Population and resources on the minor Danish islands 1860, 1900, and 1960

By Henning Mørch

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An investigation made on the basis of a simple, linear regression of the relationship between resources – defined as areas after different criteria – and size of population on the minor Danish islands 1860, 1900, and 1960. Key words: Denmark, carrying capacity, island population, population density, resources, rural population.

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Introduction

In many works the size and development of rural populations in industrialized countries are studied on the basis of economic-historical conditions, general economic development, or the urbanization process. The primary purpose of the present project has been per contra to study the rural population of Denmark on the basis of the local, exploited resources. This so, on the concept that human geography – including population geography – is primarily human ecology which studies the interaction between man-environment-resources (Odum 1959, and Christiansen 1967). This means no rejection of the great importance of the many other factors such as economic and historical ones.

The present paper is part of the above-mentioned project. A brief paper on another part of it was published earlier (Mørch, 1974).

This part is limited to deal with the Danish islands, principally the minor ones, where the population-resources relationships are most clear and simple as a matter of course. The islands shall be treated as a whole, and specific islands are not considered. Peculiar enough there are almost no systematic studies of the Danish islands, although no less than 45 % of Denmark proper are islands. The material published deals with local history and topography, and very comprising in this respect are the topographical works by Friis (1926–28) and Trap (1953–67). Furthermore some governmental reports have been issued as preliminary contributions for a public debate on the future of the minor islands in an era of rural depopulation (Ministry of Cultural Affairs 1970).

Population and resources

The size of a population (P) depends upon the resources (R) available in the area defining the population; the relationship might be expressed as: $P = f(R)$. The resources in relation to any population's size will principally be the biological, primary production based on the energy and water balance and the soil conditions. This is also due for a human population, most evident for a closed population, non-industrialized and living on a subsistence base, and for the population of the Earth as a whole. The fundamental resources can be described more generally as the bio-physical environment to which a system of utilization, traditional or modern, regardless of its political-economic system, is subjected or must govern by means of techniques. The system of utilization comprises technology, organization, choice of crops etc.; in an open system also exchange with other regions.

Under a given system of utilization a given area (properly, the available resources) can subsidize a certain population. The term carrying capacity is used. However, a given amount of resources will mean different results dependent upon the kind of utilization system adopted (Gourou 1966). Thus the strictly, resource-dependent carrying capacity has to be supplemented with an "economic carrying capacity" when considering the population that in a wider sense is able to subsist on the area in question.

The relationship between resources and a human population might therefore be more illustratively expressed by including the system of utilization: $P = f(R, S)$.

An open population as the Danish rural population is dependent partly upon the local agricultural resources partly upon trade possibilities such as industry, commercial relations with other regions, commuting and tourism, as well as upon a local service sector, the size of which is related to the other factors mentioned. Especially for island populations commuting will be out of questions in many cases, whereas fishing and shipping might be of importance.

The above general remarks are due no matter whether the population studied is optimal or not.

Terminology

Resources may be defined in a strictly physical sense and in relation to system of utilization as briefly outlined in the foregoing. However, when studying relationships between population and resources one of the greatest difficulties met with is to define the resources and also to measure the extent of them at all. The comprehensive discussions of the concept of resources shall be left out here, let it suffice to refer to United Nations (1973) and Zelinsky (1970).

In the present study it has been chosen to define the resources as areas; this should be reasonable as the majority of the population on the minor Danish islands, with few exceptions, live or have lived mainly on farming, directly or indirectly. Further, the necessary areal data were easy to get as they were already published. A specification of the six variables is given later.

Population has here been defined as "the total population in a specific region" for two reasons. First, because of the population's dependence on farming as mentioned; second, because for the whole period of investigation it would be difficult to establish consistent data on the agricultural population, as it is often done in studies of population density in rural districts, cf. below.

Density, or population density, is a term which will be applied in this paper generally on some man/land ratios, commented on briefly below. The data considered in this study imply the kind of densities treated.

The concept of density is mostly expressed by the crude, arithmetic density: number of individuals per area unit in the regions concerned. In this sense the concept has been widely applied in population studies both of animal, plant, and human populations. It should be noticed, however, that by some scientists density is used ambigously as a synonym for partly the crude density and partly the number of individuals in a population. This is especially due in animal ecology and here specifically in connection with predator/prey systems as it is seen in many well known works (Odum op.cit., Andrewartha & Birch 1954, Krebs 1972, Smith 1974). Presumably this is so because special biotopes are described and consequently also the specific areas defining these populations; but that is not density in the common sense of the word as relationships between two populations are studied; although the prey population may of course be considered a resource related to its area. In human geography density is often used as a synonym for population agglomerations without considering the areas involved.

The crude density might very well be described in general terms, but the use of it will then depend upon the degree of intra- and interregional homogeneity for the area studied; if the heterogeneity is too great, it will be meaningless to apply the crude density.

This is the background for the attempts in comparative studies instead of the total area to use more relevant areas i.e. areas being more directly a primary factor for the subsistence of a population such as cultivated land. Thus the "physiological density" might be mentioned which is the ratio between population and arable land, and the "agricultural density" which is the ratio between agricultural population and cultivated area (cf. e.g. Trewartha 1953). The physiological density describes a population-resource relationship and equals what in animal ecology has been termed "economic density" (Elton 1933) or "ecological density" (Odum op.cit.). However, these concepts of density are not comprehensive enough. One unit of cultivated land does not necessarily equal another unit, nor be of the same importance to sustain a population. To a great extent it will of course depend upon soil conditions or on system of utilization; it has therefore been attempted to revise the concept of population density in order to find more applicable measures for comparative studies.

Applying an "arable equivalent" Moore (1945) tried to revise the agricultural density by a classification of agricultural land into four classes, but disregarding soil fertility. The method was originally suggested by Poniatowsky (1936, cf. League of Nations 1939). Vincent (1946) applied similarly a "comparative density" which considers the distribution of farmland on crop land and pastures.

With the above revised measures for population density, the former conventional measures of density are on their way out; they are being replaced by indexes for over- and underpopulation or population pressure, based on capacity of production, or productivity, requirements or consumption measured by weight, value, calories, and so forth; in some cases they are also indicated in unspecified units. For examples in a wider sense, the reader is referred to the "economic densities" by Simon (1937) and George (1953), to the "index of population pressure" (Gupta 1970) and the "calorie adequacy index" (Bullock 1971).

There is a spectrum from pure arithmetic measures as the crude density over revised densities which involve other factors as e.g. system of utilization but still based on measurements of area, and to proper economic densities which are based on measurements of resources only to a limited extent. The spectrum contains measurements cognate with the concept of carrying capacity.

The population carrying capacity may be defined as the size of population a given area or area unit might sustain for a longer time without disturbing the balance of the system. The concept may of course be defined narrowly in connection with sheer survival, or with some optima of population, or with some margins of security (cf. Dasmann, 1964); furthermore, the definition may be extended to comprise resources in a wider sense than areas.

For long, the concept of carrying capacity has been implicit in discussions of population problems – ref. the Malthusian dispute. According to Andrewartha & Birch (op.cit.), however, the concept was explicitly introduced into animal ecology by Errington (1934, and later publications). Since then the concept has been widely accepted in animal ecology – not least in connection with the upper asymptote in populations with a sigmoid growth (Odum and others of the ecological works mentioned above).

In more specific studies of human populations the concept of carrying capacity seems to have been applied almost simultaneously with Errington's studies, namely in connection with traditional agricultural systems in tropical Africa (Trapnell 1943 and Allan 1949 – maybe the studies of Gourou, 1949, appeared at the same time). Allan (1964) has the term "carrying capacity", but applies often synonymously "critical density"; Gourou uses "le potential de densité de population" synonymously with carrying capacity. In these and other studies of traditional agricultural systems such as Beguin (1964), Hunter (1966), and Ojo (1968) it has beeen attempted to consider both resources and system of utilization.

The population carrying capacity as defined and applied above has been used with a view to stable, stationary systems. In this paper it will be used in a wider sense, i.e. the mean population density at a given time for a group of regions (in this case the Danish isles) with the same system of utilization, also if some of the populations are found to be in a period of growth. The definition, based on mean values and therefore giving variations within a limited interval, will be further dealt with.

The study of population density

The concept of population density has been applied to a great extent in population studies since it was invented 200 years ago (by the French biolog Buffon ?– Badley 1927). A general survey of relevant literature shall not be given here, but let it suffice with the references mentioned and a few illustrative examples. For a Dane it is tempting however to mention the, it seems, first isarithmic map of population density which was made by Ravn in 1857. Nowadays any manual in human geography gives examples of application of population density. The concept is mostly used as a descriptive tool, and Duncan (1957) is partly right when he points out that especially to geographers the concept seems to be primarily a methodical and cartographic problem and that a lack of functional studies is felt. In a way it is sympthomatic, however, that even a comprising and modern manual as "Models in Geography" (Chorley & Haggett 1967) only has two references in the index of population density, both to the chapter on urban geography, and one reference of potential density to the chapter on agricultural density; no reference is made to carrying capacity. The most fruitful functional studies of population density seem to have been made in connection with carrying capacity in systems of subsistence agriculture (Henshall 1967) and density, including rural, in urban systems (Garner 1967). On the other hand it must have been ideas of functional relationships that inspired Ratzel (1881–92) to deal with population density under different environmental conditions – and more recently Stazewski (1957, 1961) – although these studies may be characterized as "deterministic". The same might be said of so markedly methodical studies as the well known work by Robinson and Bryson (1957). Earlier works also described population densities in different systems of utilization e.g. Ratzel (op.cit.) and several more recent references appear from Braidwood & Reed (1957). Studies of population densities have also been used to determine size of population (Birdsell 1953, and Deevy 1960). The relationship between population and resources, also when the latter are defined as areas, is most conspicuous in closed systems; this explains why most of the studies deal with less developed countries where farming is performed as, or nearly as, subsistence farming. This applies not only to carrying capacity, but to many more comprehensive studies of the relationship between population and land (Zelinsky 1971, Prothero 1972). On a global basis rural densities related to labour force have been studied by Kumar (1973). As far as areal resources and rural densities in Western countries are concerned, however, the material seems to be sparse apart from some descriptive and methodical publications. In connection with the present paper the following works should be mentioned: Norborg (1968) with e.g. investigations of rural population density related to size of agricultural area and length of growing season; Kirby (1972) describes rural density in relation to land values in 17th century England; finally with a view to agricultural area used as a resource, the general model outlined by Ackerman (1959) is pointed at.

The Model

GENERAL MODEL

The relation between population and resources, $P=f(R)$, may be expressed generally as:

$$P=a\,R^{b} \qquad (1)$$

from which it appears that the population density (D) is:

$$D=a\,R^{(b-1)} \qquad (2)$$

In the present study the observations have a distribution skew to the right, however, – more small populations and areas than bigger ones – and a logarithmic transformation has therefore been made similar with other investigations of population-land relationships. Just to mention some: so different studies of populations in central place systems as Berry (1967), and of island animal populations as Mac Arthur and Wilson (1967). These works might well be described as different as to functional relationships, but in more formal respects they work along parallel lines. By transforming into logarithmic values, the illogicality is avoided that population and density formally turn out to be negative values.

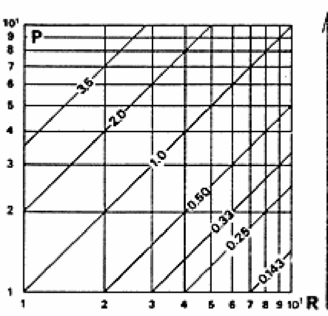


Fig. 1

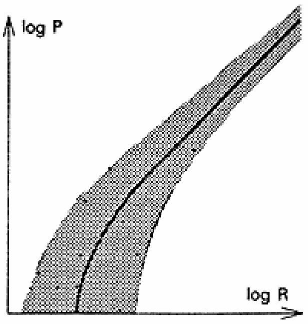


Fig. 2

Fig. 1. Relationship between population (P), resources (R) and population density (D), both axes with a logarithmic scale. The lines with a gradient of 1.0 (45°) indicate examples of population densities (D=P/R).

Fig. 1. Sammenhæng mellem population (P), ressourcer (R) og befolkningstæthed (D), når begge akser er logaritmisk inddelt. De skrå linjer med hældningen 1,0 (45°) viser eksempler på befolkningstæthed (D=P/R).

Fig. 2. Hypothetic distribution of a wide range of island as to resources (R), and population (P). The full hyperbolic curve shows the hypothetic distribution. The shadearea indicates an interval within which the observations fall.

Fig. 2. Hypotetisk fordeling af en større gruppe øer med hensyn til ressourcer (R) og population (P). Den optrukne hyperbolske kurve viser den hypotetiske fordeling. Det skyggede areal antyder et interval indenfor hvilket observationerne ligger.

After the transformation, the relations (1) and (2) get the formulars:

$$\log P = \log a + b \log R \qquad (3)$$
$$\log D = \log a + (b-1) \log R \qquad (4)$$

While relation (1) is exponential, relation (3) postulates a linear relationship between population and resources; this may be analysed by a simple, linear regression and correlation analysis. In relation (3), b is the gradient of the regression line. From (3) and (4) it appears that log a is the logarithm of the level of population density; for $\log R = 0$ (i.e. when $R = 1.0$) on the precondition that b is not significantly different from 1.0. If these conditions are fulfilled, *log a* can be regarded as the carrying capacity per resource unit (here area) at a given time even if the observed populations are in a period of growth. To a certain carrying capacity a certain straight line will correspond with a gradient of 1.0 (45°) – cf. fig. 1 If b is significantly different from 1.0 the relationship is more complex.

The analysis of the population-resource relationships has been made on the basis of the described regression model (3). The results are thus obtained by arithmic means of the observations transformed into logarithms. The antilogarithm of these means corresponds therefore to the geometric mean of the observations. This is also due for the computed *log a* value that the corresponding antilog value may be regarded as the geometric mean of population densities when b is not significantly different from 1.0.

THE MODEL AND ISLAND POPULATIONS

In the present work focussing on islands the relation between population and resources might not be strictly linear. This is a consequence of the special character of islands, such as the size of resources and population and to some extent the economic conditions resulting from these factors. Some points of importance should be mentioned:

As to area resources, an island has a well defined upper limit. An exceeding of this limit will naturally be dependent upon the exchange with other regions and thereby upon the specific conditions adherent to islands, the isolation or rather the relative isolation. This might be due both to the physical distance but also to the more os less advantageous location of the island. Further, the size of its population will be of importance; a small island population is more isolated than a big one living at the same distance from some "continent".

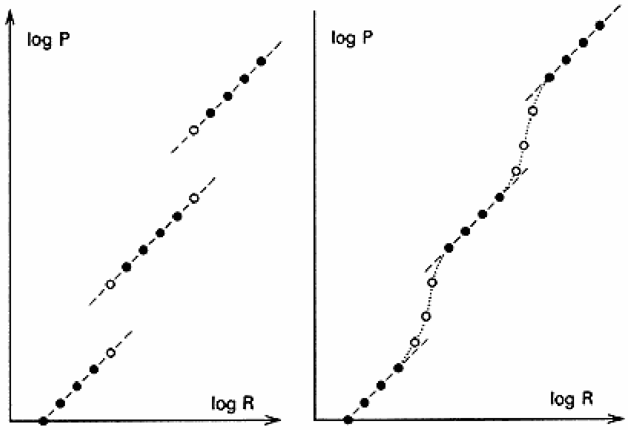
In an archipelago like the Danish where the islands by and large are formed in the same kind of terrain and of the same material, the coastal zone is of almost the same width regardless of size of island. This zone which is so to say of no value for farming, will therefore take a relatively greater share of the minor islands than of the major ones. This might tend to give a lower crude population density on the first-named than on the latter.

As said the actual size of population plays obviously a role, the greater the population, the more differentiated it might be, and the smaller the population, the less the differentiation (cf. Berry and MacArthur op.cit). Thus an island must be of some size, precisely how large cannot be stated, to make up a separate commune or parish, to constitute more than one separate administrative unit, to have enough requirements for local service functions to agglomerate in a township, to be able to "carry" more towns and so forth. In many connections there might be, not necessarily constant, threshold values. The following example is experienced on many small islands in these years:

As a result of the development in recent years increasingly more cattle are demanded to pay a permanent veterinary or to run a diary; also a constant, and previously sufficient herd of cattle may become too small with the result that the veterinary moves or the diary is closed. This and similar other events will again influence the cattle breeding.

What is said in the foregoing also implies a trend towards a higher population density on the larger islands than on the small ones.

Further, contingencies in demographic respects might have a great effect on small populations such as:



Fgi. 3. Two hypothetic examples of relationship between population (P), and resources (R) for a wide range of islands. It is assumed that the islands after size distribute in groups with an increasingly higher population density i.e. carrying capacity per unit. To the left the transition is seen as breaks from one group of islands with one population density to the next; to the right the transition is gradual. The white dots indicate the transition around some threshold values from one density group to the next one.

Fig. 3. To hypotetiske eksempler på sammenhæng mellem befolkning (P) og ressourcer (R) for en større gruppe øer. Det antages, at øerne efter størrelse fordeler sig i grupper med stadig større befolkningstæthed, d.v.s. bæreevne pr. arealenhed. Til venstre er overgangen fra én gruppe øer med én befolkningstæthed til den næste i følgen springvis, til højre er overgangen gradvis. De åbne cirkler antyder overgangen omkring nogle tærskelværdier fra én tæthedsgruppe til den næste.

- variations in birth rate or in ratio between number of female and male births
  extreme mortality caused by f.inst. epidemics
- migrations as a result of founding or closing institutions e.g. the diary mentioned above

For the small island populations these random, demographic factors might involve great fluctuations in population figure or cause a great heterogeneity as to age/sex structure; this again restricts the possibilities of marriage and without immigration, a reproduction of the population will be difficult. Additionally small, isolated populations are in an exposed position because of inbreeding and genetic drift (cf. Cavalli-Sforza & Bodmer 1971).

A precise biological threshold value or a biological population minimum is difficult to state, but Livi (1949) suggests it to lie between 300 and 500 persons.

As stated in the foregoing, the minor islands will mostly have a lower population density than the major ones and it varies more. This implies that (b) in the regression model (3) will be higher than 1.0 (the gradient of the regression line be steeper than 45°). For a wide range of islands there will hardly be found a linear relationship between population and area as the population density does not increase indefinitely. A curve describing the relationship will presumably be a curve for lower values with a gradient of more than 1.0, but gradually taking an asymptotic course towards a gradient of 1.0; i.e. a curve with hyperbolic course (fig. 2). Thus for a wide range of islands there will not be a specific carrying capacity per areal unit.

To some extent, however, it might well be that islands of same order of magnitude had same population densities and that the intervals between them, in accordance with the above, indicate threshold values. The transition from one order of magnitude to the next might be successive (and thus result in a system of sigmoid curves) or it might be by breaks. The principles are outlined in fig. 3. Here one might see a parallel to what is found in central place systems although the functional relationships differ.

It must be stressed, however, that the above are generalizations and that there will of course be individual islands deviating considerably from this general pattern.

Statistical sources and data

SOURCES

Since the first census in 1769 and with the latest one in 1970, the population of Denmark has been enumerated by 27 censuses. Before 1935 the population was counted *de facto*, after 1935 *de jure* and in 1935 after both methods with the enumeration made on communes, in some cases on parishes. There are two tables showing the population figures from these censuses, one for the period 1769–1911 and one for the period 1901–1960 (Statistics of Denmark 1911 and 1964b). The population figures on communes applied in this investigation have been taken from these two tables. Since 1901, in some cases first from 1906 or later, the population figures for the individual islands have been registered no matter how small they are. A publication of the registrations 1901–60 (Statistics of Denmark 1964b) has supplied the figures used here.

The total area of the administrative units is normally published in the censuses, but there are also specific records (e.g. Statistics of Denmark 1968). Registrations of land use for each commune have been made by a number of agricultural censuses (e.g. Statistics of Denmark 1964b and 1898) together with land taxations (e.g. Statistics of Denmark 1864, 1896, 1906, 1964a). These sources have been used in the present study. As to present-day land use it has been necessary to find another source than the statistics as no official registration has been published. Instead the data have been taken from Trap (1953–67); this work does not have figures from one specific year, but those used apply for c. 1960.

The total area (gross area) is available for both minor and major islands, whereas land use and values are only registered on communes. As to the specific sources of the data below, the reader is referred to the list behind.

DELIMITATION OF THE INVESTIGATION IN TIME AND SPACE

The investigation deals with all Danish islands (except the Faroe Islands and Greenland) for: 1) a recent year, 2) about 100 years ago when the exploitation system was much different from present-day's, and 3) an intermittant time. It was the intention to apply a material homogeneous as to basic areas and as to time of registration. On the basis hereof three years were selected: 1860, 1900, and 1960 as they will be referred to henceforth, but with the modifications which appear from the specification below.

SPECIFICATION OF THE SIX VARIABLES

The following six variables have been applied:

- P total population
- A total area
- L rotational area or crop land (landbrugsareal i omdrift)
- S total agricultural area (samlet landbrugsareal)
- H soil fertility (hartkorn)
- V value of agricultural area

Some of the letters may seem unlogical, but they refer to the Danish terms stated in brackets.

P. Total population. The use of total population figures has already been commented on.

A. Total area. The problematic use of total area in studies of population densities has also been discussed, but in any case it sets an absolute upper limit for the agricultural resources of an area. Additionally, the total area is the only area figure obtainable for islands that are not separate communes.

L. Rotation area or crop land. Indicates the most intensively utilized resources i.e. in most cases the most important.

S. Total agricultural area. Indicates the whole area under the farming system also fallow areas, permanent pastures and so forth, for a specific year mainly extensively utilized, but may be of importance in the farming system in certain regions or at certain times.

All A-, L-, and S-values are stated in hectares (=ha.). Before the introduction of the metric system (1916) land was measured in "tønder land", but here these values have been converted into hectares (1 tønde land = 0.55 ha.). The area values have been supplemented with estimates of the quality and of the value of the soil as this might differ much.

H. Soil fertility. This variable is stated in "tønde hartkorn" an ancient Danish standard unit of valuation indicating estimated productivity on the basis of quality and structure of the top soil, its thickness as well as on the structure of the subsoil.

"Tønde hartkorn" was the standard unit for reckoning land tax and represented the area of land for which the tax was one "ton" of "hard korn" (barley, wheat and rye but not oats). In Denmark as a whole, on land of average fertility, about lo ha. were needed to produce a tax of 1 "tønde hartkorn", but on very good land 4 ha. would give the same yield. The tax was thus based on land values in terms of yield and not directly on acreages" (cit. Thorpe 1951). See also Tovborg Jensen 1961.

The hartkorn-evaluation as it has been applied during the period investigated here was in all essentials established in the mid-19th century, i.e. at a time when the farming system differed significantly from present-day's; it must therefore be considered a very rough estimate of soil fertility, especially for areas which have since then been reclaimed such as heaths and meadows.

V. Value of total agricultural area. This evaluation which is made with a view to sales *might be a more* realistic estimate of fertility. For 1860 a "gammelskat" (lit., old tax) in 1000 Rigsdaler has been used; Rigsdaler was the monetary standard at that time. "Gammelskat" was an evalution for assessing taxes and mainly based upon the "hartkorn"-evalution. For *1900* and for 1960 the values have been stated as realistic as possible and approximated the sales value in 1000 Danish kroner.

In respect of population per unit of the last two variables this will thus not be a density in the conventional sense of the word.

THE METHODS

On the basis of the above material with its possibilities and limits, two sets of data were investigated, all calculations being made on the basis of data transformed into logarithms ($\log_{10}$).

1. Investigation of the rough pattern of the populations and gross areas of the individual islands as basic areas for 1906 and for 1960. Two scatter diagrams and the mean values were elaborated according to a grouping of the areal data.

2. Investigation of populations and areas after five criteria. Here the communes as subdivided in 1960 were used as basic areas, namely the 30 smallest island communes, the upper limit of which was found by breaks in the distribution of populations and areas. It is on this part of the investigation that the described regression model and correlation analysis have been applied.

The Danish Archipelago – some general features

Denmark – excl. the Faroe Island and Greenland – has an area of 43,032 sq.km of which the peninsula Jutland covers the 23,888 and the remaining 19,144 sq.km (45 %) are splitted up on a great number of islands. 409 islands are large enough to have an official place name, but in addition there are numerous unnamed small islands and islets. The largest named island is Sjælland with its 7,014 sq.km, 26 islands are of more than 1,000 ha. and 197 have less than 5 ha. About 100 of the islands are inhabited.

The Danish archipelago is part of a drowned moraine landscape from the third glaciation (Würm) and is

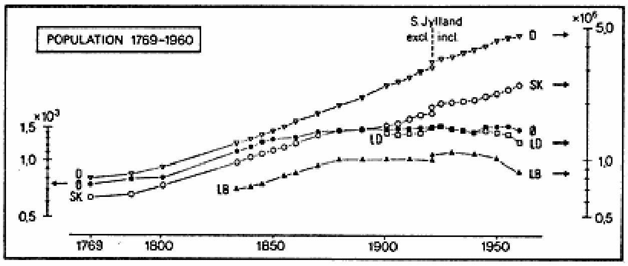


Fig. 4. The population of Denmark 1769–1960. The vertical axis with a logarithmic scale. D is the curve for all Denmark. SK is the curve for rural communes (i.e. without statute towns). LD is the curve for the proper rural districts, i.e. identical with SK but with all urbanization deducted. LB is the curve for the agricultural population. For the four curves (D, SK, LD, and LB) the scale to the right applies. Further, there are two observations for the year 1921, one with and one without Southern Jutland (SJ), a part of the country first included after 1921. Ø shows the population growth as a mean for the 30 smallest island communes (cf. text) and for this curve the scale to the left applies.
Fig. 4. Befolkningen i Danmark 1769–1960. Den lodrette akse med logaritmisk skala. D er kurven for hele Danmark. SK er kurven for rurale kommuner (dvs. uden købstæder). LD er kurven for de virkelige landdistrikter, dvs. som SK men med fradrag af urbanisationen i de rurale områder. LB er kurven for landbrugsbefolkningen. For disse fire kurver (D, SK, LD og LB) gælder skalaen til højre. Desuden er der for året 1921 to observationer, en med og en uden Sønderjylland (SJ). Ø viser befolkningsudviklingen som gennemsnit for de 30 mindste ø-kommuner (jf. tekst), og for denne kurve gælder skalaen til venstre.

rather homogeneous as to soil and terrain, although the single island shows a complex picture of moraine deposits and marine formations and may differ a good deal from the general conditions (Bornebusch & Milthers 1935, Schou 1949). A significant part of the minor Danish islands, namely approxemately 1000 ha., receive below the 600 mm of precipitation per year which is the average for the country (Meteorogical Institute 1933, Jensen 1960); this gives problems with fresh water supplies a.o. because for geological reasons many islands have difficult access to the groundwater (Berthelsen 1966 and VAND 1963). Taken as a whole, however, the minor islands have similar physical resources at disposal.

The inhabited islands vary as to population from the above-mentioned Sjælland with the capital of Copenhagen and in all 1.8 mio inhabitants to islets of 3 ha. with only 2 persons living on them. The population growth on the Danish islands is too heterogeneous to be described briefly. The demographic development on the 30 smallest islands, treated specifically, appears from fig. 4. On these islands the population increased gradually until about 1850. At this time the general, rural depopulation started, the population growth stagnated gradually, and from about 1880 until 1950 the population remained so to say constant. About 1950 a depopulation set in, and the island populations decreased markedly. It appears further that until 1850 the population growth on the minor islands corresponded to the country as a whole, and that for the last about 100 years it has corresponded to the population growth in the rural districts as a whole. The demographic development on the islands has not been so extreme as might have been expected.

The general demographic conditions on the islands shall not be further commented on, but as a supplement a survey is given below of population and area of some islands for the year 1960:

	ha.	inhabitants
Largest islands being part of other parishes or communes:		
Gavnø	522	71
Glænø	459	63
Saltholm	1582	15
Smallest island being one parish but integrated into a larger commune:		
Hjarnø	312	170
Smallest islands constituting own parish and commune:		
Bjørnø	152	42
Hirsholm (excl. one uninhab. islet)	15	16
Tunø	348	155
Largest islands constituting only one commune and one parish:		
Anholt	2175	239
Fejø (incl. 2 islets)	1862	1154
Fejø proper	1600	1103
Fur	2223	1473
Smallest islands with more than one commune		
Fanø (2 com.)	5570	2675
Tåsinge (3 com.)	6963	4866
Ærø (7 com.)	8902	10109
Largest islands without "købstad", the old statute town:		
Læsø (1 com., 3 parishes)	11269	3120
Samsø (5 com)	11162	6429
Tåsinge (3 com.)	6963	4866
Smallest islands and the largest ones with only one statute town:		
Langeland (10 com.)	28409	18692
Mors (15 com.)	36373	26766
Møn (8 com.)	21787	13107
Smallest islands with more than one statute town:		
Bornholm (7 stat.towns, 23 com.)	58729	48217
Falster (2 stat.towns, 19 com.)	51399	46662
Ærø (2 stat.towns, 7 com.)	8902	10109

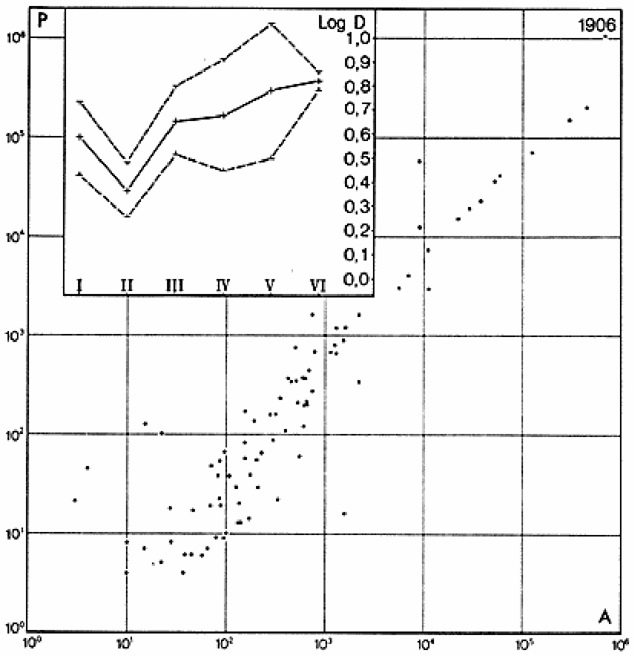


Fig. 5,1

Fig. 5. Population and areas for the investigated 87 Danish islands 1906 and 1960. Both axes with a logarithmic scale. The inserted diagrams (with log D per 10 ha.) show for the six size groups (I–VI), cf. text, the mean population density indicated by the full curve and with a 95 % confidence limit by dashed curves.

Fig. 5. Befolkning og arealer for de 87 danske øer 1906 og 1960, begge akser med logaritmisk skala. De indskudte diagrammer (med log D per 10 ha) viser for 6 størrelsesgrupper (I–VI, jf. tekst) den gennemsnitlige befolkningstæthed ved en optrukken kurve og med 95 % confidens ved stiplede kurver.

Presumably the survey does not show threshold values, but indicates the greater differentiation and to some degree the higher population density on the major islands than on the minor ones as also mentioned. However, especially for the minor islands the figures show individual exceptions as might also be expected. Thus the island of Gavnø has special property rights (1 estate). Because of its special environment Hirsholm has no farming at all, its population gains their livelihood by fishing like they do on Anholt (95 % of Anholt consist of sand and dunes). In spite of its rather large area Saltholm cannot be utilized for farming, as large part of it is often drowned in wintertime, and the island is used for summergrazing by the farmers from the neigbouring island Amager. On Læsø, large areas are poor, sandy heaths and lie unutilized.

In order to focus on the earliest urbanization and differentiation of population the above outline was restricted to comprise "købstæder" – the ancient priviliged urban settlements which date back to the 13th and 14th century. On small islands, however, urban formations and

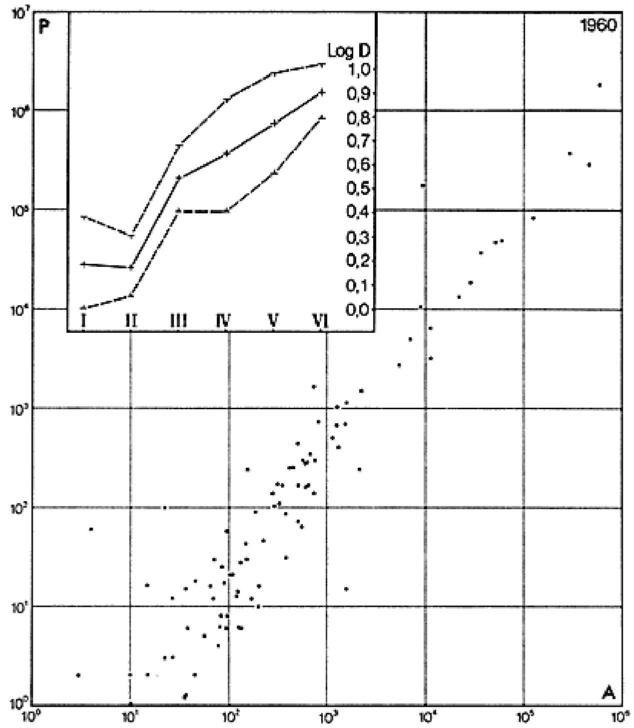


Fig. 5,2

service centers are only found at the lowest levels, and the concept of central place systems is thus inapplicable.

Observations

GROSS PATTERNS 1906 AND 1960

Since 1769 the population of Denmark has been enumerated with parishes as basic areas. For the minor islands that only constitute parts of other parishes, censuses are available only from 1901. In this century the population has thus been enumerated separately on 104 islands (Statistics of Denmark 1964 b). In 1960, four of these islands were not inhabited, one has not been regarded an island since 1935 because of reclamation, and on twelve islands the population was registered separately later than 1906 (six of them were under German Control until 1921). In order to get as homogeneous a material as possible, these 17 islands were excluded in the investigation. The remaining 87 islands were then used for a description of a gross pattern as to area and population on the basis of data for 1906 and for 1960, as it is shown on fig. 5. A comparison between the two diagrams show a trend of increasing population on the major islands and a decline on the minor ones, but some features are characteristic and common for the two census years 1906 and 1960.

The skew distribution of both area and population is obvious and can be briefly described by quartiles when the range between highest and lowest values is taken into

Quartiles	N	Population density 1906	1960
1	22	0,33	0,19
2	22	0,29	0,21
3	22	0,61	0,45
4	23	0,64	0,67

Table 1. The median population density per ha. for the 87 islands classified in quartiles according to area.
Tabel 1. Befolkningstæthed (medianværdi) for øerne opdelt i kvartiler efter størrelse.

consideration. 25 % of the islands have an area of less than 86 ha., 50 % (the median) less than 312 ha., and 75 % less than 1310 ha. Accordingly for the populations: in 1906 25 % of the islands had less than 21 inhabitants, 50 % less than 123, and 75 % less than 780; for 1960 the corresponding quartiles were 15, 95, and 668 inhabitants; the decline in population on the small islands is evident.

On the two diagrams the majority of observations fall in a rather narrow band and reveal the high correlation between area and population implying that the population density is found within a limited interval. A range from 0.1 to 1.0 inhabitant per ha. (i.e. from 10 to 100 per sq.km. OBS. population density will here be indicated per ha. only) might seem a wide one, but the greater part of the islands fall within this interval. A comparison between islands above with islands below 100 ha. shows that the population density on the major islands clusters within a narrow interval from 0.5 to 1.0, whereas the minor islands show far greater variations. Additionally there is a trend towards a relatively higher population density on the major islands than on the minor ones although the picture is less distinct for the latter. Furthermore, as to population density islands of about 300 and up to 1000 ha. apparently represent an intermediant group between a lower and a higher level. Most islands of more than 1000 ha. have a population density above 0.5. As to the small islands the picture is more indistinct, and some of the smallest ones range among those with the highest density. However of the more than twenty islands with a density below 0.25 only a few of them are above 1000 ha. whereas half of them are below 100 ha. In 1906, two thirds of the islands below 1000 ha. had a population density below 0.5 and in 1960 three fourth of them. In table 1 this has been simplified; the median population density for the 87 islands has been classified into quartiles according to size. As the distribution is uneven, the grouping into quartiles is not necessarily a "natural" one. The density/size relationship was therefore analyzed by means of another classification excluding some atypical islands. Five were omitted of the smallest islands whose inhabitants apparently do not depend on areas for their livelihood as they work as fishermen or in the ferry and pilot services or similar. Of the larger islands Saltholm

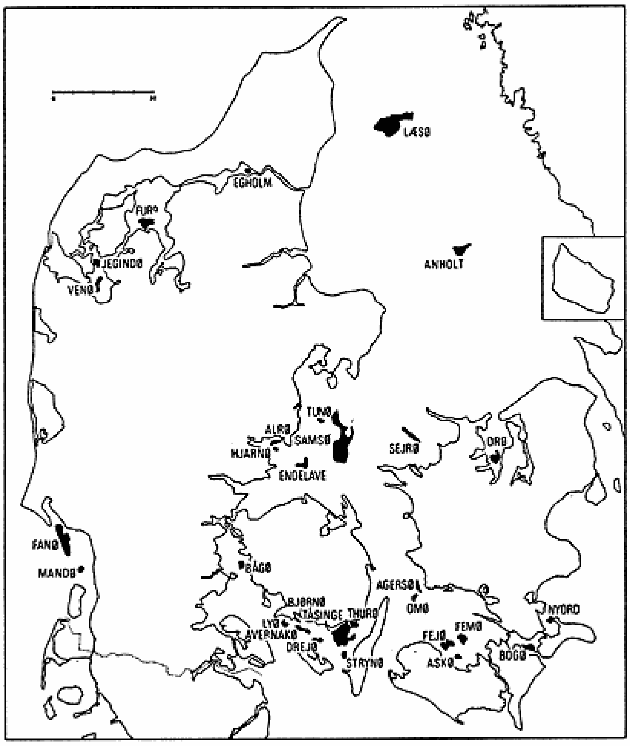


Fig. 6. The location of the 30 smallest island communes.
Fig. 6. Lokaliseringen af de 30 mindste »ø-kommuner«.

has been disregarded with its previously mentioned extremely low density, and Amager too with the highest density of them all because this island houses part of the capital of Copenhagen. Finally the four largest islands were excluded. The remaining islands were then divided into six size classes as follows:

I.	6 islands with less than	30 ha.
II.	28 islands with	30– 230 ha.
III.	24 islands with	280– 800 ha.
IV.	8 islands with	1,100– 2,100 ha.
V.	6 islands with	5,000–12,000 ha.
VI.	7 islands with	22,000–60,000 ha.

On the basis of the to $\log_{10}$ transformed values, the mean population density and the corresponding 95 % confidence limits were then calculated for the six groups. The confidence limits were calculated by the formular: $\overline{x} \pm t\,s$, $\overline{x}$ being the mean, s the standard error and t the t-value of the adequate degrees of fredom. The results are shown in the diagrams on fig. 5. Still bearing in mind that the mean of logarithmic values corresponds to the logarithm of the geometric mean, also this method shows that generally the density is highest on the major islands. For the 1906 values, the density increased from 0.35 to 0.90 per ha.. from the smallest to the largest size groups; for 1960, from 0.15 to 0.80. Additionally a regression ana-

	1860		1900		1960	
	x̄	anti-log	x̄	anti-log	x̄	anti-log
P	2,7067	509	2,7456	557	2,6496	446
A	2,9892	989	3,0013	1003	3,0100	1023
L	2,4772	300	2,5111	325	2,7633	580
S	2,8117	648	2,8251	684	2,8533	713
H	2,0248	106	2,0254	106	1,9587	91
V	2,8189	659	2,8192	660	3,0314	1075

Table 2. Mean of the six variables for the 30 minor islands. x̄ indicates the means of transformed values.
Tabel 2. Gennemsnit for de 30 mindre øer af de seks variable. x̄ angiver gennemsnit af de transformerede værdier.

lysis for each group was made. Only for the largest islands (group VI) the parameter b was so close to 1.0 that a factual carrying capacity could be stated. For the other five groups the material was regarded too heterogeneous to allow further advance by this means.

REGRESSION AND CORRELATION ANALYSES FOR 1860, 1900, AND 1960

As it appears from the above, the correlation between population and gross area is in general obvious enough, but application of gross areas might be misleading. It was therefore attempted to apply more relevant areas such as agricultural land to elucidate the population/resource relationship. These more specified area data are only available with communes or in some cases parishes as basic areas. Simultaneously it was tried to select a group of fairly homogeneous islands; thus those with statute towns and those with no farming at well were omitted. Based upon breaks in distribution, it was finally decided to set an upper limit at 12,000 ha. Hereby 30 units emerged which were composed as follows in 1960: One constituted a parish but not an individual commune, twenty made up twenty communes, six communes were composed of twenty small islands, and finally three islands made up two, three, and five communes respectively. These 30 units are the basic areas of the regression analysis and shall be referred to as islands in the following; their location appears from the map fig. 6. The regression analysis was made for three periods on the basis of the to $\log_{10}$ transformed variables: the population and the area resources classed after five definitions as described earlier.

In connection with the regression analysis the mean values of the 6 variables were found. They give a picture of some general dimensions and trends still bearing in mind that antilogarithmic values represent the geometric means (table 2).

From 1860 to 1900 the population increased by 10 %; from 1900 to 1960 it decreased by 20 % cf. the curve in fig. 4, which also shows the 30 islands' populations development but by the arithmetic mean. The gross area (A) is naturally fairly constant throughout the whole period;

	1860	1900	1960
S/A	0,65 (0,65)	0,68 (0,73)	0,70 (0,72)
L/S	0,46 (0,44)	0,47 (0,83)	0,76 (0,89)
L/A	0,30 (0,29)	0,32 (0,63)	0,57 (0,64)

Table 3. The ratio between the total area (A), rotation area (L), and the total agricultural area (S) for the 30 minor islands. Figures for all Denmark in brackets.
Tabel 3. Forholdstal mellem det samlede areal (A), omdrifts areal (L) og det samlede landbrugsareal (S) for de 30 mindre øer. I parentes tilsvarende tal for hele Danmark.

the increase of a few per cent might be due to a proper growth by marine deposits or uncertainty as to measuring coastlines. The rotational area (L) has nearly doubled, and the total agricultural area has increased by 10 %. The number of "hartkorn" (H), which might be a measure of the fertility of the islands, was constant for the first period but declined by 10–15 % for the last period due to some revising of the taxation. The total value of agricultural areas (V) was estimated in prices at three separate times and are consequently not immediately comparable. Compared with figures for the whole country, how-

log P =	a	+	b	log R	r	n	anti-log a
1860							
log P =	-0,0733	+	0,9300	log A	0,8616	30	0,85
	0,3306	+	0,9592	log L	0,8936	30	2,14
	-0,0127	+	0,9672	log S	0,8666	30	0,97
	0,8833	+	0,9006	log H	0,8668	30	7,65
	0,4502	+	0,8006	log V	0,7993	30	(2,82)
1900							
log P =	-0,0794	+	0,9413	log A	0,8647	30	0,83
	0,4903	+	0,8982	log L	0,8598	30	3,09
	-0,2907	+	1,0748	log S	0,9011	30	0,85
	1,0093	+	0,8573	log H	0,8291	30	10,22
	0,1583	+	0,9245	log V	0,9146	29	1,44
1960							
log P =	-0,4740	+	1,0377	log A	0,8797	30	0,34
	-0,1715	+	1,0299	log L	0,8186	28	0,67
	-0,2147	+	1,0089	log S	0,7997	29	0,61
	1,2333	+	0,7605	log H	0,7139	29	(17,12)
	0,4795	+	0,7206	log V	0,7426	29	(3,02)

Understregning af b-værdier angiver, at b er signifikant forskellig fra 1,0 således: – – – på 0,05 og ——— på 0,01 niveau.

Underlining of b-values indicates that b is significantly different from 1.0 as follows: – – – at the 0.05 level, and ——— at the 0.01 level.

Table 4. Analysis of regression and correlation of population and resources on the 30 minor islands. A: total area, L: rotation area, S: total agricultural area, H: soil fertility, V: land value.
Tabel 4. Regressions- og korrelationsanalyse af befolkning og ressourcer på de 30 mindre øer. A: samlet areal, L: omdrifsareal, S: samlet landbrugsareal, H: hartkorn, V: vurdering af landbrugsjord.

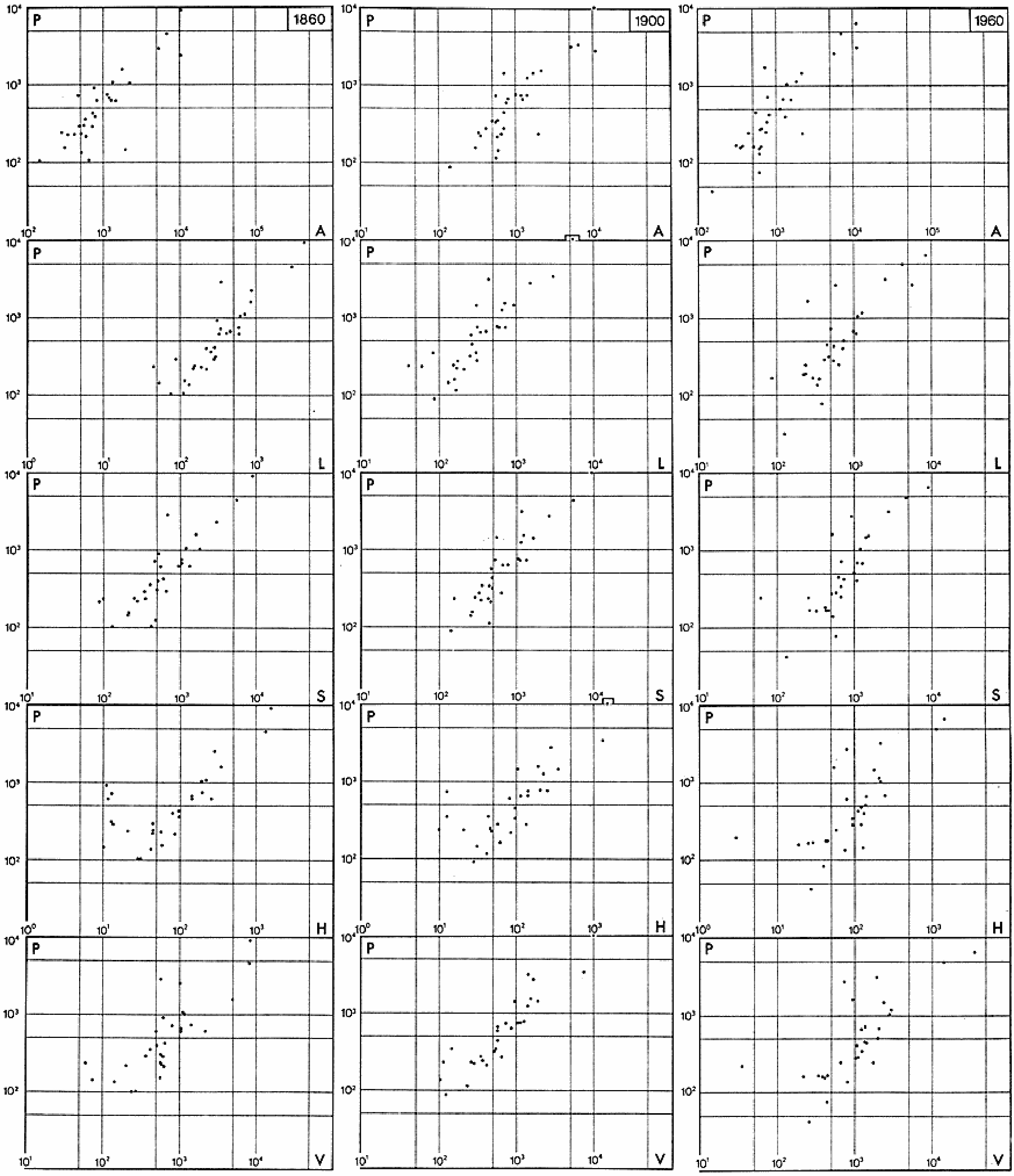


Fig. 7. Population and resources 1860, 1900, and 1960 for the 30 smallest island communes. P: population, – A: gross area, – L: crop (rotation) area, – S: total agricultural area, – H: soil fertility, "hartkorn", – V: value of total agricultural area.
Fig. 7. Befolkning og ressourcer 1860, 1900 og 1960 for de 30 mindste ø-kommuner. P: befolkning, – A: bruttoareal, – L: omdriftsareal, – S: samlet landbrugsareal, – H: hartkorn, – V: vurderinger af samlet landbrugsareal.

ever, the islands seem to have experienced a relative small increase in values for the first period, whereas a heavy decline took place for the second period.

The increase in rotational areas is due to alterations of the agricultural system, whereas the extension of farmland has been brought about by cultivation, i.e. a greater part of the resources have been exploited. These changes are very well illustrated by the ratio between gross area, total agricultural areas and rotational areas (table 3). The extension of agricultural area by 5 %, from 65 to 70 % of the total area, corresponds to the development for the country as a whole. The changes in the agricultural system are reflected in the share of the rotation area; in 1860 it constituted a little less than half of the total agricultural area (same as for the whole country and grew to three fourth in 1960 (somewhat below the whole country with its nine tenths of the areas under rotation crops). The fourth of the agricultural area that remains outside rotation on the islands is mostly the poor, low-lying coastal areas under permanent grazing which make up a fairly large part of many islands. The increase in rotation area took place after the turn of the century, somewhat later than in the remaining parts of the country.

The correlation between the population and the five measures of resources appears from the scatter diagrams and the table, fig. 7 and table 4. It is seen that the correlation is high everywhere, statistically it is significant at a 0.01 % level. The coefficient of determination fluctuates from 0.84 and down to 0.50. By the regression analysis the calculated b-values are not significantly different from 1.0 in 12 of the 15 cases. This means that certain levels for the carrying capacity can de deduced, as indicated in the table by antilog a. The applicability of the model on P=f (A) was doubted beforehand. It appears, however, that the model fits just as well as when the factual area data are used. Contrary to expectation, the assumption of a certain carrying capacity per unit for P=f (H) in 1960 and for P=f (V) in 1860 and 1960 must be rejected as the calculated b-values are significantly different from 1.0. Of the diagrams it is further seen as to P=f (H) that the observations are not evenly distributed. Especially as to P=f (H) for 1960, it appears from the diagram that the observations fall into two groups; 1) the 8 smallest islands with a comparatively high population density and 2) the remaining islands which tend to group around a gradient of 1.0 (45°) but with a carrying capacity per unit at a lower level than found by the regression analysis. It might be concluded that in this case the result has been a general overestimation of the carrying capacity although the model seems to be applicable enough and a high correlation was found by the conventional, statistical procedure.

Conclusion

In an earlier study a simple linear model was used to describe the relation population/resources in rural areas. The present investigation attempts to modify this model and use it on island populations. In some respects the material might be regarded as rather restricted, but for a wide range of islands some mutual features emerge such as the greater variation in population density for the minor islands than for the major ones. Also there is a general trend towards a lower population density on the minor islands than on the major ones. Islands above a certain size appear to have a "rational" population density in relation to the carrying capacity; so, islands above c. 1000 ha. seem to sustain a balanced number of people per unit of measured resources.

For a homogeneous group of islands the linear model is applicable, and generally a high correlation has been observed between population and resources. With application of factual areal data the observations point at a certain carrying capacity per unit of resource; this is, in spite of what might be expected, also due when gross areas are applied, but not when soil fertility or values are taken as measures. From this might be deduced that in the Danish archipelago the size of areal resources determine how many people might gain a living from them, whereas soil fertility and value of agricultural land, in spite of a high correlation, rather must be considered rough estimates and more decisive for the standard of living gained than for the actual number of persons able to live from the resources available.

In the cases where the calculated b-values are significantly different from 1.0 and a certain carrying capacity cannot be deduced, the relationship must be considered a more complex one. If *b* is higher than 1.0 this might indicate that the islands as to size lie in a transition zone between two levels of carrying capacity. It was found, however, that most b-values fell below 1.0; from this may be deduced that the minor islands are relatively overpopulated and/or the major islands relatively underpopulated. Presumably it will not be possible to set up absolute criteria for over- or underpopulation apart from statistical criteria based upon for example residuals from regression.

The carrying capacity of the islands depends of course not only upon available resources, but also on how they are exploited. In this study only some general patterns have been discussed on the basis of different measures of the area resources such as total area, rotation area, and total agricultural area. Indirectly, however, the exploitation system has also been considered as the ratio between the three categories of areas reflects the actual agricultural system.

It would no doubt be interesting, but lies beyond the scope of this paper, to elucidate for example the residuals from regression on the basis of the single island's specific character as to environment, degree of isolation, soil, and hydrology; further to include the agricultural system with a view to specific crops, size of farms, and supplementary professions such as fishing.

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RESUMÉ

Denne undersøgelse er en del af et projekt, der har som formål at belyse befolkningen i danske landdistrikter på basis af de lokale, udnyttede ressourcer. I en tidligere artikel anvendtes en simpel, lineær regressionsmodel på sammenhængen mellem befolkning og ressourcer; i denne undersøgelse søges modellen tilpasset og anvendt på de danske øer.

En alvorlig vanskelighed ved at behandle relationen mellem befolkning og ressourcer og for så vidt også udnyttelsessystemet er at måle omfanget af ressourcerne. Der er valgt at anvende arealer, der under et givet udnyttelsessystem afspejler udnyttede, naturlige ressourcer. Materialet stammer fra den offentliggjorte statistik og omfatter:

A. – Det totale areal, som sætter en absolut øvre grænse for omfanget af ressourcerne.

L. – Landbrugsareal i omdrift, som angiver et omfang af de ressourcer der udnyttes kraftigst, og som i de fleste tilfælde kan betegnes som vigtigst.

S. – Det samlede landbrugsareal, dvs. omfanget af hele det areal, der anvendes i landbrugsproduktionen. Heri er således medregnet brakarealer, vedvarende græsningsarealer o.lign., der til visse tider, i visse områder og udnyttelsessystemer kan spille en betydelig rolle.

Disse tre arealtal er suppleret med to skøn over jordens værdi (bonitet eller ydeevne), da arealer af samme størrelse kan være af meget forskellig beskaffenhed.

H. – Hartkorn, som er et sammenfattende mål for jordens ydeevne baseret på en analyse af overjordens beskaffenhed og dybde samt underjordens beskaffenhed. Hartkorn-vurderingen blev i det væsentlige fastlagt i første halvdel af forrige århundrede, altså under et udnyttelsessystem, der er ret forskelligt fra vore dages og den må betegnes som et groft skøn over jordens ydeevne, specielt for egne, der siden er blevet opdyrket, men også hvad angår senere ændringer i udnyttelsessystemet.

V. – Vurdering af landbrugsjord, der kunne være et mere realistisk skøn over jordens ydeevne.

Som mål på befolkningens størrelse er anvendt:

P. – Samlet folketal, selv om det i vore dage indbefatter en del, der ikke kun er »afhængige« af lokale arealer.

Materialet er taget fra den officielle statistik (nær) ved tre tidspunkter: 1860, 1900 og 1960. A, L og S er regnet i hektar, H i »tønder hartkorn« og V i 1000 rigsdaler »gammelskat« for 1860 og i 1000 kr. for 1900 og 1960. Som basisarealer er anvendt dels de enkelte øer dels kommuner som ved inddelingen 1960. For de enkelte øer kan man kun få oplysning om bruttoarealer og befolkning fra 1901 og fremefter. De 6 variable er anvendt efter transformationen til $\log_{10}$.

Materialet kan i visse henseender forekomme lille, men nogle forhold synes bekræftet.

I et bredt spektrum af øer, bredspektret m.h.t. areal, er der blandt de mindre øer i almindelighed større variation i, men også en tendens til mindre befolkningstæthed end blandt de større. Blandt de større øer vil der på et givet tidspunkt være en tendens til en bestemt befolkningstæthed, dvs. en bestemt bæreevne pr. enhed som ressourcerne er målt i. For et bredt spektrum kan sammenhængen mellem befolkning og ressourcer således beskrives med en krum (hyperbolsk) kurve.

For en homogen gruppe øer kan den lineære model (Mørch 1974) anvendes. Generelt er der observeret høj korrelation mellem befolkning og ressourcer. Anvendelsen af egentlige arealtal peger på en bestemt bæreevne pr. arealenhed; dette gælder på trods af, hvad man på forhånd kunne forvente, også ved anvendelse af bruttoarealer. Derimod gælder det ikke ved anvendelsen af hartkorn- og arealvurderinger trods høj korrelation. Disse forhold kan tolkes således, at det er arealressourcerne, der er bestemmende for hvor mange, der på et givet tidspunkt kan få deres udkomme, dvs. er bestemmende for bæreevnen. Derimod må hartkorn og værdi, trods høj korrelation, betragtes som grove skøn, som mere har betydning for størrelsen af befolkningens udkomme end for, hvor mange, der kan leve på de pågældende ressourcer. I de tilfælde, hvor den lineære model ikke passer, kan det generelt udlægges som, at de mindre øer er relativt overbefolkede og/eller de større øer er relativt underbefolkede, selv om det ikke vil være muligt at anføre andre end rent statistiske kriterier for denne over/underbefolkning.

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RESUMÉ
Denne undersøgelse er en del af et projekt, der har som formål at belyse befolkningen i danske landdistrikter på basis af de lokale, udnyttede ressourcer. I en tidligere artikel anvendtes en simpel, lineær regressionsmodel på sammenhængen mellem befolkning og ressourcer; i denne undersøgelse søges modellen tilpasset og anvendt på de danske øer.

En alvorlig vanskelighed ved at behandle relationen mellem befolkning og ressourcer og for så vidt også udnyttelsessystemet er at måle omfanget af ressourcerne. Der er valgt at anvende arealer, der under et givet udnyttelsessystem afspejler udnyttede, naturlige ressourcer. Materialet stammer fra den offentliggjorte statistik og omfatter:

A. – Det totale areal, som sætter en absolut øvre grænse for omfanget af ressourcerne.

L. – Landbrugsareal i omdrift, som angiver et omfang af de ressourcer der udnyttes kraftigst, og som i de fleste tilfælde kan betegnes som vigtigst.

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