle où l'on avait pêché, le taux de croissance des coques dans la parcelle pêchée ne différait pas de cette dans le gisement non-pêché. 54% des coques re-semées disparut dans le premier mois après le semencement. Le taux de croissance des coques re-semées était plus haute que dans leur gisement d'origine. La biomasse sur la parcelle éclaircie, augmentée de la quantité de coques sur la parcelle ensemencée, était 11,1 kg de poids vivant par m2, contre 7,5 kg sur la parcelle non-draguée. Le rendement de cette opération etait alors 3.6 kg/m2 ou 45% environ.
La conclusion était que, en dépit de pertes de semencement considerables - que peuvent etre evitées- il y a un avantage dans le re-semencement de gisements de coques très denses. Cette avantage apparut surtout la "sauvetage" de cettes coques que autrement seraient expulsées du gisement. La taille supérieure, atteinte sur la parcelle de resemencement, a laquelle sur la parcelle d' origine a bien contribuée au resultat. Bien qu'on na pas réussi a démontrer un effet positif de l'éclaircissement sur la croissance des coques, on trouvait dans une population adjacente une pousse qu'était nettement relatée a la densité de population.

1. INTRODUCTION

1.1 The cockle fishery in The Netherlands

Until the sixties, cockle fishery in The Netherlands was practised on a rather limited scale, by hand. The product was sold to the United Kingdom, mainly as preserves.
During the sixties, interest for cockles arose from the side of Spanish importers. The subsequent rise in demand and in price stimulated large-scale mechanisation of cockle dredging in the Netherlands. Since 1974 cockle dredging is regulated by means of a license system, in total 35 licenses being issued. This number is fixed until this moment, to avoid over-exploitation.
Before 1974, in total 10 dredging ships were in use, which indicates that not all 35 issued licenses were then fully used. Since 1974 the number of ships is increasing gradually: 21 ships in 1981, 35 in 1986.
The increase in capacity showed a marked dip when in 1981 overproduction, combined with suspended export to Spain due to problems with toxic food oil, caused a price slump and serious troubles for quite a lot of enterprises. Afterwards, the industry succeeded in strengthening his position by diversifying the product

and exploring new markets.

The recently built ships are specilly designed for cockle dredging. They are flat pontoons with a length of about 30 and a width of about 8 m. Their draught does not exceed 50 cm. On deck they can store 100 - 200 tons of fresh cockles. Three bigger ships (40 m) are under construction. About half of the fleet is equipped for cooking and de-shelling the cockles at sea.

Fishery is mostly done with aid of suction dredges. These are attached to both sides of the ship by means of their 8 - 10 m long pression and suction pipes. While dredging, the cockles are whirled up from the sand with a strong water jet through a slot and subsequently scooped up by means of an adjustable rectangular "knife", which cuts obliquely through the sediment, reaching about 5 cm deep. The width of the dredges is officially fixed at 100 cm, as is the width between the bars of the dredge cage. This is to enable small cockles to escape.
Damaging of small cockles, mostly at the umbonal end, by the suction dredges was considerable in the beginning: 15 - 25% of the captured cockles showed punctures. The non-suction dredges cause little damage: 3 - 6%.
The damage rate, caused by the suction dredge is now brought down considerably by improvements at the adjustment of suction force, type and capacity of the pump and knife adjustment. The official exigency of maximally 10% damaged cockles can now, in most cases, easily be met.
The sand/water/cockle mixture within the cage of the dredge is pumped up through a 3-6 inch pipe, connected to the top of the dredge cage. Once on board, cockles, water and sediment are separated in rotating sieves and the cockles are stored on deck. The last 5 years de-sanding of the cockles is realised by flooding the deck with a water layer of some decimeters, thus enabling the cockles to dispose of sand and silt in the intestinal tract and in the mantle cavity.

The cockles are then cooked, which on many ships is done on board, but partially also on shore. The cooked product is then cooled and transported to deep freeze plants as rapidly as possible, or to factories for further processing. The final product is mostly block frozen, but exports of the canned or IQF frozen product are in the rise.
The latest development is the development of bacterial purification of seawater for rinsing and cooling the cooked product on board, by means of UV light or ultrafiltration, in order to minimise bacterial contamination of the product. Also re-use of cooling water is being tried out.

Landings of cockles (fresh weight) during the last years are shown in the following table:

year	tons fresh weight
1980	45 000
1981	45 000
1982	40 000
1983	55 000
1984	60 000
1985	50 000

Table 1.
Landings, expressed as fresh weight, of cockles captured in the Dutch waters. For the weight as cooked meat, multiply by a factor 0.15 x (A.C. Drinkwaard, pers. comm.).

1.2 The natural cockle stocks

About 75% of the landings are captured in the Waddenzee, (see fig. 1), where large areas of intertidal sandflats offer good conditions for spatfall and development. The remainder is fished in the Oosterschelde and on the North Sea coast. Intertidal areas are also most suitable for the mechanised cockle fishery described above. In deeper waters offshore and in some tidal channels also considerable stocks of cockles occur, but these can at this moment only be fished to a small extent because the tubes of the hydraulic dredges allow fishing depths of maximally 8 m. At our institute, research is under way to develop methods for locating and dredging these stocks.
The growth rate of cockles in the Oosterschelde is highest in the mouth of the estuary, declining in upstream direction. In the upstream SE part of the estuary, cockles often do not reach a size which is generally considered marketable (a cooked meat weight of more than 1 gram). A legal size for cockles does not exist. In practice the commercial size is inversely related to the market price and when demand is high, even cockles with a cooked meat weight as low as 0.7 g are landed.

Fishing and relaying of small cockles was introduced in 1980 and six experimental plots were selected for this in the mouth of the Oosterschelde and 12 in the Waddenzee (see fig. 2). The plots in the Oosterschelde were situated in the lower littoral zone where the growth rate, according to practical experience, was highest. The abundant yearclass of cockles, born in the spring after the strong winter of 1979 gave rise to natural cockle beds with extremely high densities. In the spring of 1980 these amounted up to 5,000 individuals per square meter.

Already in april 1980, at the start of the growing season, it became apparent that the cockles in the natural beds were living in such high densities that they touched each other and growth was

making the cockles to push each other out of the sediment, just as described earlier by Kreger (1940) for the Waddenzee. Locally, concentrations of cockles could be observed on top of the sediment. During warm days mortality among these cockles was obvious, numerous gaping and dead individuals could be observed in these heaps. The reason that these heaps did not disperse was probably that the tidal currents on this location are not strong enough to move the cockles.
A storm would, however, inevitably sweep them into the surrounding tidal channels, where most of them would perish in either moving sand or in mud. Migration of adult cockles into tidal channels by waves and current was earlier described by Kristensen (1957).

In view of this threatening loss of a part of the stock, the cockle fishing industry approached the Ministry of Agriculture and Fisheries and asked for an experiment to be carried out to assess the feasibility of thinning out such overcrowded populations and relaying the fished cockles onto cultivation plots. In the spring of 1980 these plans materialised into the setup of an experiment on pilot scale.
With the cooperation of the cockle fishing industry, which supplied a cockle dredging ship and of the Directorate of Fisheries of the Ministry, which provided a cultivation plot, the Mariculture Department of the Netherlands Institute for Fishery Investigations in Yerseke worked out a schedule for the experiment to be described in the sequel. The experiment was also supported by a monitoring program of density and population biomass of cockles on different intertidal flats in the Oosterschelde.

2. MATERIALS AND METHODS

Measurements of current velocity were done with aid of "Ott" propeller current speed meters, used from an anchored research vessel.
Two experimental plots measuring 50 x 200 m were selected on the tidal flats for fishing and relaying of the cockles.
The plot to be fished was situated in a large cockle bed on the tidal flat "Roggenplaat", the plot to be seeded was situated on the tidal flat "Neeltje Jans" (fig.1). These plots were demarcated with wooden stakes. On each plot the initial density of cockles was determined after taking 30 samples, evenly distributed over the plot. These were taken with a hand core sampler with a surface area of 78.5 square centimeter, at low tide. To investigate the unfished cockles outside the plot, 5 stations were chosen on a transect through the intact cockle bed, immediately next to the fished plot on Roggenplaat. On each station, 6 core samples were taken and pooled. On the plot to be fished 2530 cockles per square meter were present, which density is not extremely high. No cockles were found on the plot where the fished cockles were to be re-seeded. It was decided to thin out the population on the plot to be fished by about 50%. This was done on the 9th of May 1980, with aid of the commercial cockle dredger YE 59,using two non-suction water-jet dredges of one meter wide. The dredging was carried out in a cris-cross pattern, as regularly as possible over the plot. After estimatedly half of the standing stock on the plot was

fished up, the dredger moved to the other location on Neeltje Jans. There the cockles, stored on deck of the dredger, were relaid on the plot to be seeded, by washing them through a seeding hatch in the center of the vessel.
Sampling on the plot after fishing learnt that the population density of the cockles had been reduced from 2530 to 1523 cockles per m2.

After fishing and seeding, standing stock biomass, population density and growth in length and fresh weight were followed by monthly taking 30 samples on the plots as described before.
The same parameters were followed within the framework of another routine programme of cockles on an undisturbed bed on Neeltje Jans in a transect through an undisturbed natural cockle bed during 1980 and 1981. This transect was situated in a natural bed about 300 m away from the location of re-seeding. In this transect 3 stations were chosen in an area with high and 3 stations in an area with a low population density. On each station 6 random core samples were taken and pooled. Of all cockles sampled, shell length was measured with vernier calipers at the longest axis of the shell, parallell to the hinge. Ashfree Dry Weight was determined after incinerating at 580 deg. C. during 4 hours.

3. RELEVANT ENVIRONMENTAL FACTORS

Elevation	
Roggenplaat:	20.0 dm above LLWS
Neeltje Jans:	17.2 dm above LLWS
Transect Neeltje Jans:	8.7 - 18.7 dm above LLWS
Tidal range:	3.5 m (spring tide)
	3.0 m (neap tide)
Maximum current velocity at average tide at 65% of depth	
Roggenplaat:	38 cm/s (ebb)
	71 cm/s (flood)
Neeltje Jans:	106 cm/s (ebb)
	40 cm/s (flood)
Tidal emergence period	
Plot Roggenplaat:	5 - 6 hours
Plot Neeltje Jans:	0 - 1 hour
Median grain size	
on cockle beds:	100 - 130 μ m
outside beds:	> 150 μ m
Lutum fraction	
on cockle beds:	>5%
outside beds:	0 - 2%

Water temperature range:	- 1 - 18 deg. C
pH:	7.6 - 8.6
Salinity:	28 - 33 g/l

4. RESULTS

Fresh weight, shell length, biomass and number per square meter, determined at monthly intervals between May and August on the fished plot and on the plot where the cockles were relaid are given in tables 2 a - c and figs. 3 - 6.

The population density on the fished plot on Roggenplaat was reduced by 40% to 1523 cockles/m2 or 3.75 kg/m2. After the fishery, the population density and standing stock biomass appeared not to differ noticeably from those in the transect in the adjacent, unfished bed. Also there appears not to be any difference in growth rate in length or in weight between the fished and the unfished location.
On the unfished location population density decreased by about 35% during the sampling period. After fishing, density of cockles on the fished location did not change for the rest of the period.

Growth rate of the cockles on the seeded plot appeared to be distinctly higher than of the cockles that had remained on the fished plot.

Population density of the re-seeded cockles showed a marked decrease during the first month after re-seeding: their number dropped from 981 to 456 per m^2, which means a reduction by 54% .

Cockles on an undisturbed natural bed on Neeltje Jans (table 3 and figs 7 and 8) show a significantly lower growth rate in length and in weight on a densely populated area (5000/m2) than on an area where the population density amounted only 30% of that value. Conditions for growth seemed comparable in both areas. Individual weight gain during 1980 was two times as high at the low population density than on the high density location. Standing stock biomass, however, remained more than two times higher in the high density area. The decrease in population density during 1980 was about equal at both population densities: 23% on the high density and 33% in the low density area.

4.1 Statistical analysis of the results.

A significant relation between the increase of individual fresh weight and standing stock biomass on the fished and the re-seeded plot and the unfished transect could be demonstrated, calculating the respective correlation coefficients: r = 0.975, r = 0.982 and r = 0.945 ($P<0.05$). From the squares of these values it could be deduced that resp. 98, 97 and 89% of the variation in the standing stock biomass could be explained by changes in the individual fresh weight.

Population density of the cockles on the fished plot and the unfished transect were tested for possible trends by means of linear regression analysis.The density of the cockles on the fished plot did not show a significant trend (r = 0.29). Although the results strongly indicate a decrease in density, there proved to be no significant trend in population density on the unfished transect (r=0.67, n=4).

The growth rates of the cockles on the fished and the re-seeded plot and on the unfished transect were tested for differences in growth rate by means of variance analysis. When these differences appeared significant (Fs = 19.0629), an "unplanned comparison analysis" was carried out between the three groups (Rohlf and Sokal, 1981). This resulted in a significant difference between the growth rate of the cockles on the seeded plot versus the two other groups. The difference between the growth rate on the fished plot and on the unfished transect appeared not to be significant. The results of this comparison are represented below.

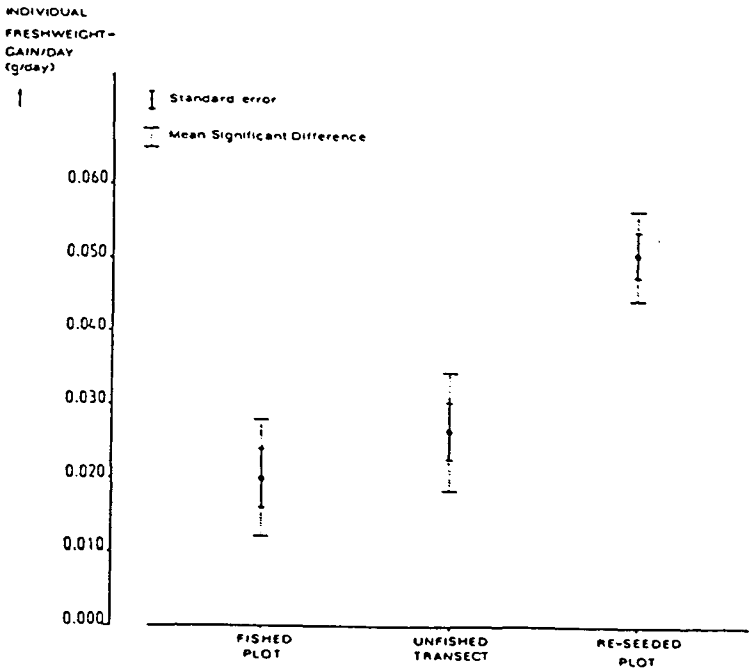


Figure 1 - Comparison of individual weight gain per day between the three locations with the respective standard errors (SE dotted line) and ½ mean significant difference (solid line).

5. DISCUSSION AND CONCLUSIONS

As the highest population densities appeared to occur just within the area of the fished plot, there was hardly any difference in population density between the locations with the fished and the unfished cockles. Neither was there a difference in growth rate between the fished and the unfished location. A possible positive effect of thinning out on the growth rate could therefore not be demonstrated. That growth of cockles can be density-dependent, appeared from the data, obtained on the undisturbed transect on Neeltje Jans, which will be discussed below.

It seems probable that the higher growth rate of the cockles on the seeded plot is only very partially due to the reduced population density. Rather can better conditions for growth: a lower elevation and hence longer submergence period and better food provision due to higher current velocities be held responsible for the much better growth results on that location. Just as in bottom culture of other molluscs, the advantage of re-seeding is the possibility to select locations which are more favourable than the location where the seed is fished. Such locations are not automatically the same locations where natural populations occur. In the practice of bottom-cultivation in the Netherlands, the factors growth and survival, the latter notably in terms of shelter from waves or strong currents, are considered to be the most important criteria in site selection.
From the marked decline in the population density of the re-seeded cockles in the month directly following seeding, it must be concluded that a considerable part of the cockles died or was dislocated after seeding.
That this happened can be ascribed mainly to the conditions during seeding: As the fished plot was situated rather high in the tidal range, seeding had to be carried out late, rather hurriedly and just in that phase of the ebb when the current speed was highest and water depth limited to 1 m. As the draught of the ship was 50 cm, this caused a rather irregular spreading of the cockles on the plot, because such a limited "sinking distance" is not sufficient for the cockles to disperse properly in the wake of the ship. Additionally, the high current velocities between seeding and burrowing of the cockles may have attributed to their displacement while still above the bottom, and consequently their disappearance from the -rather small- plot. As could be observed in the field, also cockles swept onto ridges by the current showed an increased mortality and did not burrow.

High initial losses at re-seeding cockles do occur often, according to professionals. They are sometimes used as arguments against re-seeding of cockles, because a part of the material is wasted.
In the opinion of the authors, such high losses can for a great deal be avoided. In the first place, the the moment of seeding must be chosen as carefully as possible, with a water depth of more than one meter below the vessel, preferably at slack tide. Further, the reseeding must be carried out as gently as possible, which requires special attention of the skipper and, before all, time.

Further causes of seeding loss can be mortality caused by shell fracture or punction or by internal lesions of the cockles. Visible shell damage can, when the right type of dredge is used and the gear is properly adjusted, be less than 7%, but there is a fair possibility that actual seeding mortality is much higher. See "introduction". Although it was observed that punctures in shells can be successfully sealed off from inside by the cockle, fair numbers of burrowed cockles which apparently had died recently, were found in the bottom during the samplings. These cockles must have died some time after seeding. Also a part of the injured cockles can fail to burrow and may be swept away or eaten by predators.
It may well be possible that the cockle is a species, more susceptible to mechanical injury than non-burrowing bivalves like mussels or oysters.

The difference in population density of the cockles on the transect on Neeltje Jans has obviously caused a considerable difference in growth rate. On the other hand, mortality in both the dense and the less dense area do not show any difference between the densities. This is in contradiction with Kristensen (1957), who found that population density and annual mortality were positively correlated in the range from 170 until 2010 cockles/m2. The mortality rate in this case amounted to 15% per 3 months during the summer period. Hancock and Urquhart (1965) found in South-Wales a mortality of 21% per 3 months in the second summer.
Their cockles were subjected to heavy predation by oystercatchers.
It is remarkable that the cockles in the dense area succeeded in reaching such a high standing stock biomass (3 800 cockles/m2 and 11;1 kg/m2 by the end of october, 1980) without an increased mortality. In the bed of the fished plot the cockles had already started to push one another out of the sand at a much lower density: around 2 500 cockles per m2 and at about the same size. According to observations in the field, the high biomass in the transect is not representative for the normal situation in the cockle beds in that area.

As overall yield of the re-seeding experiment can be considered the sum of the biomnass, present on the fished and on the reseeded plot at the end of the experiment.
The intrapolated fresh weight biomass on 16-9-1980 on the fished plot was 7.12 kg/m2 and that on the seeded plot 4.11 kg/m2. Together this means a yield of 11.23 kg/m2. The intrapolated fresh weight biomass on the unfished plot was by that time 7.6 kg/m2, which means that during this experiment the net result was a gain of 3.6 kg of fresh cockles per m2 or about 45%. Calculation on basis of the yield per individual cockle, which eliminates an existing difference in density at the start of the experiment, demonstrates an even larger difference: 2.13 g/cockle on the fished plus the re-seeded plot and 1,38 g/cockle on the unfished bed. This means a net gain in weight of 54 %.
An additional profit is the larger size of the cockles, grown on the re-seeded plot, which may fetch a better price.
The weight increase per seeded cockle on Neeltje Jans (1,97 g) is still lower than that per cockle which stayed behind on Roggenplaat (2,23 g/cockle). This illustrates the importance of keeping (seeding)

mortality as low as possible.

5.1 Conclusions

Re-seeding cockles from a densely populated bed resulted in a net gain of 45-54 % in biomass, plus a larger size of the re-seeded cockles.

Thinning out and re-seeding can be considered as a profitable tool in the management of those cockle stocks which show densities of 2.500 cockles/m2 and higher.

Selection of favourable locations for re-seeding the fished cockles can result in a considerable improvement of growth rate compared with the bed of origin. Depth, current velocity and exposition are the most important criteria for the "culture-value" of such plots.

In this experiment an influence of thinning out on growth rate could not be demonstrated. In another location with a high population density, growth rate was, however, clearly density-dependent. At higher densities a positive effect on growth is therefore most probable.

Mortality caused by wrong seeding methods can be considerable. The yield of a re seeding operation can be higher than described in this paper when attention is payed to this aspect.

6. REFERENCES

BAGGERMAN, B. 1954
Spatfall and transport of Cardium edule L.
Arch. Neerl. de Zool., Tome 10, pp 315 - 342.

HANCOCK, D.A. AND A.E. URQUHART, 1965.
The determination of natural mortality and its causes in an exploited population of cockles (Cardium edule L.)
Ministry of Agriculture, Fisheries and Food, Fish. Investig. series II, Vol XXIV, Number 2. London, 1965

KREGER, D., 1939. On the ecology of Cardium edule L.
Arch. Neerl. de Zool. Tome IV, pp 156 - 200

KRISTENSEN, I, 1957.
Differences in density and growth in a cockle population in the Dutch Wadden Sea. Arch. Neerl. de Zool. tome 12, 3-e livr., pp 351 - 453

ROHLF, F.J. & R.R.SOKAL.
Biometry, second edition, San Francisco, 1981

6. TABLES AND FIGURES

Table 2 a

LOCATION ROGGENPLAAT
fished plot

Date	Shell length (mm)	Individ. fresh weight (g)	Population density (N/m2)	Biomass in fresh weight (kg/m2)
28-5	16.0 (0.5)	2.11 (0.47)	2530 (866)	5.22 (1.62)
10-6	17.0 (0.9)	2.42 (0.26)	1523 (1599)	3.72 (3.90)
15-7	18.4 (2.2)	2.72 (0.38)	1667 (1016)	4.61 (2.69)
14-8	19.6 (0.8)	3.06 (0.58)	1719 (727)	5.37 (2.49)
16-9	20.8 (1.1)	4.42 (0.59)	1571 (733)	7.12 (3.35)

Table 2 b

LOCATION NEELTJE JANS
seeded plot

11-6	17.3 (0.6)	2.20 (0.53)	981 (958)	2.18 (2.16)
15-7	19.7 (1.1)	3.48 (0.67)	456 (544)	1.52 (1.81)
14-8	21.3 (1.1)	5.02 (0.92)	356 (466)	1.90 (2.32)
16-9	23.8 (1.0)	7.13 (1.13)	573 (482)	4.11 (3.53)

Table 2 c

LOCATION ROGGENPLAAT
transect in unfished part

28-5	16.6	2.1	2168	4.52
30-6	18.9	3.1	1709	5.38
30-7	19.3	3.5	1690	5.89
25-8	20.5	4.6	1338	6.21
29-9	22.1	5.4	1558	8.44

Table 2
Shell length, fresh weight, density and fresh weight biomass of cockles, 30 pooled samples, taken at monthly intervals on the experimental plots on the fished location Roggenplaat (2-a), at the location Neeltje Jans where the fished cockles were re-seeded (2-b). In a transect in an adjacent unfished cockle bed on the Roggenplaat (2-c), 6 samples were pooled each time.
Standard deviations between brackets.

table 3-a

T R A N S E C T N E E L T J E J A N S , low population density.

Date	Popul. density (N/m2)	Shell length (mm)	Ind. ADW (mg)	Stock Biomass (mg ADW/m2)	Stock Biomass (g FW/m2)
24-03-80	1460	11.8	23.4	34.2	1200
28-04-80	1035	12.2	23.5	48.8	1400
27-05-80	1316	16.3	99.5	130.9	3400
30-06-80	1251	19.3	152.1	190.3	3500
30-07-80	1189	19.3	161.4	191.9	4100
25-08-80	1168	21.0	243.2	284.0	4900
29-09-80	807	22.3	285.0	230 0	4000
27-10-80	991	23.0	278.0	275.5	5200
24-03-81	679	24.0	231.0	111.6	4300
21-04-81	623	24.1	284.0	145.6	3900
26-05-81	687	24.5	280.5	120.2	3400
02-07-81	637	23.9	266.2	148.2	3900
11-08-81	446	25.2	406.8	153.9	3300
07-09-81	468	27.2	676.4	200.7	4400
29-10-81	439	26.4	525.7	107.8	3700
30-11-81	290	25.8	513.7	113.4	2420

table 3-b

T R A N S E C T N E E L T J E J A N S, high population density.

24-03-80	5008	11.1	17.6	88.5	3500
18-04-80	4690	11.1	23.5	102.2	3200
27-05-80	3801	14.3	62.6	271.1	5300
30-06-80	4070	16.6	105.4	429.1	8500
30-07-80	4160	16.7	100.3	416.8	9500
25-08-80	4246	17.0	117.3	498.2	10200
29-09-80	4225	17.8	142.2	600.8	12200
27-10-80	3857	17.4	133.4	515.6	11100
24-03-81	2611	18.3	86.5	192.7	6500
21-04-81	2357	18.5	103.5	242.9	6600
26-05-81	2242	19.1	123.5	277.6	8100
02-07-81	2597	19.2	122.6	318.5	6900
11-08-81	2541	19.7	157.8	400.9	8600
07-09-81	2349	21.0	217.3	510.8	10264
29-10-81	2010	21.2	198.5	399.0	8100
30-11-81	1814	21.1	200.6	361.9	7300

Table 3
Development of growth, density, shell length and biomass of yearclass 1979 cockles on a density populated and a less density populated part of the Neeltje Jans cockle bed, 1980 and 1981. Obtained from 18 pooled samples.

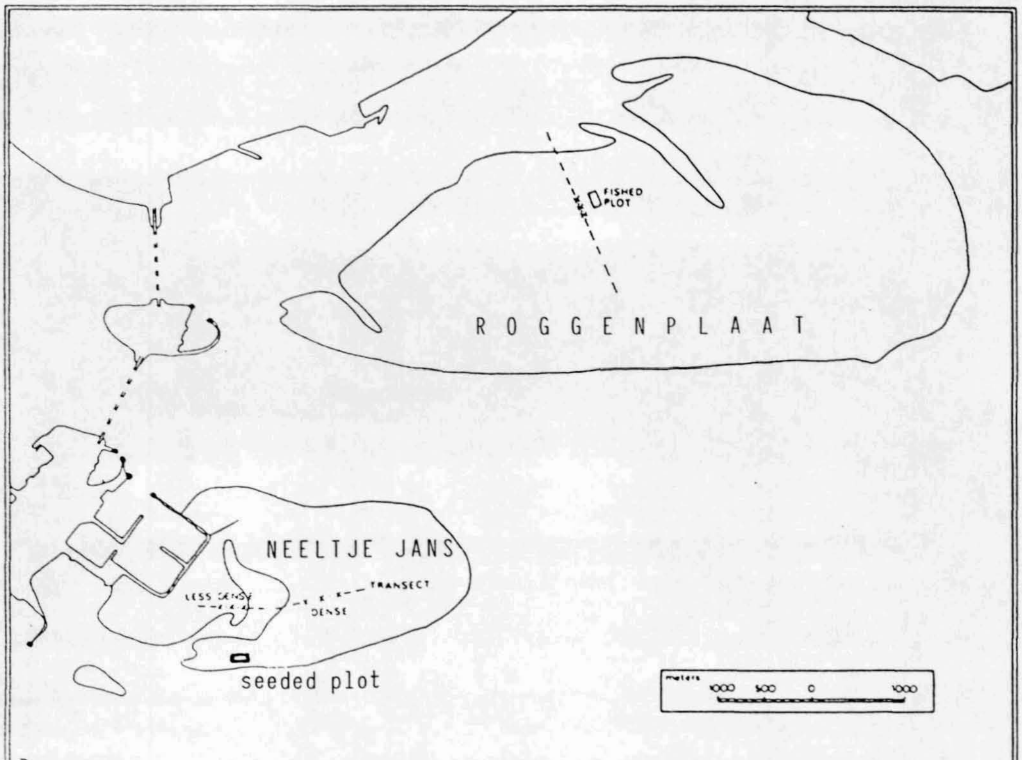


Figure 2 - Situation of the experimental locations in the Oosterschelde.

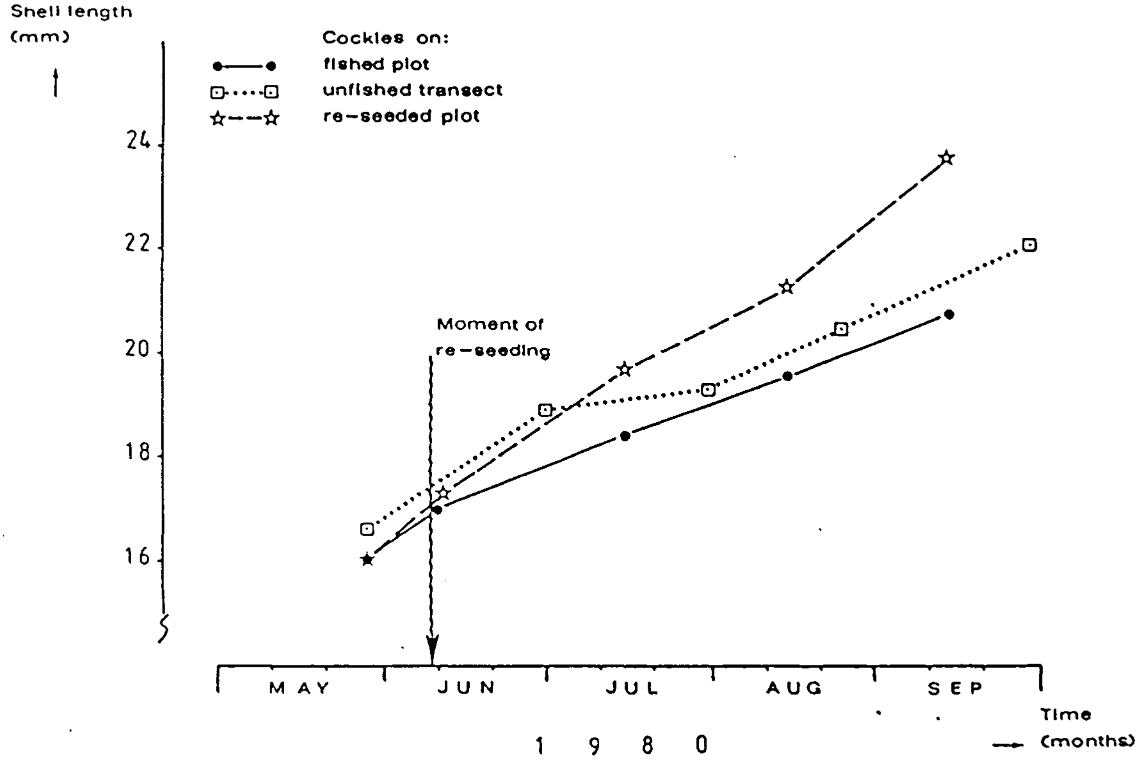


Fig. 3: Shell length of cockles on the fished and unfished location and on the plot where the fished cockles were re-seeded.

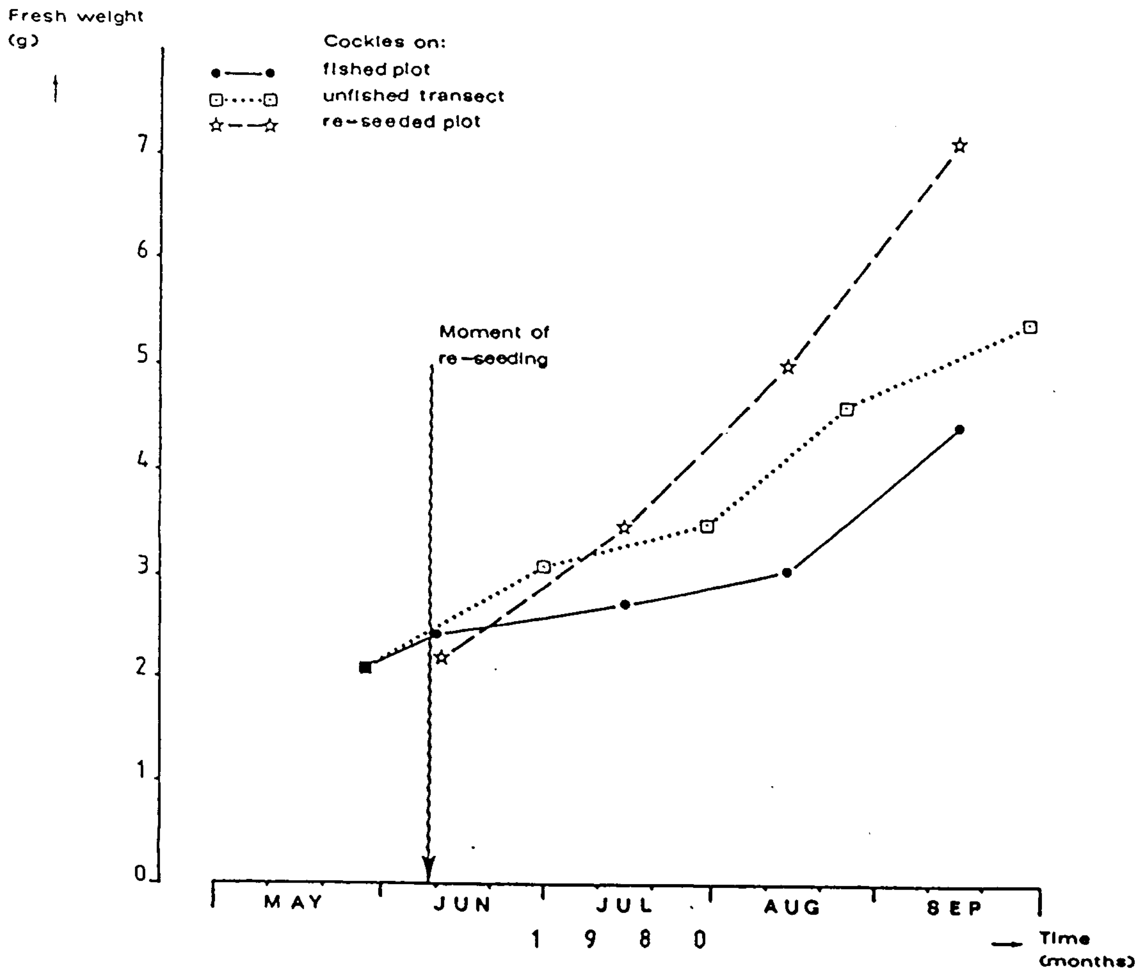


Fig. 4 : Individual fresh weight of cockles on the fished and the unfished location as well as on the plot where the fished cockles were re-seeded.

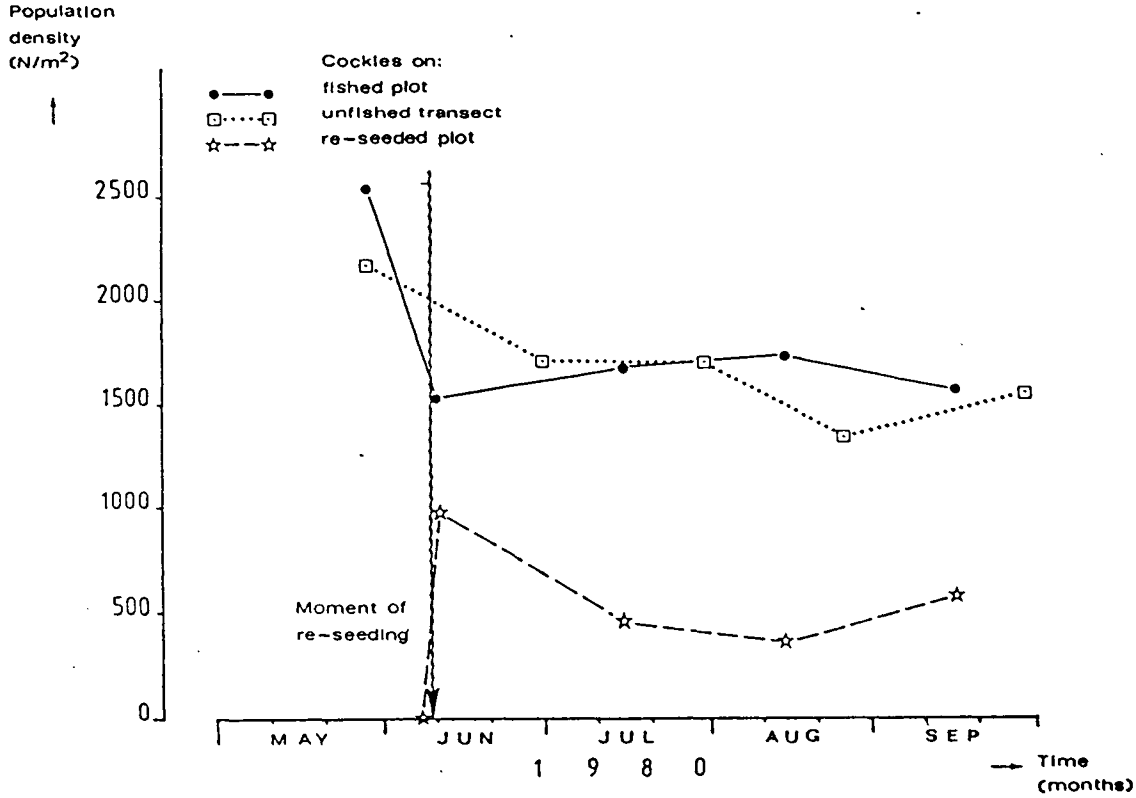


Fig. 5 : Population density of cockles on the fished and the unfished location as well as on the plot where the fished cockles were re-seeded.

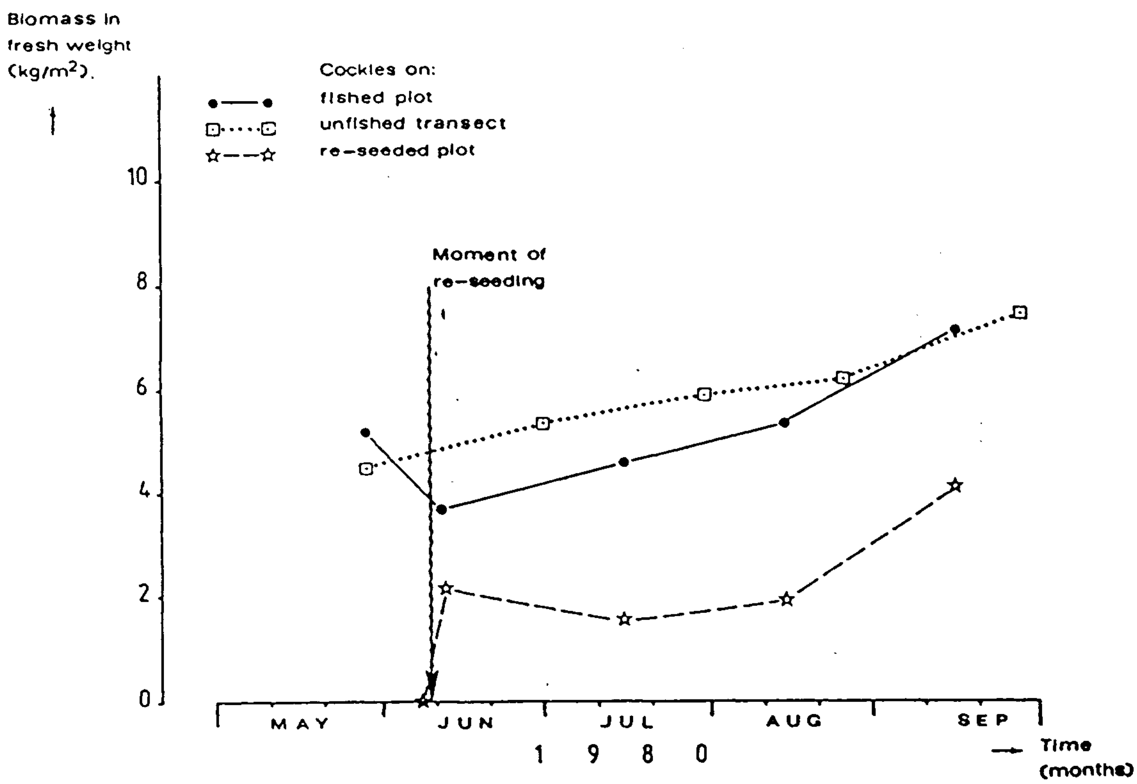


Fig.6 : Standing stock biomass (fresh weight) of cockles on the fished and the unfished location, as well as on the plot where the fished cockles were re-seeded.

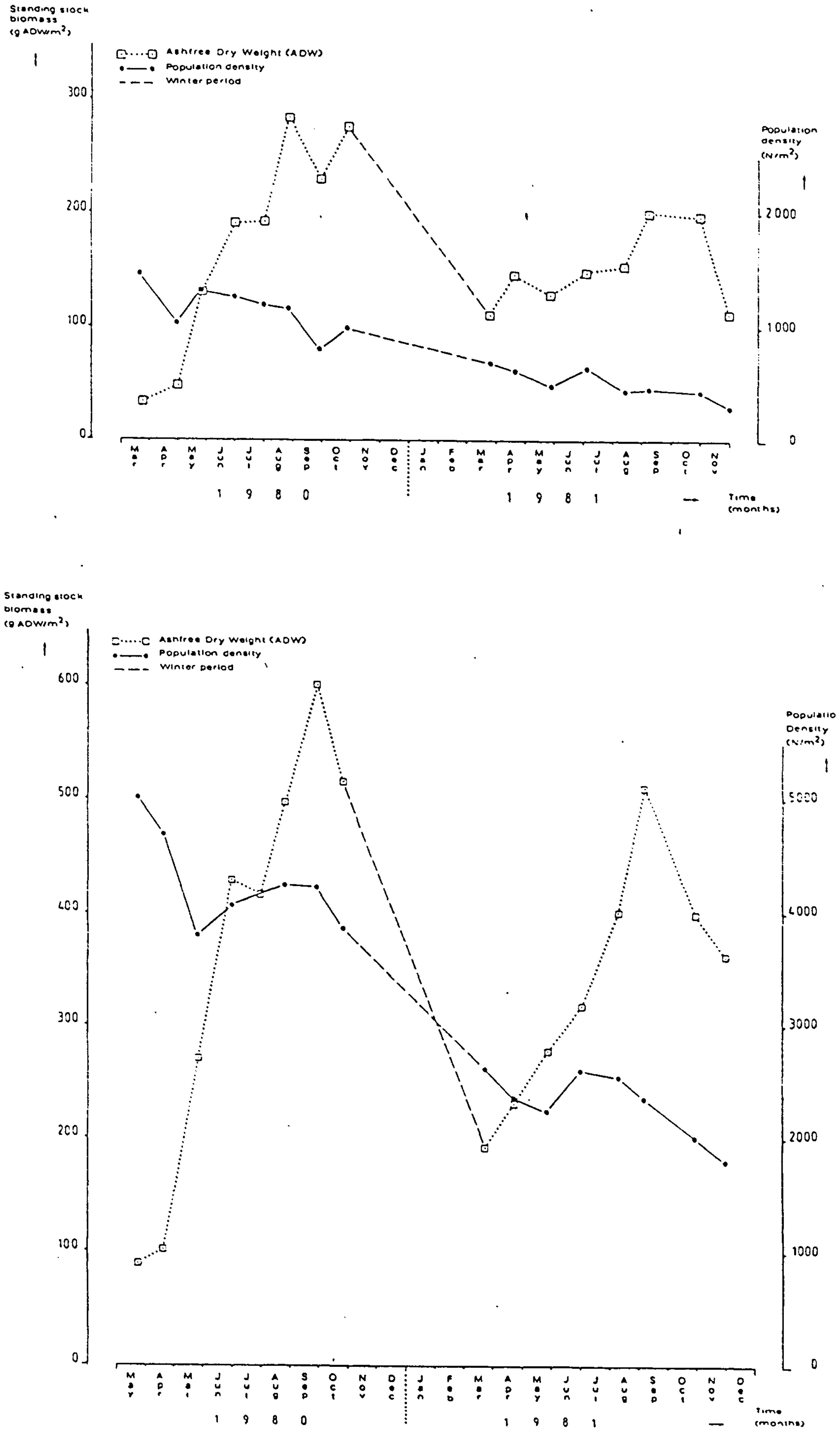


Fig.7: Standing stock biomass and population density of yearclass 1979 cockles on two adjacent locatopns on Neeltje Jans, differing in population density, in 1980 and 1981.

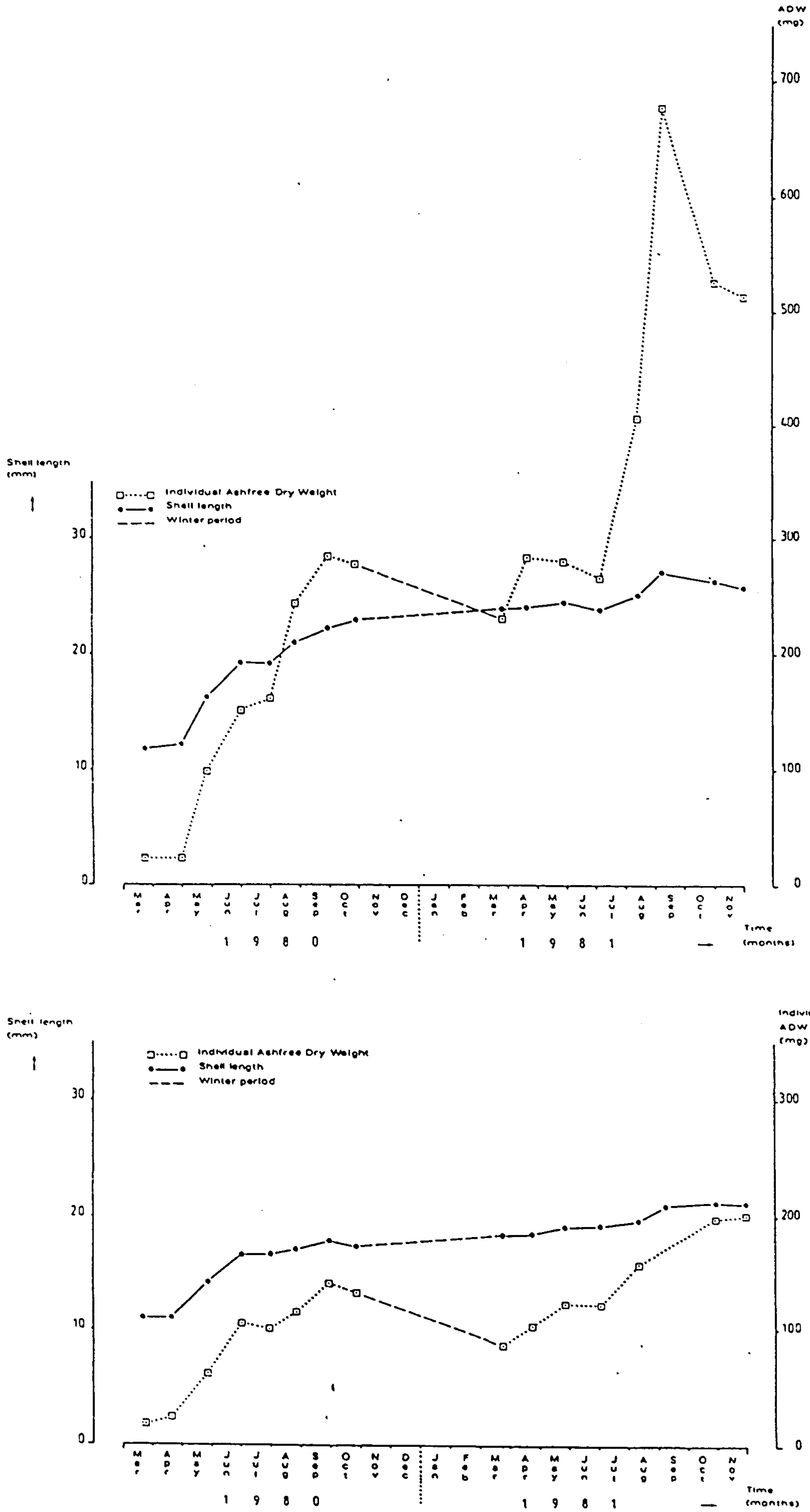
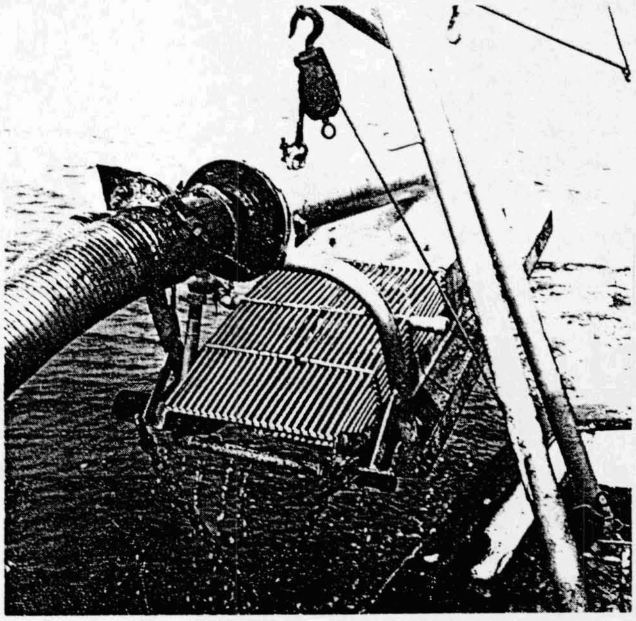


Fig. 8 : Individual Ash Free Dry Weight and Shell length of yearclass 1979 cockles at two adjacent locations on Neeltje Jansplaat, differing in population density, in 1980 and 1981.



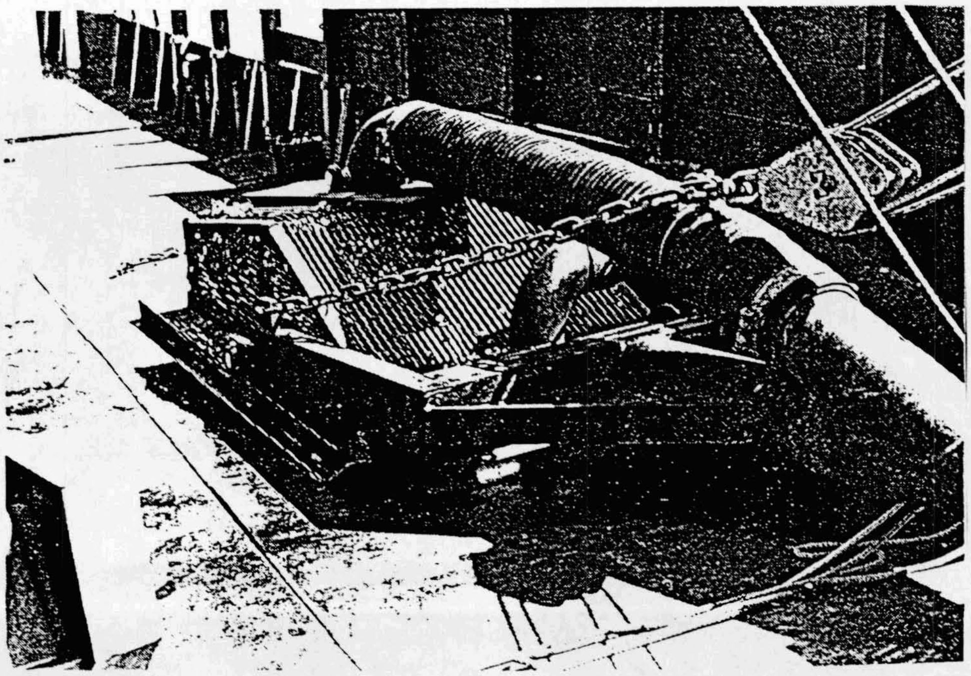


Figure 9 - Hydraulic Cockle Dredges