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Analysis of the catch curves for *Pandalus borealis* in Disko Bay, West Greenland.

by

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Abstract.

From Disko Bay available length frequency samples of *Pandalus borealis* go back to 1947. The commercial fishery in the area started in 1950. In the beginning it was a very small fishery compared to what later developed. It is thus possible to estimate M for the early period of the fishery, assuming $M = Z$. Good samples are at hand from the periods 1947-54, 1963-64, 1974-81 and 1990-91, and for these four periods Z is estimated utilizing the so called 'length-converted catch curve' method. For the two latest periods an estimate of F is given. The method needs the von Bertalanffy growth constants as input, and these are estimated by means of the ELEFAN I program.

The catch curves from Disko Bay show a distinct 'shoulder' at the age of five to seven years. The 'shoulder' is believed to represent an extra recruitment of large shrimp from the offshore area in Davis Strait. This extra recruitment is calculated.

It is supposed that the shrimp in Disko Bay should be considered a part of the Davis Strait population rather than a separate population.

Introduction.

The Disko Bay is the most important inshore fishing area at West Greenland for *Pandalus borealis*. In 1947 the first length frequency samples were taken, before the fishery started in 1950. In the first ten years the fishery was rather small compared to later years. The length frequency samples collected in the period 1947-54 makes it possible to estimate the natural instantaneous mortality coefficient (M), assuming that the fishery in that period is so small, that it can be ignored and thus $M = Z$ (the total instantaneous mortality coefficient). Assuming that M is constant, it is then possible to estimate F (the instantaneous fishing mortality coefficient) for the later periods from which length frequency samples are available. This analysis is done by the 'length-converted catch curve' method. In this analysis a 'shoulder' is observed in all catch curves, possibly representing an extra recruitment of large shrimp from the offshore area.

Materials.

The research area is shown on the map in **Fig. 1**. In this area length frequency samples have been collected during the periods 1947-54, 1963-64, 1974-81 and 1990-91 with different intensities. In **Appendix A** it is shown how the samples are collected over the time together with the sample sizes. For the period 1947-74 the lateral carapace length (LCL) was measured as shown in **Fig. 2**, from 1975 the oblique carapace length (OCL) was measured as shown in **Fig. 3**. During all periods the shrimps were also often sorted into sexes.

Methods.

The von Bertalanffy growth parameters are found using the ELEFAN I computer program (Pauly, 1987). The estimation of Z is done by aid of the 'length-converted catch curve' method (Sparre et al. 1989). The way of finding the extra recruitment is through an analysis of this catch curve. If Z is the same before and after the recruitment, the difference between the two constants in the expression of the two lines reflects the extra recruitment.

The equation for the catch curve without the extra recruitment can be written:

$$\ln\frac{C(L_1,L_2)}{dt(L_1,L_2)} = lnR + lnF + ZTr - Z*\frac{t_{L_1}+t_{L_2}}{2}$$

where

$C(L_1,L_2)$ is the catch in the length interval L_1-L_2
$dt(L_1,L_2)$ is the time interval for the growth between L_1 and L_2
R is the recruitment within the area
F is the instantaneous fishing mortality
Z is the instantaneous total mortality
Tr is the recruitment age.

The equation for the catch curve with the extra recruitment can be written:

$$\ln\frac{C(L_1,L_2)}{dt(L_1,L_2)} = lnR_1 + lnF + ZTr - Z*\frac{t_{L_1}+t_{L_2}}{2}$$

where

R_1 is the recruitment within the area plus the extra recruitment.

The relationship between original recruitment and the total recruitment can then be calculated like this:

$$lnR_1 - lnR = \ln\frac{R_1}{R}$$

Results and discussion.

Table 1 gives the von Bertalanffy growth parameters after analysis with ELEFAN I for the four periods in which length frequency samples have been collected. Because of the two different measuring methods data from 1974 are calculated separately. In **Fig. 4** the resulting three growth curves are shown for the periods in which the lateral carapace length was measured, and **Fig. 5** shows the two growth curves based on the oblique carapace length. **Fig. 6-10** show the catch curves for the five periods based on simple pooling of all samples for each period.

All five curves exhibit a 'shoulder' on the right side of the curve instead of a strait line. If growth and recruitment is constant over time and the chance of catching shrimp is equal for different sizes among the recruited individuals, the right side of the catch curve should be a straight line with -Z as the slope.

For the first period (1947-54) it is possible to calculate the extra recruitment. Z is calculated to 0.61, and the difference between the two constants is 0.9434. The relationship between the original recruitment (R) and the total recruitment (R_1) is exp(0.9434), or approximately 2.57. This means that the ratio between the originally recruited shrimp and the extra recruited is about 2:3.

For the other periods it is not possible to make the same calculation, because of the changed slope of the catch curve after the possible extra recruitment. The reason could be, that the extra recruitment in the later periods is spread over several age groups. Another explanation could be, that Z was the same inside and outside the Disko Bay in the first period, when the exploitation was nearly zero. In later periods when the fishery escalated both inside and outside the Bay this might have changed.

If the first parts of the curves to the left of the 'shoulder' are used separately Z can be estimated for the five periods:

1947-54:	0.6-0.7 per year
1963-64:	0.5-0.6 per year
1974:	0.8-1.1 per year
1975-81:	1.1-1.2 per year
1990-91:	0.8-0.9 per year

For the period 1947-54 the fishery was so limited compared to later periods that it is reasonable to suppose that $Z = M$ (see the increase in Disko Bay catch on **Fig. 11**). Under the assumption that M has been stable in the meantime F can be calculated for the later periods. For the period 1974-81 F is calculated to around 0.1-0.6 per year, and for the period 1990-91 to 0.1-0.3 per year. For 1963-64 F is calculated to zero, but the material from this period is very limited and the estimate is therefore not reliable.

The level of M = 0.6-0.7 per year seems reasonable compared to other known estimates. Anon. (1977) gives M for Icelandic areas to 0.2-0.3 per year, and for Fladen (North Sea) and Skagerak values of 0.5-1.0 per year are stated, but these figures are without empirical foundation. In Balsfjord (northern Norway) Hopkins and Nilssen (1990) have calculated Z using the catch curve method to a value of 1.8-2.1. This very high value is said to be due to a high predation by cod combined with a high fishing pressure. For Pavlof Bay, Alaska, Anderson (1989) reports very varying M values for different year-classes and ages between 0.067 and 6.890 per year, but it seems to be a special situation after the drastic decline of the stock and the closing of the fishery. Fréchette and Labonté (1981) have estimated M in the northwest Gulf of St. Lawrence to be 0.48-0.80 per year.

Unfortunately there are no estimates for the Davis Strait shrimp population, which would be the most obvious population to compare with. In fact the Disko Bay population is very likely a part of a larger West Greenland population.

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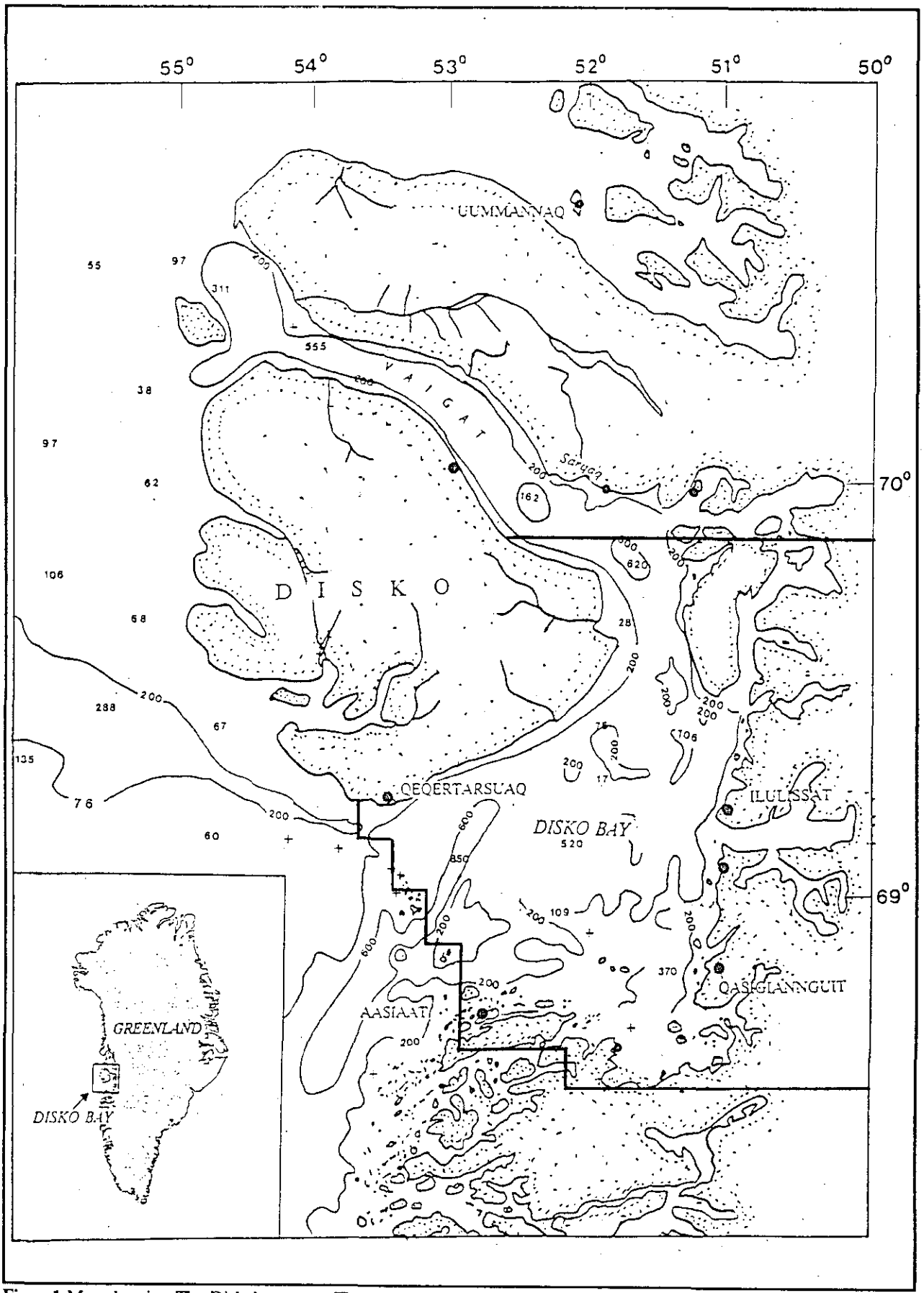
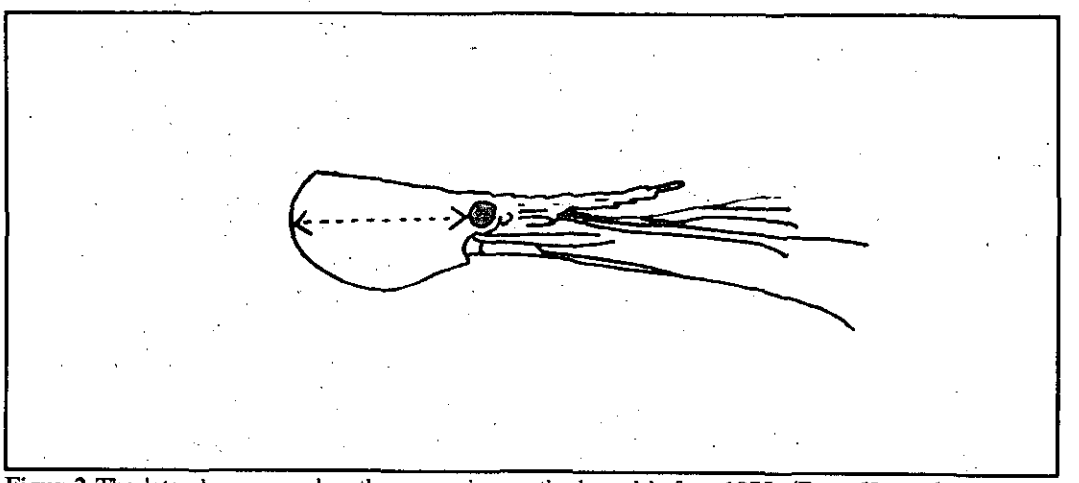
Table 1. Von Bertalanffy growth parameters for the four periods growth curves.

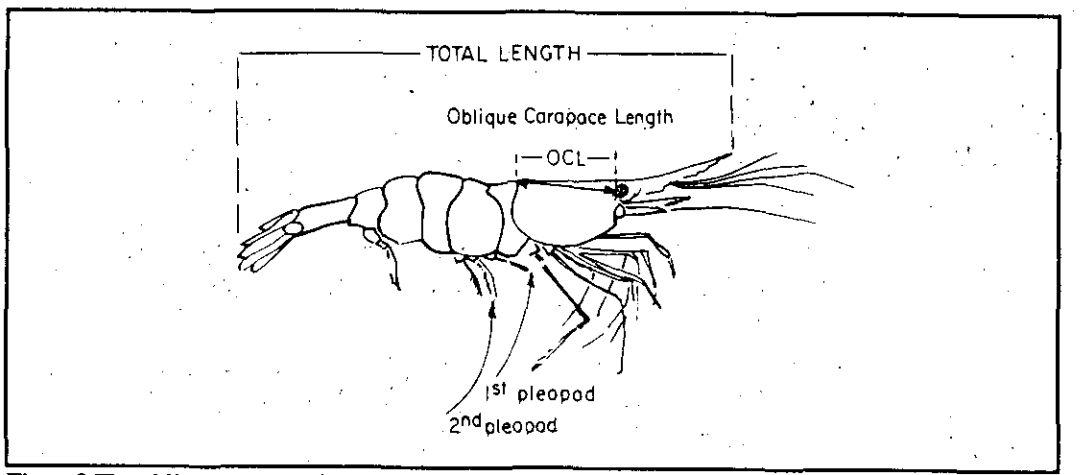
	L_∞	K per year	t_0 year
1947-54	33 mm LCL	0.274	-0.47
1963-64	32.5 mm LCL	0.205	-0.64
1974	33 mm LCL	0.232	-0.56
1975-81	30 mm OCL	0.260	-0.48
1990-91	30 mm OCL	0.240	-0.52



Figur 1 Map showing The Diskobugt area. The research area is framed with a solid line.



Figur 2 The lateral carapace length, measuring method used before 1975. (From Horsted and Smidt 1956).



Figur 3 The oblique carapace length, measuring method used after 1975. (From Shumway et al. 1985).

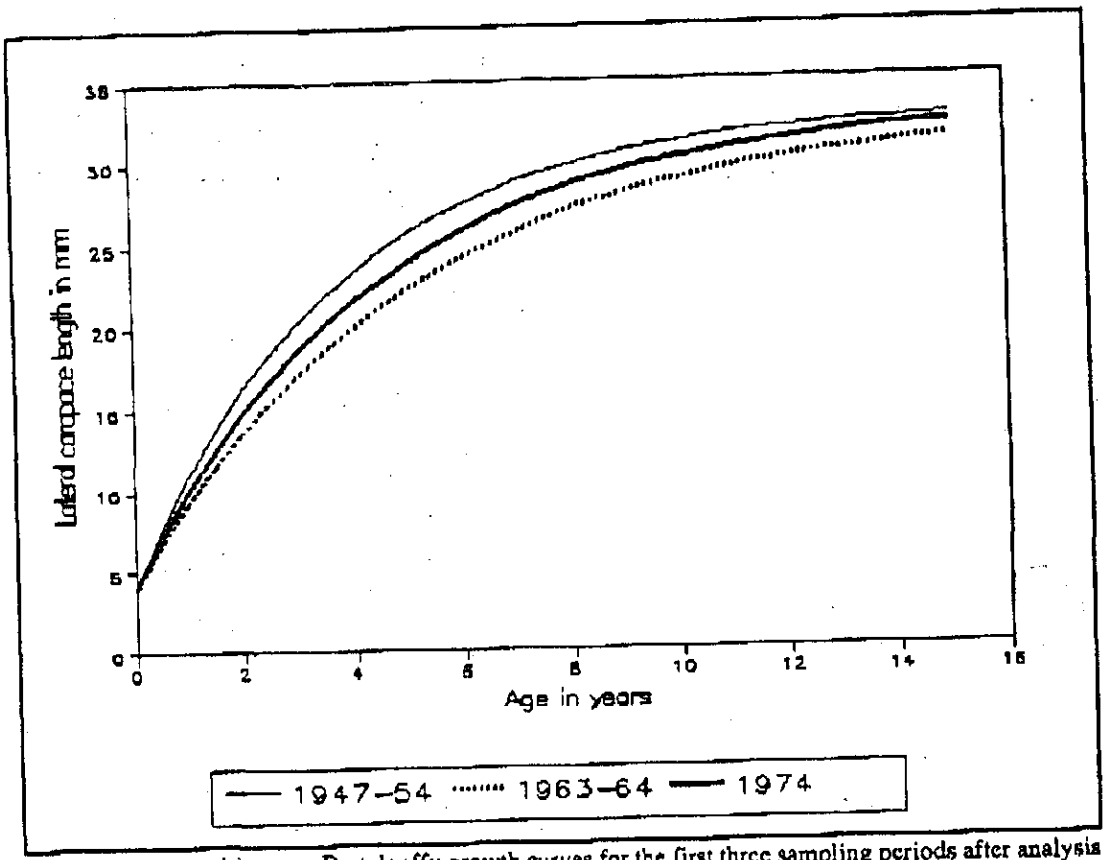


Figure 4. The resulting von Bertalanffy growth curves for the first three sampling periods after analysis with EELEFAN I.

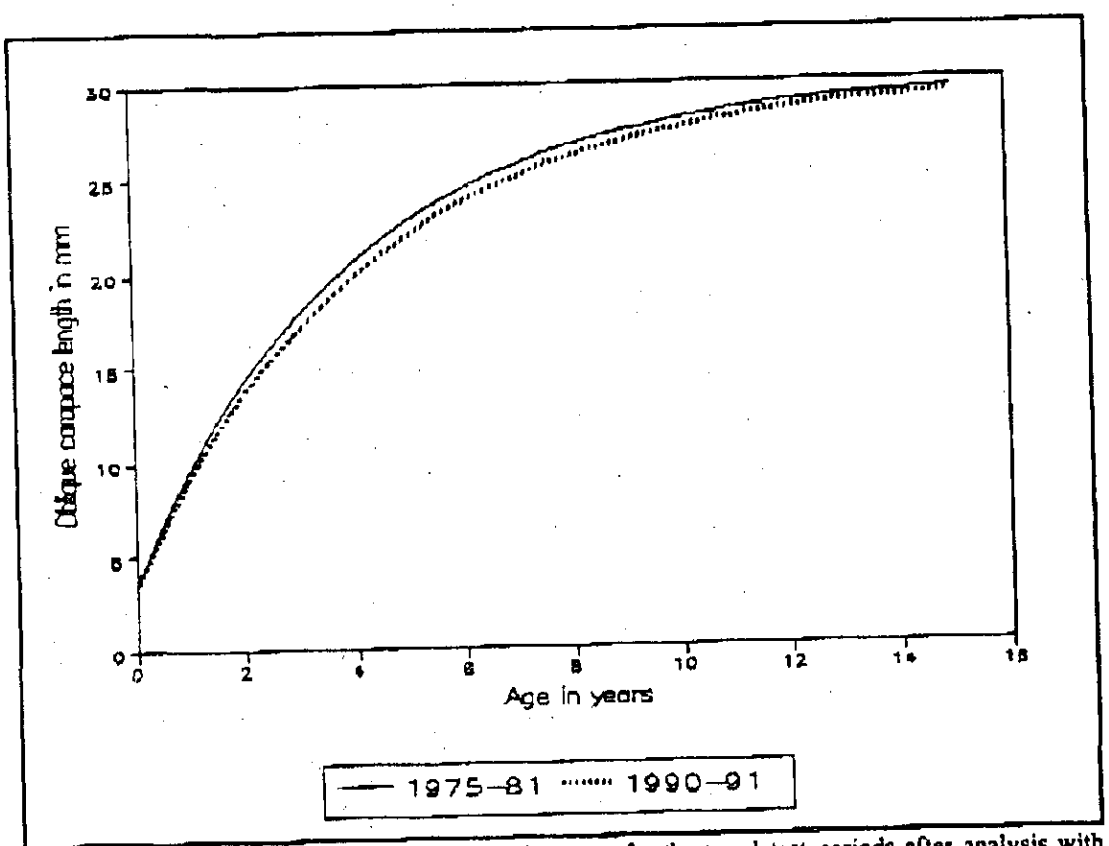


Figure 5. The resulting von Bertalanffy growth curves for the two latest periods after analysis with ELEFAN I.

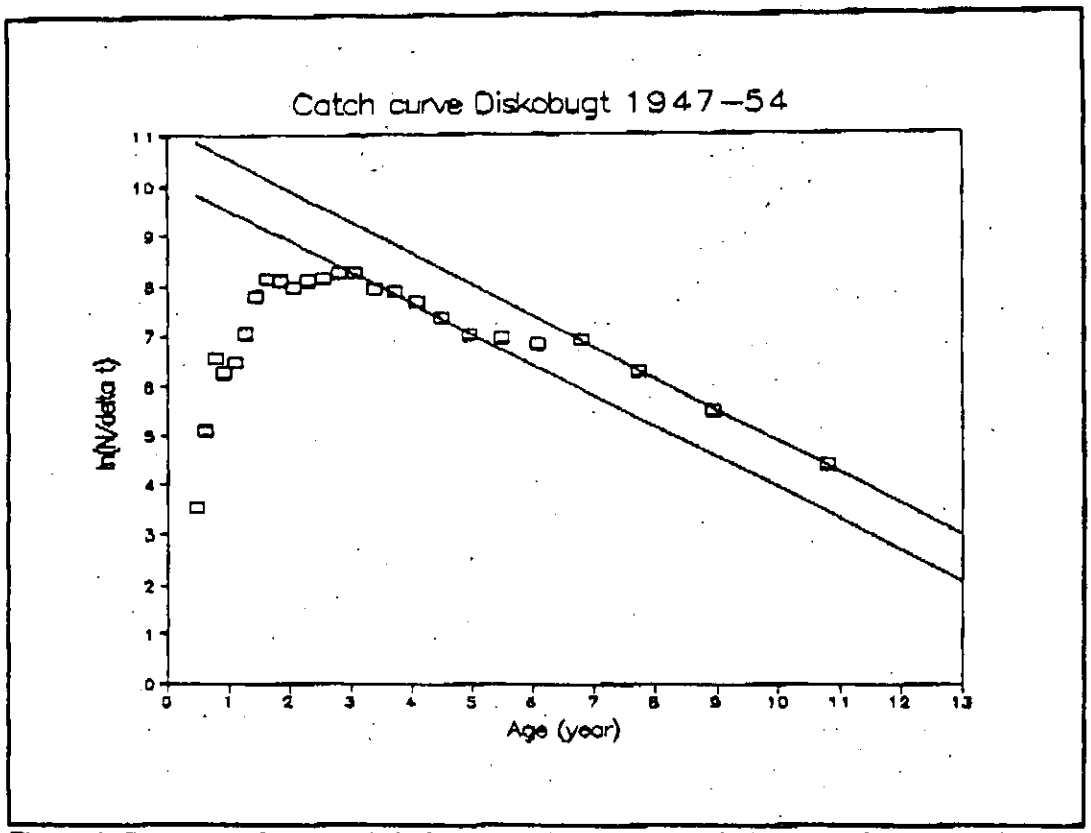


Figure 6. Catch curve for the period 1947–54 made by addition of all samples for the period.

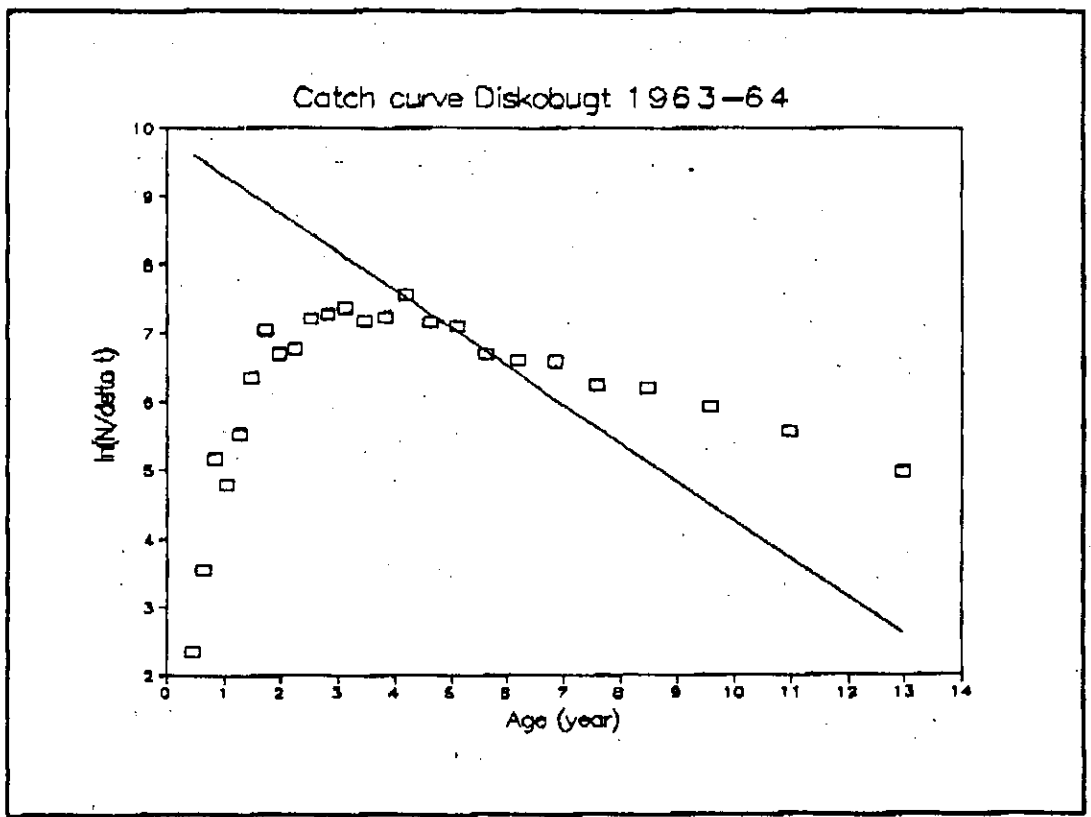


Figure 7. Catch curve for the period 1963–64 made by addition of all samples for the period.

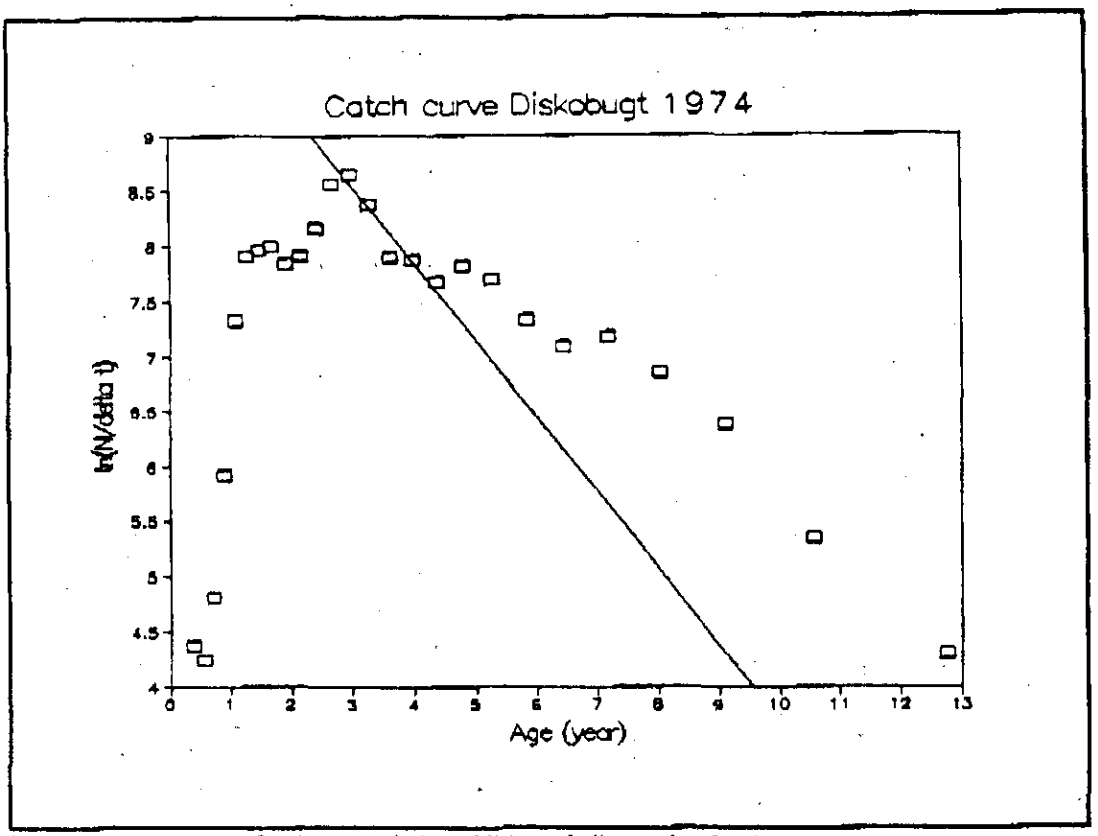


Figure 8. Catch curve for 1974 made by addition of all samples for the year.

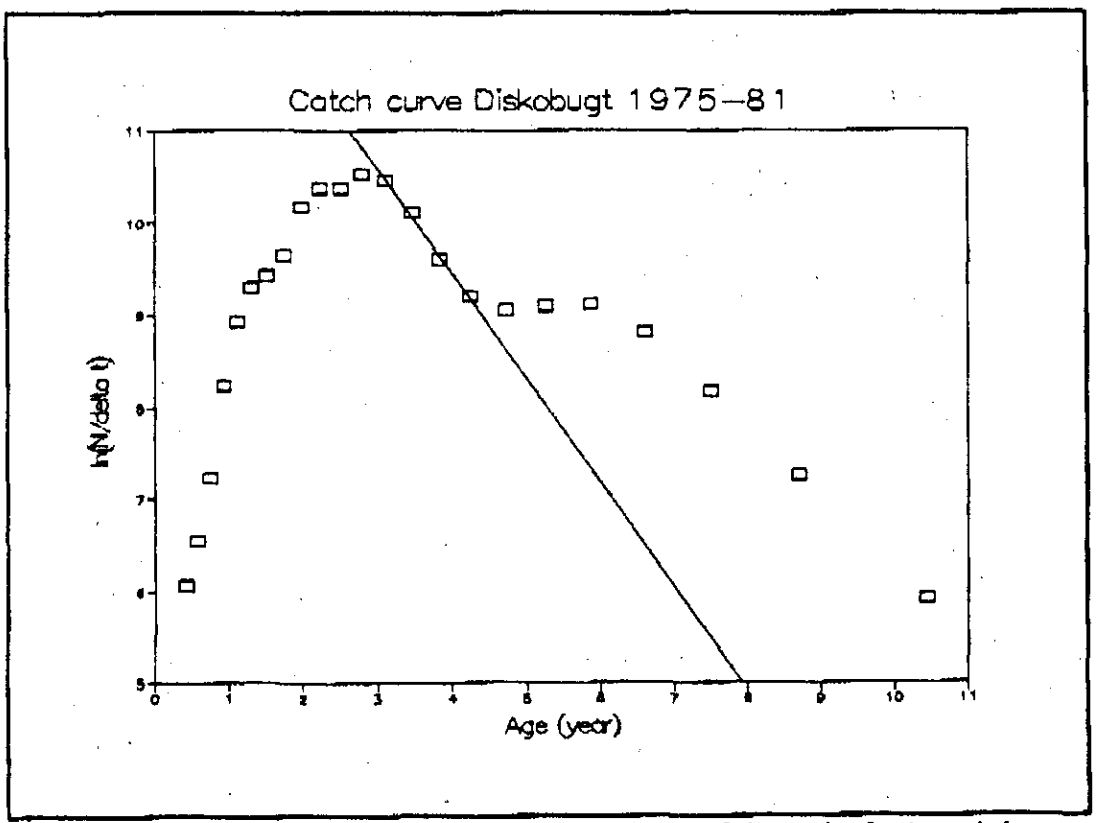


Figure 9. Catch curve for the period 1975-81 made by addition of all samples for the period.

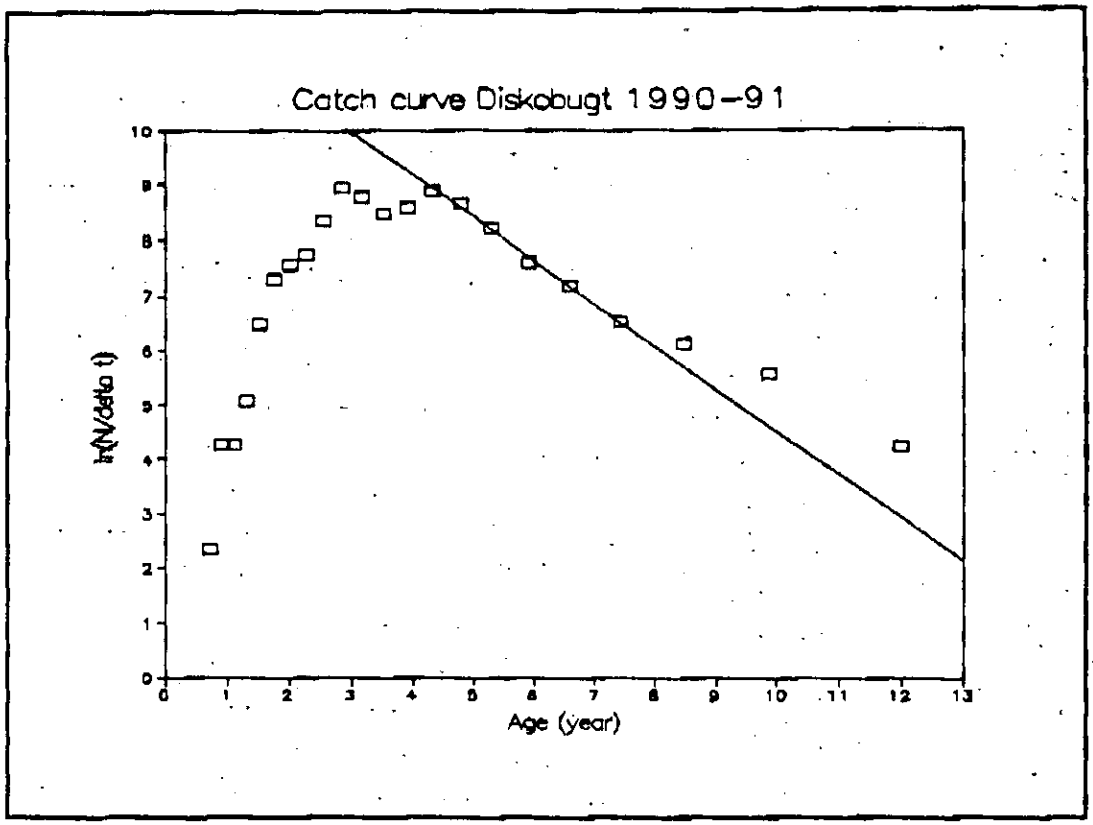


Figure 10. Catch curve for the period 1990-91 made by addition of all samples for the period.

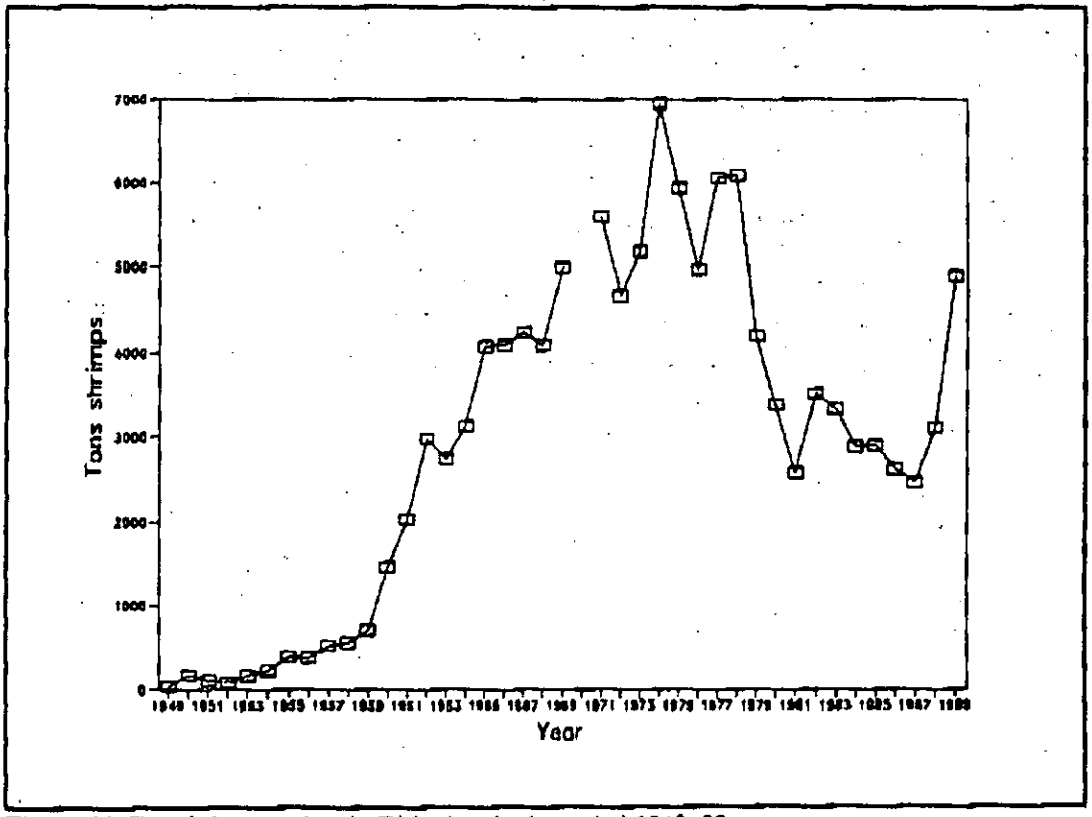


Figure 11. The shrimp catches in Disko bay in the period 1949-89.

Appendix A.

This appendix contains an overview of the length frequency samples.

1947:

Month	Number of samples	Sample size	Number of shrimps
September	2	207-324	531

1948:

Month	Number of samples	Sample size	Number of shrimps
June	2	387-626	1013
July	1	353	353
August	7	245-760	2989
September	1	183	183

1949:

Month	Number of samples	Sample size	Number of shrimps
July	3	320-364	1007
August	5	247-421	1547

1950:

Month	Number of samples	Sample size	Number of shrimps
June	1	341	341
July	5	239-404	1696
August	2	114-168	282
September	1	161	161

1952:

Month	Number of samples	Sample size	Number of shrimps
June	1	162	162
July	2	204-277	481

1953:

Month	Number of samples	Sample size	Number of shrimps
July	6	179-544	2167
August	2	384-442	826
September	2	187-207	394

1954:

Month	Number of samples	Sample size	Number of shrimps
June	1	114	114
August	2	252-460	712
September	1	148	148

1963:

Month	Number of samples	Sample size	Number of shrimps
July	4	101-249	705
August	5	159-248	990
September	5	110-220	856

1964:

Month	Number of samples	Sample size	Number of shrimps
July	19	144-466	4899
August	10	109-253	1901
September	1	426	426

1974:

Month	Number of samples	Sample size	Number of shrimps
July	2	654-829	1483
August	12	249-599	5683
September	14	208-1030	7598
October	7	377-918	4027
November	4	390-448	1667

1975:

Month	Number of samples	Sample size	Number of shrimps
February	1	449	449
April	3	1456-3675	8472
Maj	1	838	838
June	2	716-2522	3238
July	10	817-6292	18364
August	5	749-1236	4760
September	5	867-10497	16167
October	10	607-1461	10986
November	3	3283-7510	16003

1976:

Month	Number of samples	Sample size	Number of shrimps
Maj	8	834-1688	9208
July	7	797-1705	8459

1977:

Month	Number of samples	Sample size	Number of shrimps
April	2	844-1781	2625
Maj	4	508-1319	3743
August	2	598-1729	2327

1978:

Month	Number of samples	Sample size	Number of shrimps
October	1	392	392
November	2	903-919	1822

1980:

Month	Number of samples	Sample size	Number of shrimps
July	4	356-1110	2529

1981:

Month	Number of samples	Sample size	Number of shrimps
July	1	328	328

1990:

Month	Number of samples	Sample size	Number of shrimps
November	5	278-860	2967

1991:

Month	Number of samples	Sample size	Number of shrimps
September	30	447-1054	22050