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A method for assessing the optimal yield of Pandalus borealis populations in Icelandic waters

by

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Abstract

In this paper an attempt is made to assess the optimal yield of two Pandalus borealis populations in Icelandic waters, i.e. that of Arnarfjörður and that of Ísafjarðardjúp, by the method of Gulland (1961). In order to justify the separate treatment of each population, age determination is introduced.

From this it appears that there is little or no connection between the two populations after the age at first recruitment. The method of age determination is based on the method of Sund (1930) with modifications by the author.

Introduction

The fishery of Pandalus borealis in Icelandic waters has been exercised under the control of the Marine Research Institute of Iceland since the year 1962. In that year there seemed to be a collapse in the fishery in Ísafjarðardjúp. In the following years limitations were introduced with the aim to restore what was thought to be the overfished population of Ísafjarðardjúp (Sigurðsson and Hallgrímsson 1965).

An attempt was made to estimate the maximum sustainable yield of Pandalus borealis in these 2 areas in the year 1967 (Skúladóttir 1967). In this paper the same method is tried again for the years 1968 to 1973.

The method of age determination will also be described in this paper, and the possibilities of connection between the two areas will be discussed.

Material and methods

Written reports were obtained from every skipper of every shrimper with information e.g. on length of each haul and shrimpcatch. As the total catch given by the factories was usually higher than that of the shrimpcaptains, these were used as correcting figures for catch and effort. In this paper the effort figures for the years 1972 and ´73 are still uncorrected but the difference will only be slight or adding a little bit to the average effort denoted by 72 and 73 (see Table and Fig. 1 and 2). The results for the year 1967 were not used, as during that year a larger more effective trawl was taken up in both areas. This large trawl fishes about 2.3 times more shrimp per hour than the previous trawl (Skúladóttir 1970). This had the effect that fishing was from then on carried out in areas where fishing was not profitable before. But the introduction of the large trawl was gradual and the results of the year 1967 were therefore not comparable to those of the following years. The calculations used were the same as Gulland (1961) used on several species of fish. Gulland points out that every yearclass is subject so a certain amount of fishing effort throughout its exploited phase. While the youngest members of the exploited phase are virtually independent of the amount of fishing the oldest members have been subject to fishing for a number of years. In other words abundance is dependent on the fishing effort exercised in the past years or the average time for which the fish are exposed to fishing. When abundance was plotted against fishing effort, the correlation between the two variables was significant and a straight line could be fitted to the points, giving the relation:

$$Y/f = a + bf \quad (1)$$

Hence $$Y = af + bf^2 \quad (2)$$

where Y = catch

f = effort

From the relation between catch per effort and mean effort (equation (1)) the relation between catch and effort in a steady state could be determined (equation (2)). This gives the catch which would be obtained if the effort was maintained at the same level for several years, or long enough for all the members of a given population or stock to have undergone the same steady fishing effort throughout their lives in the exploited phase. The second relation is a curve with a maximum at one point where effort in the steady state is optimal.

The method used for age determination was modified by the author from the method Oscar Sund used on cod (Sund 1930). Here all measurements from the years 1964-1970 from Arnarfjörður and Ísafjarðardjúp were pooled together for each month, i.e. the length frequency distribution were added together in each millimeter group. The resulting length distribution was then called the monthly mean length frequency distribution of the years 1964-70. Then the mean length frequency distribution of every month and every year was subtracted from the mean length frequency distribution of the years 1964-70 in the same month. The result can be seen in Fig. 3. The deviations were thought to represent good and poor yearclasses. It is known from cod for example that a strong yearclass can be prominent year after year. Assuming the same is the case with shrimp one considered that the large positive deviations at one or more points represented a strong yearclass.

When the large positive deviation moved to the right in a years time, this was considered to correspond to a years growth. The total number measured in February in the years 1964-1974 was about 15 480 for Arnarfjörður and 20 730 for Ísafjarðardjúp.

Discussion and results

In 1967 the relation between catch per hour and mean effort was calculated (Skúladóttir 1967). At that time is was tried with the average effort of 2, 3, 4 and 5 years respectively. Of these the average effort of 3 years seemed to give the best fit. This is shown here in Fig. 1 for both areas. The correlation was rather good for the period 1958-66 for Arnarfjörður or statistically significant at the level $P < 0.01$, but statistically significant at the level $P < 0.02$ for the period 1960-66 in Ísafjarðardjúp. From Fig. 1 it is evident that there are at least 2 periods in the fisheries in Arnarfjörður and Ísafjarðardjúp. The first period is already mentioned or the one before 1967. The second period is from 1968 and onwards. The first period is in fact not without changes as there was the change in mesh from 25 mm to 32 that was completed in 1962. This has no doubt caused an increase in maximum sustainable yield. In the second period the slope of the calculated line is much less in both areas and there is more catch per trawling hour even with increased average fishing effort. The curves for sustainable yield in both areas are nearly 3 times higher at their maxima than the maxima for the period before 1967, (see Fig. 1). The maximum sustainable yield has thus increased from 720 metric tons to 2190 tons for Ísafjarðardjúp and from 200 tons to 560 tons for Arnarfjörður. When the two periods are compared with regard to the total number of shrimps caught, it appears that the number has increased of about 200% in Arnarfjörður and about 370% in Ísafjarðardjúp. Moreover, it is a fact that the fishing area has expanded tremendously in both areas since the introduction of the aforementioned enlarged trawl in 1967.

In Fig. 2 relation is also shown between catch per trawling hour and the average effort of every 2 years for the period 1968-73. This seems to give a slightly better fit than that of 3 years. But as Gulland points out, it is not certain that the relation is a straight line. He finds that for plaice a curve fits the data better than a straight line. The maxima in Fig. 2 are at 2350 tons for Ísafjarðardjúp and at 600 tons for Arnarfjörður.

From the age determination (see Fig. 3) several interesting things are to be noted. First of all it is striking how little similarity there is between the 2 populations. In Arnarfjörður growth appears to be slower to judge from the prominent 1963-yearclass (marked I in the year 1965) which is considered to be come 8 years old at its oldest (Hatching is fixed at 1st of April). However, there is another strong yearclass i.e. the 1967-yearclass which does not become so old and grows faster. This can be explained by higher sea temperatures and perhaps more fishing in the latter period. Secondly the strong yearclasses do not appear simultaneously, or have a different growth rate, note the 1967 yearclass (II in the year 1969) in both areas. And thirdly a strong yearclass once seen as a large deviation can be followed from year to year for several years (see Fig. 3) within the same area, but this is actually what the method of age determination is based upon.

Conclusion

It appears that the two populations have very little or no connection after the age at first recruitment. Nor is there any evidence of any migrations of large shrimps on a large scale from outside the fiords. The two populations can therefore be looked upon as more or less self-contained, apart from larval recruitment, which has not been investigated yet.

It is evident from what has been related here that one must be very careful to say the least in using this method for assessing the optimal yield of Pandalus or indeed any other species. There must be no changes at all. This great increase due to the introduction of the enlarged trawl was not anticipated and it was with some reluctance that the limitations were lessened. The rise in catch per trawling hour was simply considered to be due to the increase in efficiency of the trawls. During the period 1968-73 there have been several changes in the fisheries. Such as seasonal closure of certain areas, more price difference between size classes, and change in mesh. All these factors will cause an increase in maximum sustainable yield and are therefore a further step towards the optimal yield. Another factor which some of us think would be beneficial is the sorting of shrimp alive in machines.

On the whole this method to assess the maximum sustainable yield from the relation between catch per trawling hour and average fishing effort can be used to give the direction towards our goal.
This is a crude method justified by the lack of other important parameters necessary in the more complicated calculations for optimal yield.

The method could also be used for comparison to the more complicated calculations when these will be attempted.

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Table I. Average annual catch per trawling hour of Pandalus and the average fishing effort of that year and one or two preceding years.

	Arnarfjörður			Ísafjarðardjúp		
Year	kg/hour	average effort 3 yrs	average effort 2 yrs	kg/hour	average effort 3 yrs	average effort 2 yrs
1958	108	1816				
59	94	2015				
60	86	2417		145	4477	
61	94	2269		103	7225	
62	105	1915		74	7844	
63	146	1464		71	7587	
64	109	1595		113	5455	
65	101	1735		168	5129	
66	94	2155		111	6520	
67	88	2381	2561	100	8134	10156
68	119	3101	3148	144	10447	9990
69	128	3671	4448	148	10677	11540
70	88	5571	6267	167	12594	13376
71	56	7679	9159	116	17287	19905
72	58	9026	9630	83	21568	25001
73	72	9275	8662	98	25172	25203

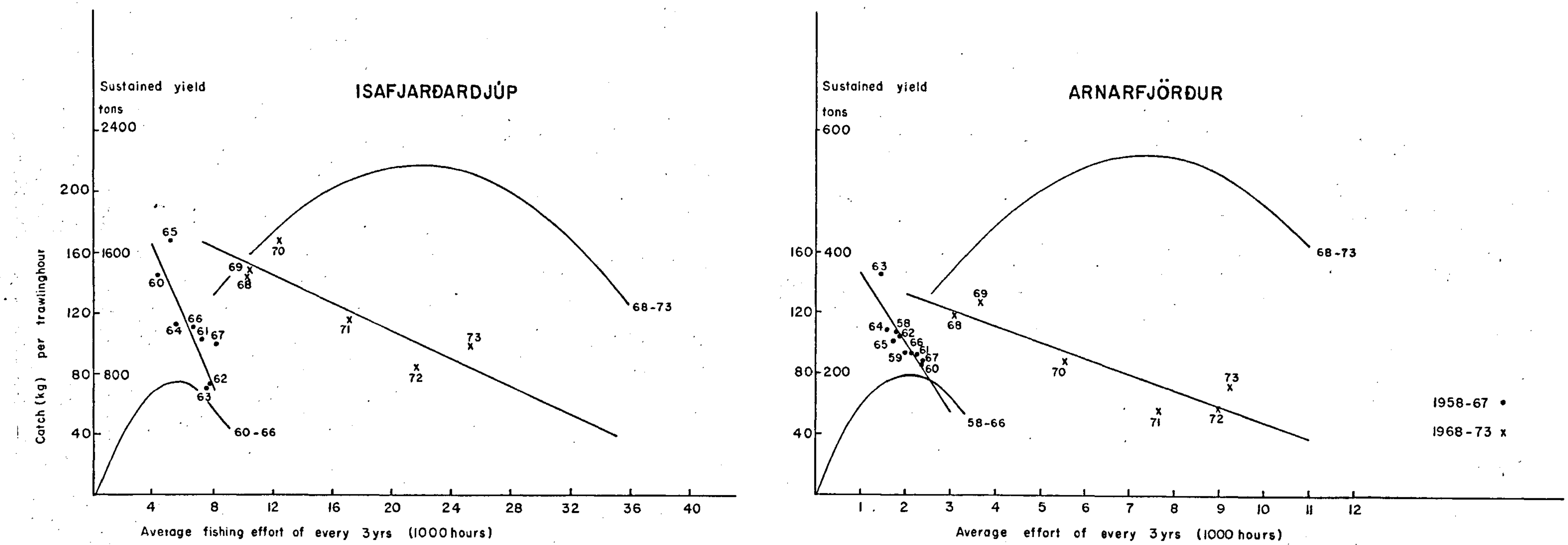

Fig. 1. The line shows the relation between average effort of every 3 years and the average catch of Pandalus per trawling hour in the last year, indicated by that year. The curve shows the calculated sustained yield given by sustained effort where the average effort of every 3 years is used.

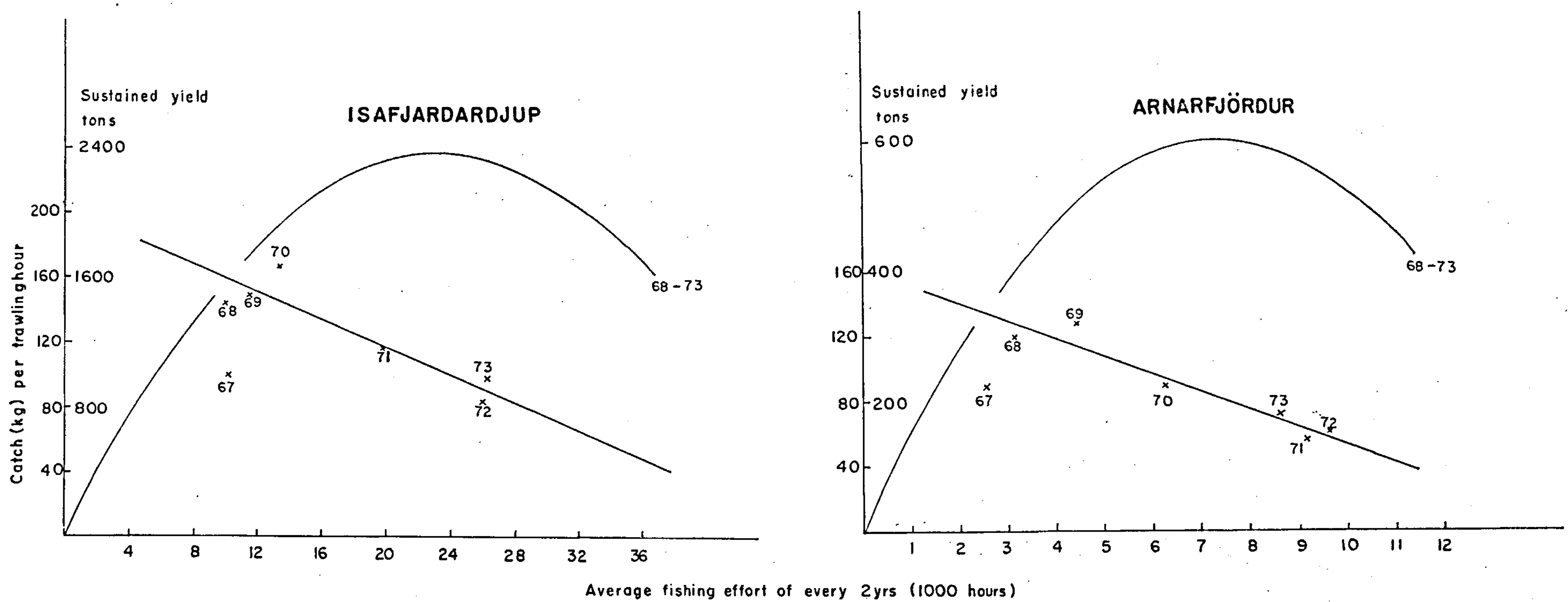

Fig. 2. The line shows here the relation between average effort of every 2 years and the average catch of Pandalus per trawling hour in the last year. The curve shows the calculated sustained yield given by sustained effort.

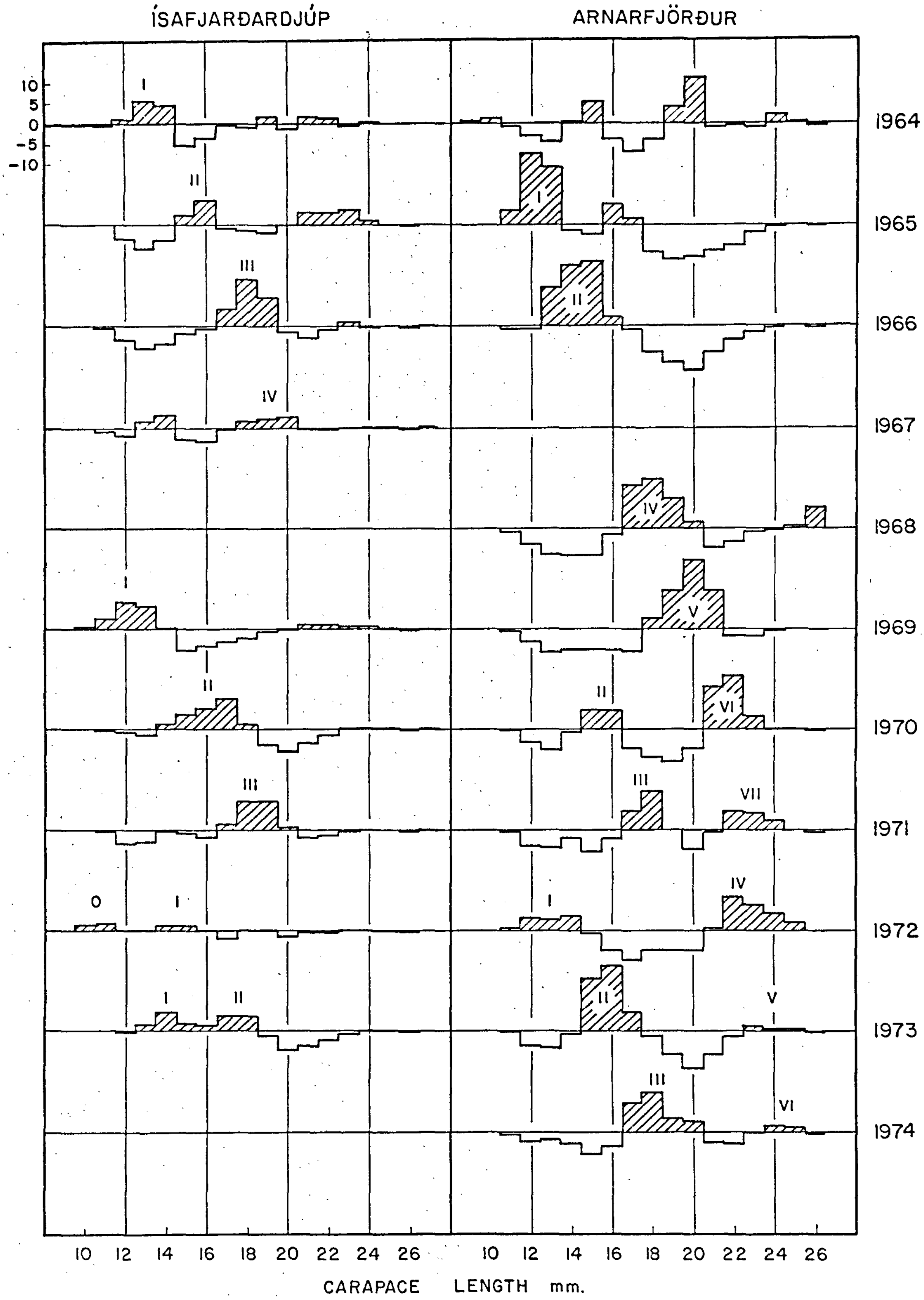

Fig. 3. Deviations from the monthly mean length frequency distribution of the years 1964–1970 in the month of February. Positive deviations are lined. The strong yearclasses are marked with Roman numerals.