Arctic char in Iceland

The connection between growth and size at sexual maturity in Icelandic arctic char (Salvelinus alpinus)

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A paper prepared for the

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ABSTRACT

During surveys for exploitation programmes of several arctic char populations in Iceland, samples were obtained on size distribution, age, sex and maturity. Gillnets from 10-46 mm knot-to-knot were used to sample the lake populations and electrofishing was used for a riverine population and a population in a small isolated pool. Otoliths were used for aging.

The fish community was in every case dominated by arctic char, which in some cases was the only fish species present. In other communities, three-spined stickleback and/or brown trout and/or european eel were also present.

Growth curves vary greatly among the populations, and size at sexaul maturity ranges from 8 cm to greater than 45 cm T.L. Usually, males mature at a smaller size and tend to grow to a larger size than females.

Size at sexual maturity is directly proportional to the asymptotic length. In situations where large food organisms (e.g. sticklebacks) are absent, in dense populations and unproductive environments, size at sexual maturity was smallest.

The differences observed can be explained in terms of opportunities for growth, dictating optimum size at maturity. Arctic char can adjust quickly in size at sexual maturity to changes in available food supply.

INTRODUCTION

Many species of fish are well known for great variations in growth rates and size obtained (Mann, Mills & Crisp 1984). This is particularly true in freshwater fish and is well documented in arctic char (Johnson 1980).

Several authors have tried to explain the connection between growth and size at sexual maturity. The best known paper is that by Alm (1959). He, and Iles (1974) argued that sexual maturity was brought about by reduced growth rates, but many other authors have stated the opposite.

Two points of view exist on the great variation in size at sexual maturity among different populations of fish species. Some would argue that the variation is genetic even reflecting allopatric or sympatric speciation (Nyman, Hammar & Gydemo 1981). Others suggest it reflects various life history strategies (Balon 1984, Stearns & Crandall 1984), which may influence natural selection. Arctic char has received much attention in this regard.

The data presented in this study support the idea of a uniform life history strategy for the whole species. Differences in growth and size at sexual maturity can be adequately explained in terms of varying conditions for growth, rather than expressing genetic differences among populations.

Arctic char has a circumpolar distribution, occurring in three continents, and is found in fairly simple ecosystems often being the only fish species present (Johnson 1980). It therefore takes on various roles in the ecosystems, and this is reflected in great variations in size attained, external morphology and behaviour.

In this paper I will present some information on arctic char populations in northern Iceland and a preliminary analysis on the connection between size at sexual maturity and size attained in arctic char populations.

MATERIAL AND METHODS

Samples were obtained from seven localities during surveys for the establishment of exploitation programmes or, in two cases, during stream surveys. In the lakes fish were caught in eight 25 m long, 1,5 m deep, bottom set monofilament gillnets of varying mesh sizes (20.5, 21, 26, 29, 35, 40, 46 and 52 mm knot-to-knot). This combination of gillnets is commonly used in Iceland for survey purposes of arctic char and brown trout populations. It has been found to catch a representative sample of brown trout ranging from 20 to 55 cm in total length (Jensen 1977), but is at variance slightly with the series recommended for arctic char by Hammar and Filipson (1985).

The gillnets were set for one night in each lake and it is likely that limited sampling effort as well as variation in body condition introduces a greater uncertainty into the estimated size distribution of the populations than the selectivity of the gillnets.

One of the samples came from a riverine population and in one case a small pond adjacent to a river was sampled. In these two cases electrofishing was employed. Sampling was convenient and is likely to reflect the true population structure in both cases.

All sampling, except at locality 6 (the small pond) was done in the autumn of 1985 and 1986, when mature fish had ripe gonads. All fish caught were measured to the nearest mm T.L. Sex and maturity were determined by inspection. In the pond, sampling was done in early spring. All ripe females had large numbers of residual eggs, which had not resorbed, indicating that spawning had not taken place the previous autumn. It was more difficult to determine maturity in the males. Size at sexual maturity is taken to be when 50% of the fish in a given cm group have attained maturity.

Otoliths were taken from a subsample for ageing. They were read in reflected light, immersed in methyl salicylate, using a microscope. They were generally easy to interpret, but in many cases had to be ground on a sandstone to make the annuli more distinct.

In this preliminary analysis growth curves were fitted by eye and estimates of average asymptotic length obtained from these.

DESCRIPTION OF THE SAMPLE SITES

Generally, aquatic communities in Iceland are made up of few species. Fish are the only vertebrates and only five species occur in the wild, three salmonid species, the three-spined stickleback and the european eel. All of these species are potentially anadromous or catadromous. The lakes are generally cool and clear and ice-covered for six to seven months. The growing season is therefore short, but near 24 hours of daylight in summer make for an intensive production period.

Arctic char in Iceland generally specialize on different food species at any given time. At different stages of their lives plankton, benthic invertebrates or other fish become important. This sometimes reflects the development of individuals, but the degree of specialization may even lead to different morphs.

All sample localities are in northern Iceland, between the latitudes of 65°30' and 66°. They are given in order from west to east below.

Locality 1. Ölversvatn, a 300 ha lake, 169 m.a.s.l., depth 2 - 4 m. Harbours landlocked populations of arctic char, brown trout (*Salmo trutta*) and the three-spined stickleback (*Gasterosteus aculeatus*). Lightly exploited by anglers. Fish community dominated by arctic char. Commercial fishing in operation since sampling.

Locality 2. Vatnshlíðarvatn, a 70 ha lake, 280 m.a.s.l., depth 2 - 5 m. Landlocked arctic char is the only fish species present and forms a dense population. Neglible exploitation before study. Commercial fishing now in operation.

Locality 3. Garðsvatn, a 35 ha lake, 2 m.a.s.l., depth 1 - 2 m. Harbours arctic char, sticklebacks and eels. Fine sand and mud substrate, spawning limited to a small inflowing stream limiting recruitment. Outflow filters through sandbars, but connected to the sea during spring floods. Fish community dominated by arctic char. Commercially exploited by 46 - 52 mm mesh gillnets before study. Now exploited with 35-40 mm gillnets.

Locality 4. Ólafsfjarðará, a small river, 1 m^3/sec, 200 m.a.s.l. The river is cold and unproductive, fed by snowmelt and low in TDS. The principal food organisms are small chironomid species. Landlocked arctic char the only species present. Not exploited.

Locality 5. Ólafsfjarðarvatn, a 225 ha lake, 1 m.a.s.l. Average depth 3.7 m, maximum depth 10 m. Meromictic, with a 1.5 - 2 m surface layer of fresh water (Stefánsson & Jóhannesson 1983). In the freshwater layer fish fauna dominated by arctic char, resident and anadromous. Also present are sticklebacks and salmon released from a lakeside hatchery. The char reproduces exclusively in the inflowing river. Several species of marine fish in the deeper, saltwater layer. Exploited by gillnets $\geq$ 45 mm mesh and anglers before study. Smaller (29-32 mm) mesh size recommended.

Locality 6. Bröndupollur. Approximately 40 m^2 natural pond fed by ground water. Depth 1 m. The nearby River Laxá í Aðaldal floods this pond every few years. Arctic char the only fish species present. Not exploited.

Locality 7. Eilifsvötn, a 280 ha lake, 354 m.a.s.l. Approx. 4-12m deep. Harbours landlocked arctic char introduced 15 years ago, a large population of sticklebacks which the char predate on and a small population of brown trout. Heavily exploited with 43 - 50 mm mesh gill nets. No change advocated.

RESULTS AND DISCUSSION

The results are summarized in Figures 1 to 7.

Size at sexual maturity

With one exception (locality 1), females tend to mature at a larger size and attain a higher age than males. This indicates that maturity and the act of spawning brings on accelerated mortality. This is particularly evident at locality 4 where of age 6+ - 10+ individuals, only two out of sixteen were males (Fig. 4b).

At locality 1 where males mature at a larger size than females, there is a preponderance of males at age 8+. Of seventeen older fish, there were only three females (Fig. 1b).

It is often the case with salmonids that males tend to mature at a smaller size than females, but the largest individuals also tend to be males. This might be related to more aggressive behaviour in males, enabling them to exploit different food resources to females. In Lake Mývatn in the north of Iceland in the autumn of 1985, the largest individuals were all immature males and sticklebacks were their principal diet. Size at sexual maturity was indeterminate in males, but females matured at 35 cm T.L. and their main diet was planctonic crustacea (Daphnia sp) (Kristjánsson, personal communication). It may be that the observed differences are the results of the sexes to some extent exploiting different niches. That males grow to a considerably larger size than females in Lake Mývatn has also been observed by Lamby (1941). In most of the other populations sampled males were among the largest and oldest individuals in the population, although the general pattern was for them to mature earlier than females.

In locality 2 both males and females tend to mature at one of two sizes. It is well documented that different morphs exist in many lakes and that these mature at different sizes. This is especially true for large and/or deep lakes. Examples are in given in Johnson's (1980) review paper. In some of these studies it is suggested that a small form may be recruited to a larger form by not spawning for a few years while entering a period of rapid growth (e.g. Johnson 1976, Riget, Nygaard & Christensen 1986). Age-length data from locality 2 (Fig. 2b) do not indicate such a transfer between the two groups.

In Lake Vangvatnet in Norway, Jonson and Hindar (1982) studied a similar situation to that found in locality 2 with arctic char maturing at two sizes. They did not find any evidence of dwarfs "graduating" to the larger groups, but rearing experiments showed that offspring from either type could give rise to both morphs. Other rearing experiments (Nordeng 1983) have shown similar results.

Extensive genetic studies on arctic char have not shown genetic differences among populations to be related to the size attained by different morphs (Hindar _et al_. 1986).

Size at maturity and asymptotic length

The relationship between size at sexual maturity and asymptotic length is summarised in Table 1 and presented in Figure 8. There is a good positive proportional relationship. Theoretical considerations (Stearns & Crandall 1984) have shown that when reduced growth rate is associated with increased natural mortality, this will result in reduced size at sexual maturity. The observations in this study support this conclusion.

The close fit in Figure 8 suggests that different populations react similarly to variations in feeding conditions and the different populations and morphs all have a common strategy. In the three localities (2, 4 and 6) where sticklebacks do not occur, size at sexual maturity is smaller than in any of the other localities (Table 1).

Changes in food supply e.g. by removal of large proportions of the populations of arctic char (Langeland

1986) and transplantation experiments (Pechlaner 1984) show that density and thereby food supply is the main factor determining growth and size at sexual maturity.

The limits an environment puts on individual fish are in part determined by the size of the fish, since its potential to exploit resources in the environment may depend for example on a temperature dependent metabolism, the size of the gape, swimming speed and vulnerability to predators (Werner & Gilliam 1984). This then gives rise to different "morphs" attaining different sizes and exploiting different parts of the environment, especially where generalists such as arctic char occur with little competition from other species.

The strong correlation between size at sexual maturity and maximum length attained suggests that feeding conditions dominate over genetical factors in determining size at sexual maturity in different populations or ecotypes of arctic char.

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Table 1 Size at sexual maturity and asymptotic length (in cm) of different ecotypes of arctic char, estimated from Figures 1 to 7.

Locality	Sex	Size at maturity	Asymptotic length (cm)
1	M	29-30	38
1	F	27-28	33
2	M+F	17-19	21-22
2	M+F	22-24	29-30
3	M+F	33	43
4	M	13-14	18
4	F	17-18	25
5	M+F	25-27	33
6	F	8	10
7	M+F	indeterminate	

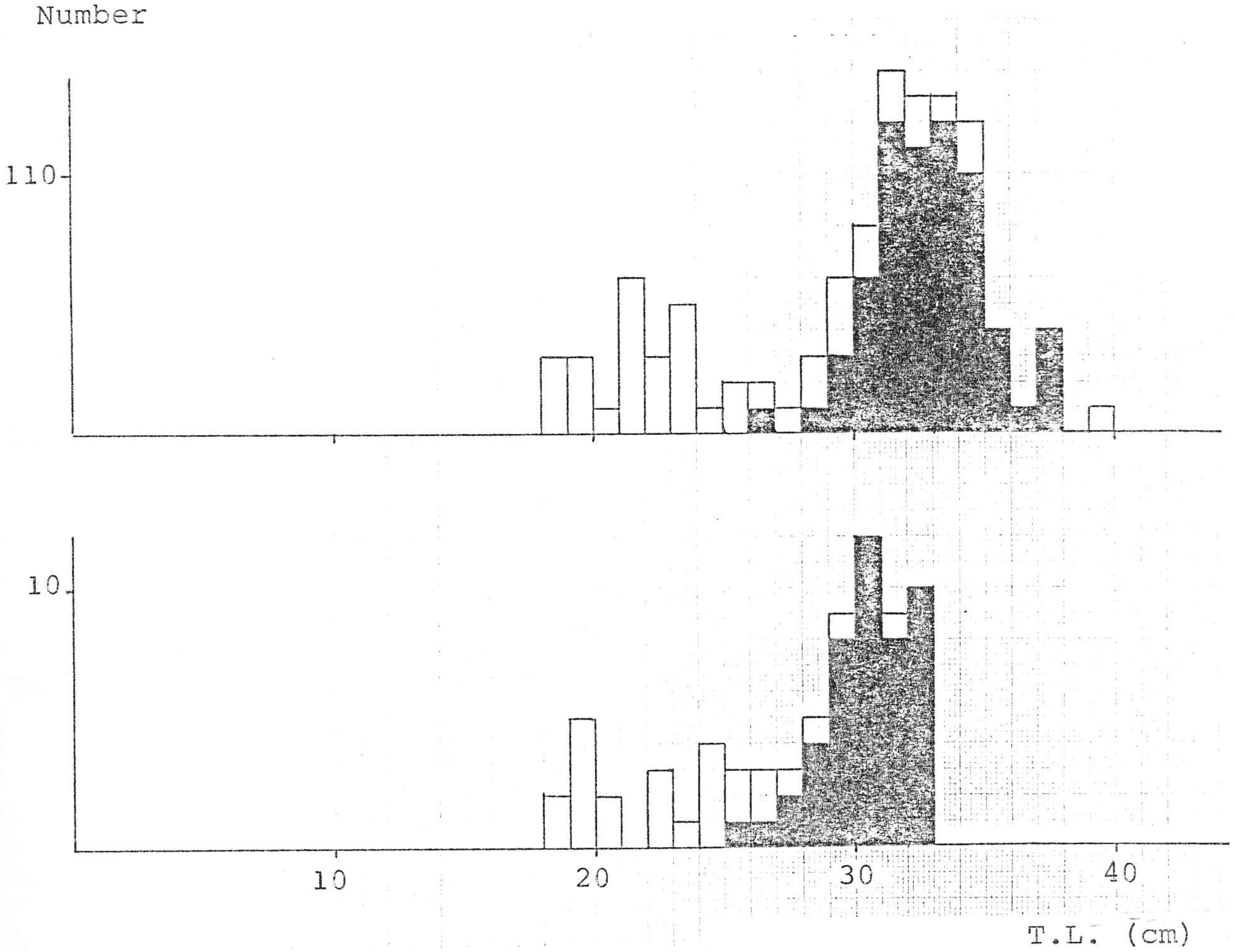

Figure 1a. Length frequency distribution of arctic char from experimental gillnets in Lake Ölversvatn, locality 1, 28/9 1985. Shaded areas indicate mature individuals.

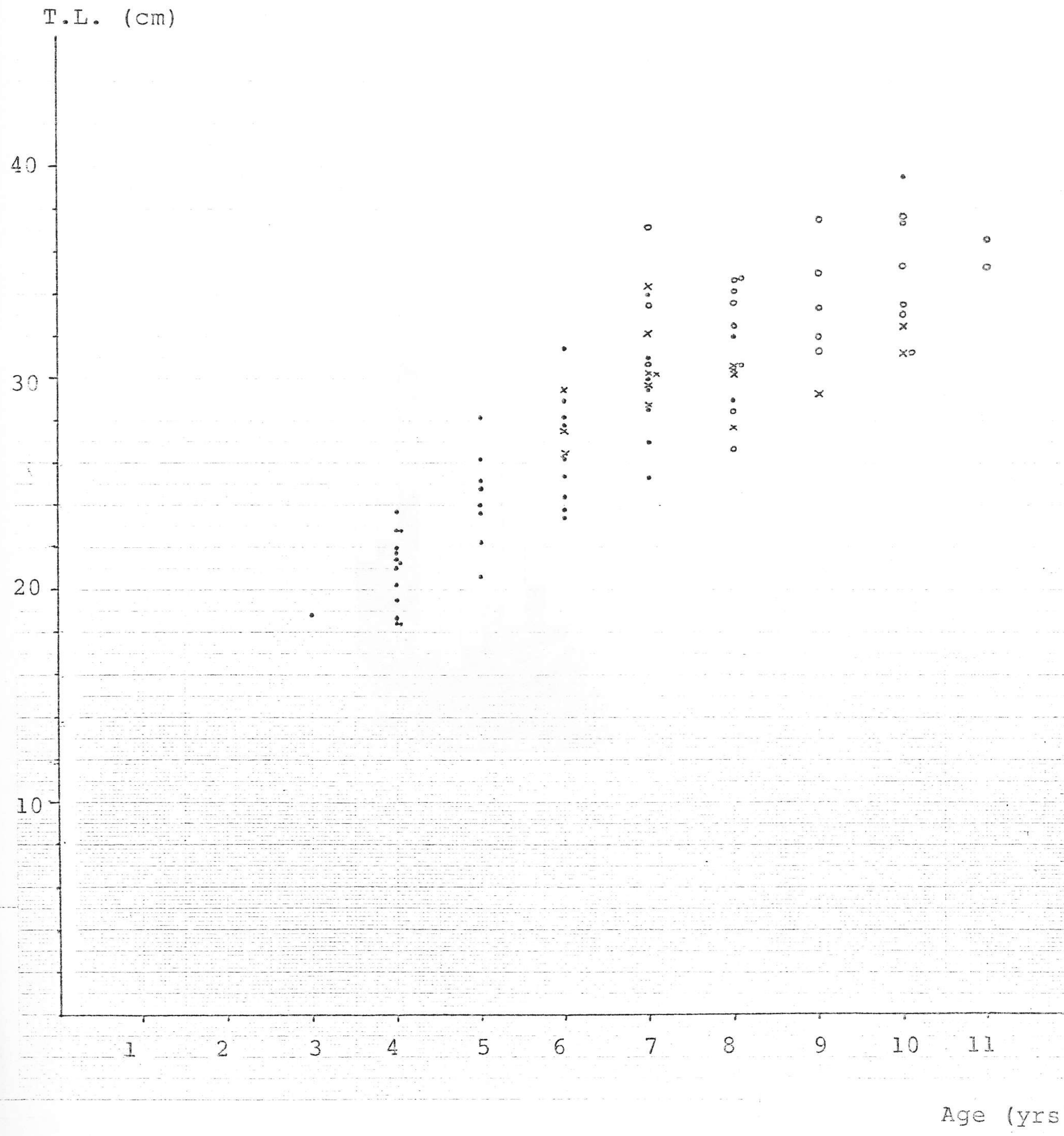

Figure 1b. Age-length data on arctic char from locality 1.
x = mature females
o = mature males
● = immatures

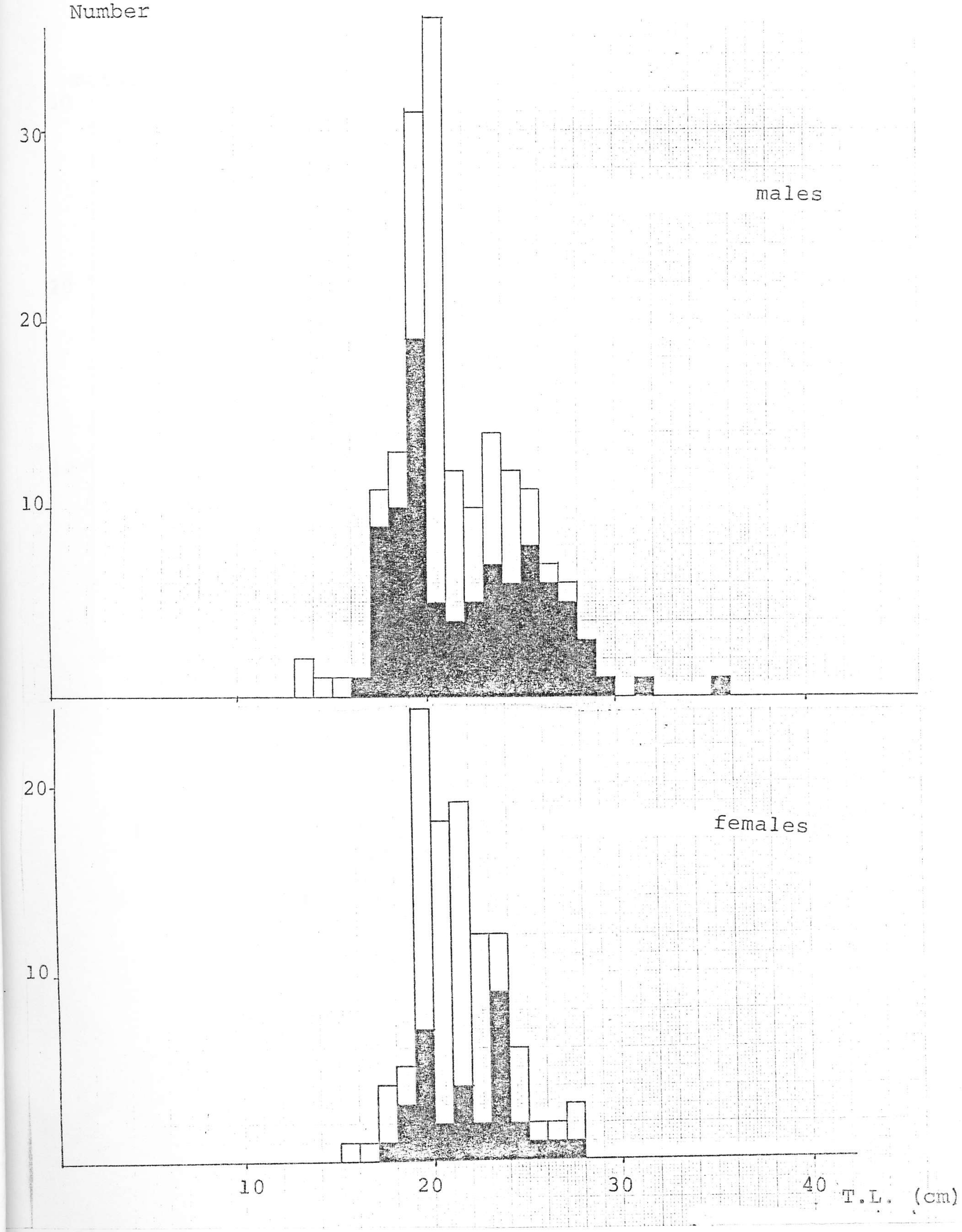

Figure 2a. Length frequency distribution of arctic char from experimental gillnets in Lake Vatnshlíðarvatn, locality 2, 27/9 1985. Shaded areas indicate mature individuals.

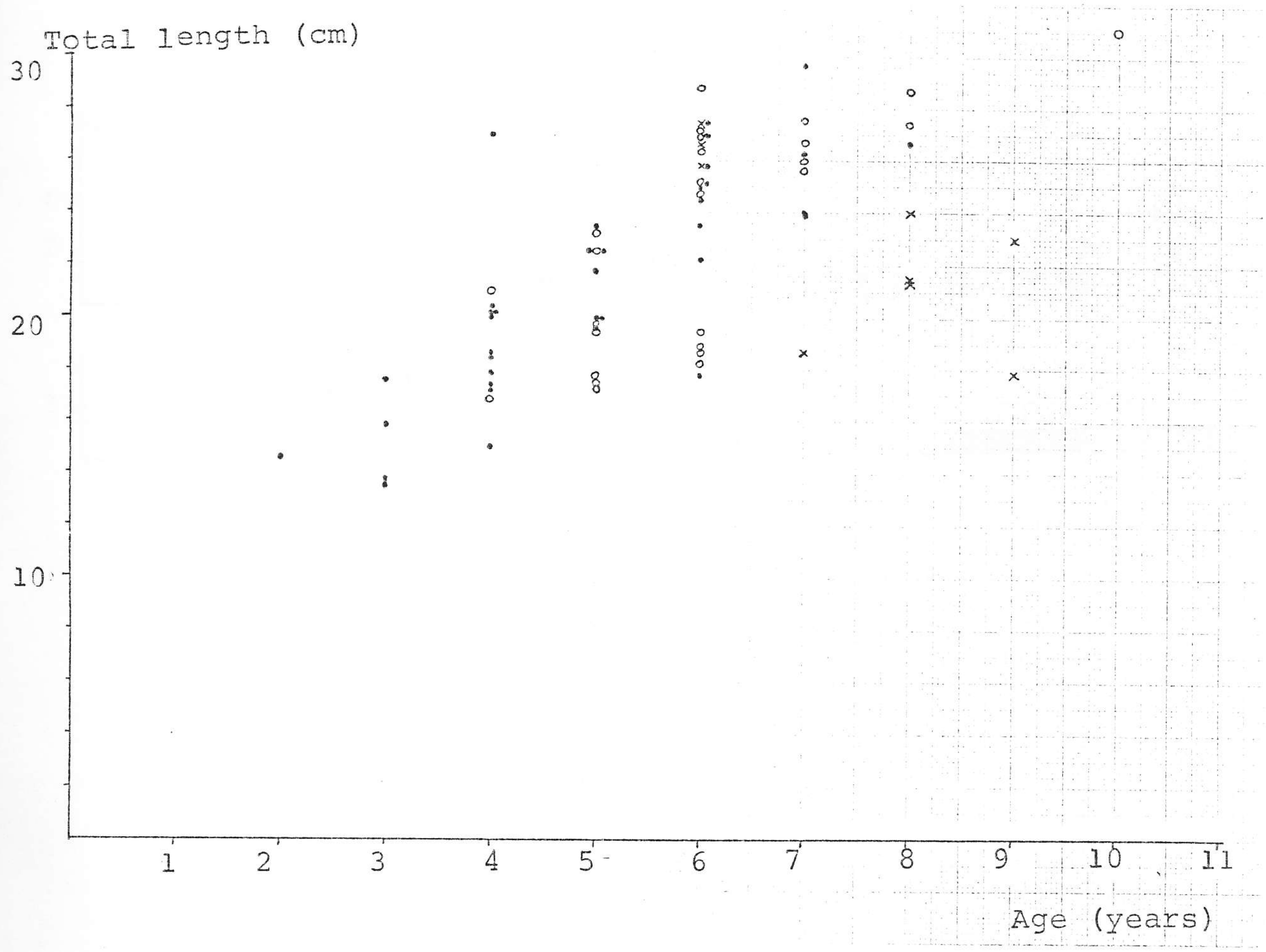

Figure 2b. Age-length data on arctic char from locality 2.
x = mature females
o = mature males
● = immatures

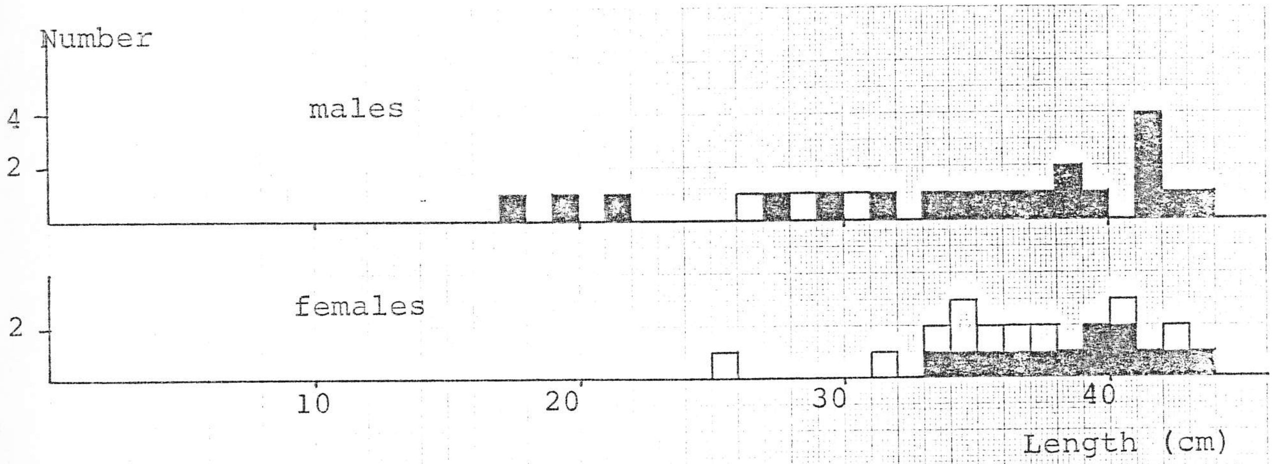

Figure 3a. Length frequency distribution of arctic char from experimental gillnets in Lake Garðsvatn, locality 3, 30/9 1985. Shaded areas indicate mature individuals.

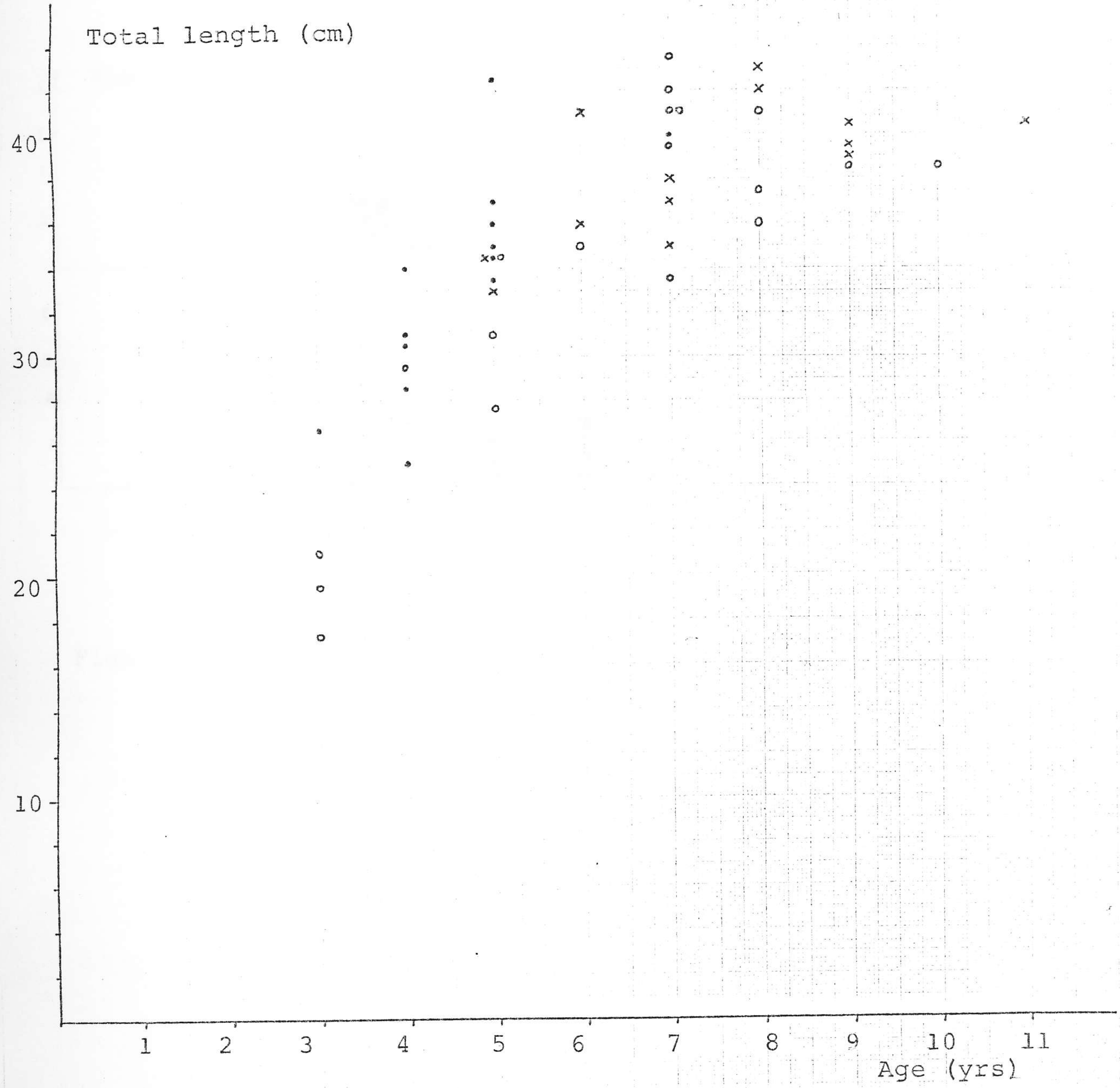

Figure 3b. Age-length data on arctic char from locality 3.
x = mature females
o = mature males
● = immatures

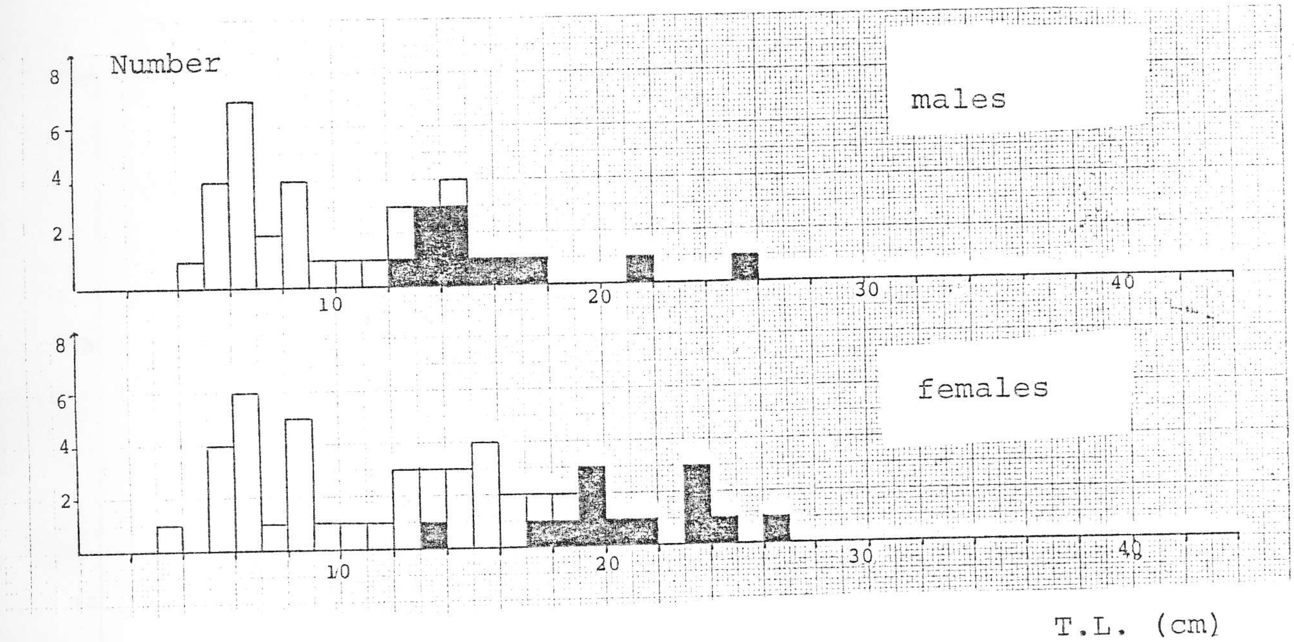

Figure 4a. Length frequency distribution of arctic char from River Ólafsfjarðará, locality 4, 7/8 1986. Shaded areas indicate mature individuals.

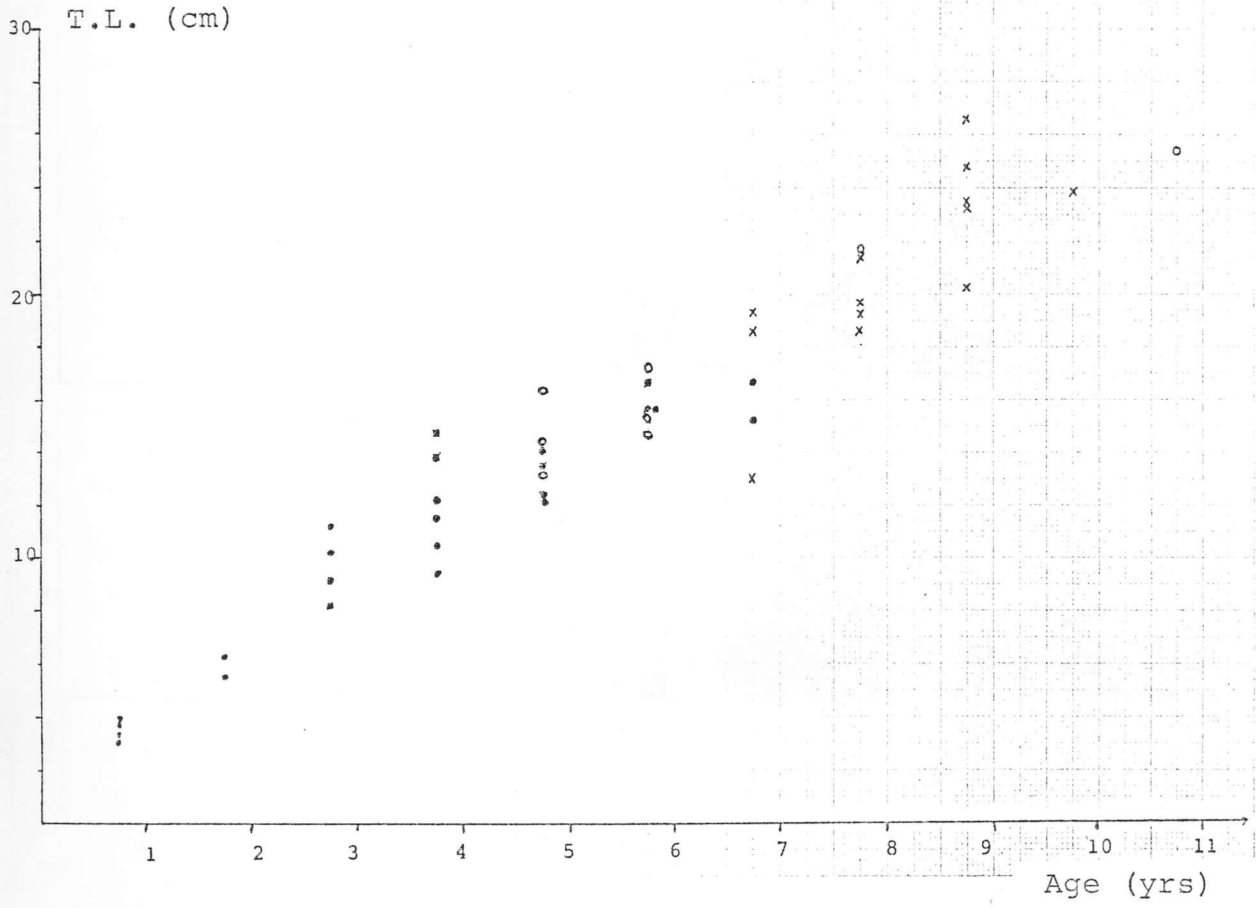

Figure 4b. Age-length data on arctic char from locality 4.
x = mature females
o = mature males
● = immatures

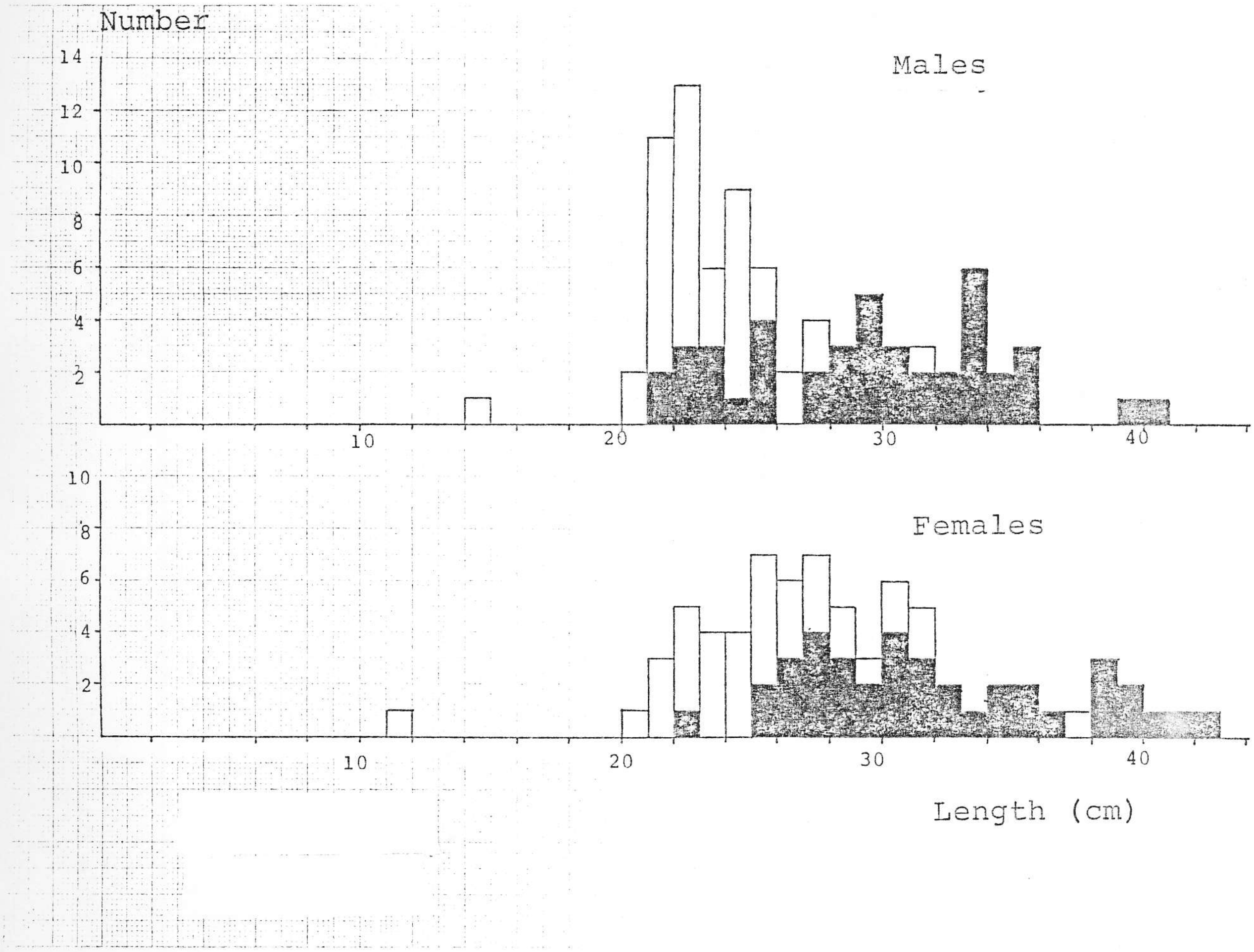

Figure 5a. Length frequency distribution of arctic char from experimental gillnets in Lake Ólafsfjarðarvatn, locality 5, 8/8 1986. Shaded areas indicate mature individuals.

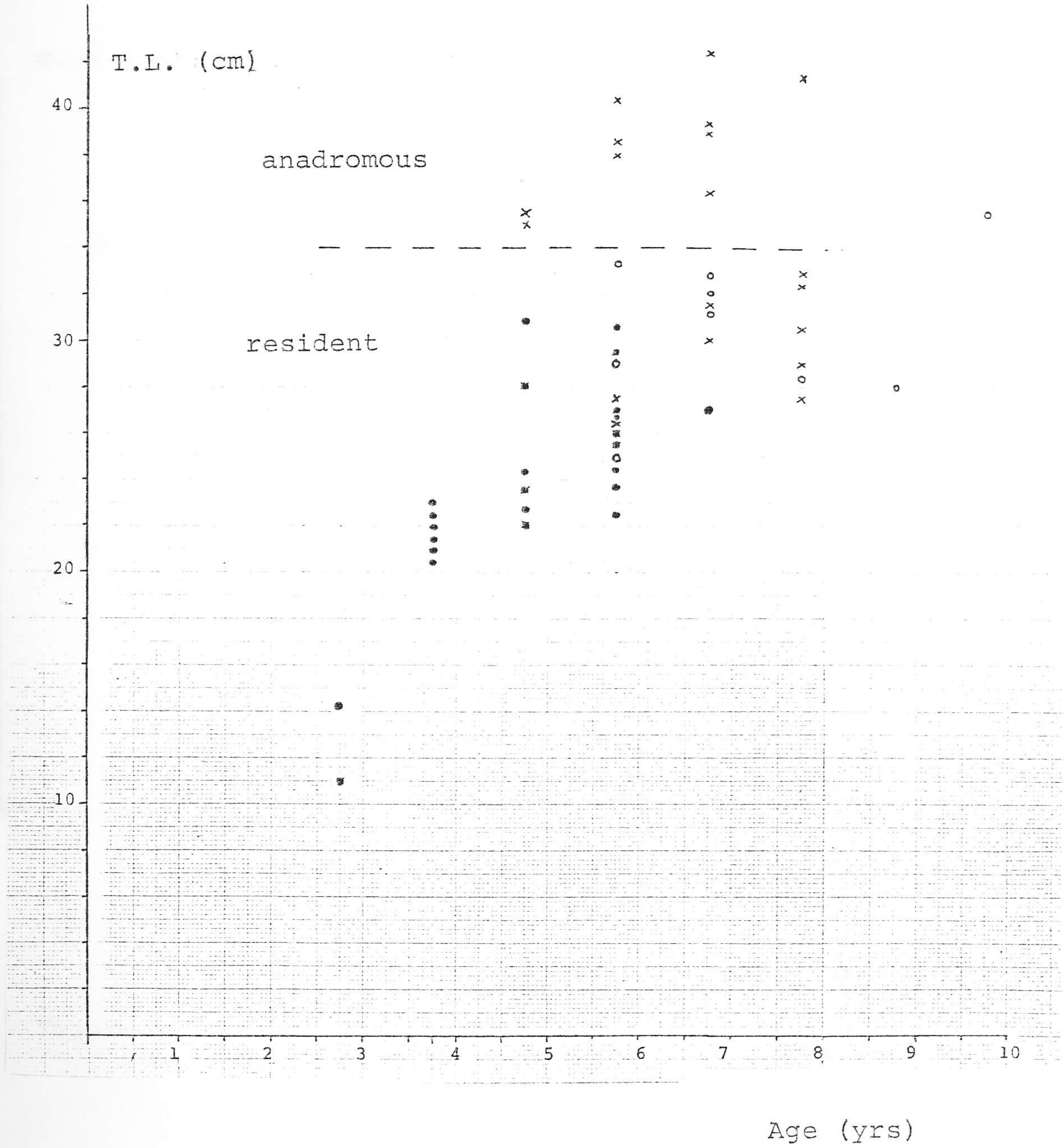

Figure 5b. Age-length data on arctic char from locality 5.
x = mature females
o = mature males
● = immatures

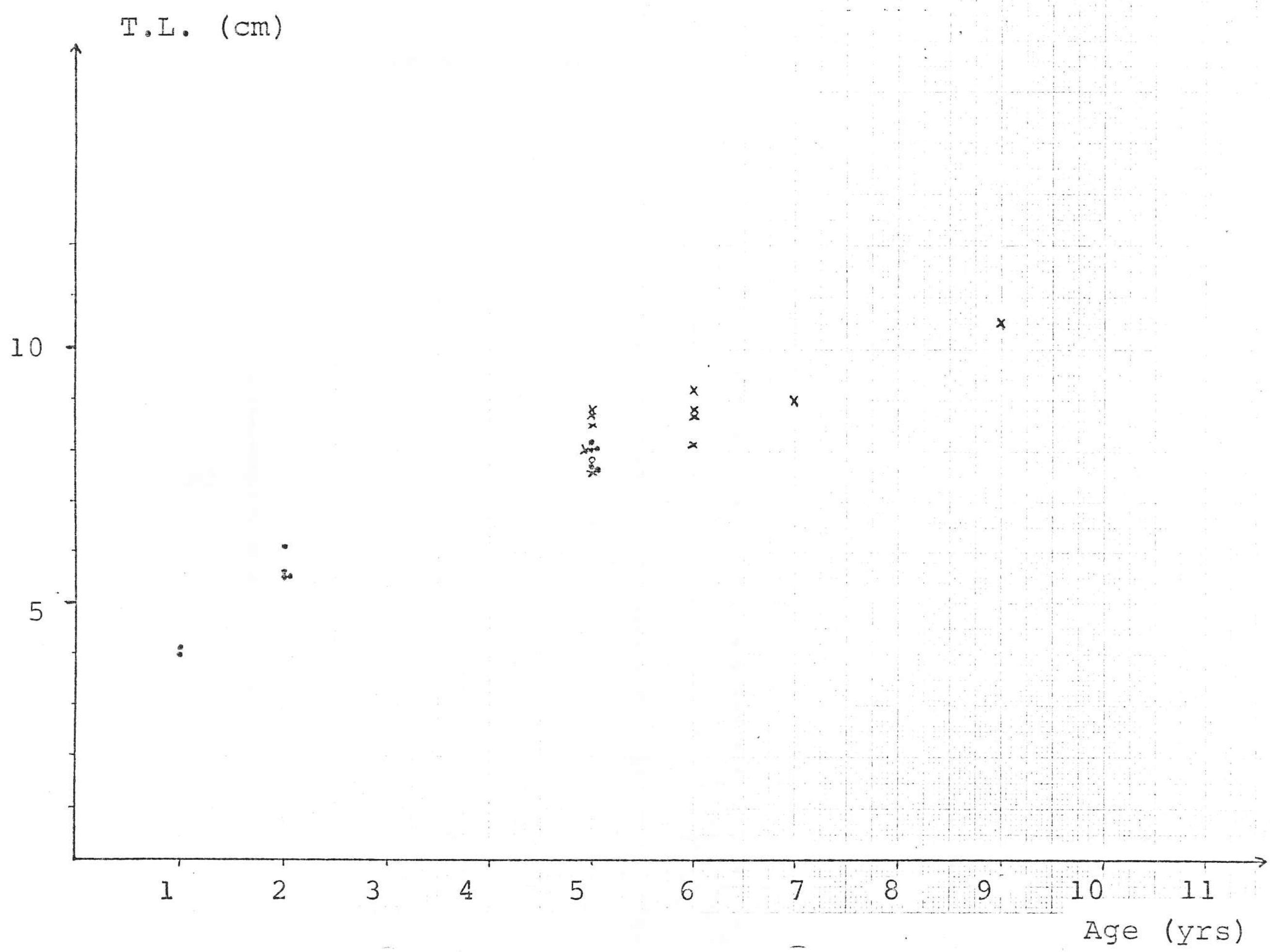

Figure 6. Age-length data on arctic char from a small pond, Bröndupollur, locality 6, 22/5 1985.
x = mature females
o = mature males
● = immatures

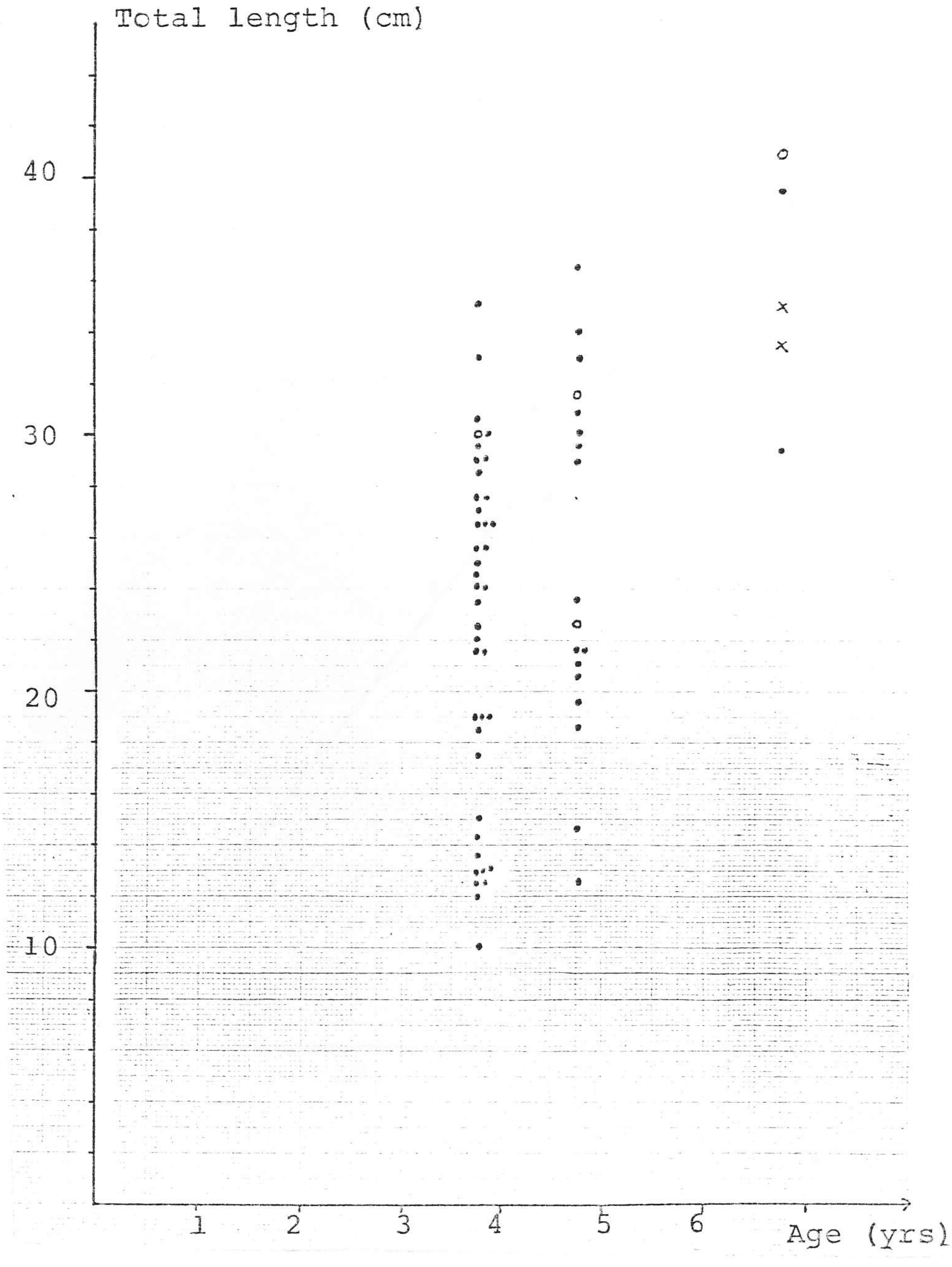

Figure 7. Age-length data on arctic char in Lake Eilifsvötn , locality 7, 2/9 1986.
x = mature females
o = mature males
• = immatures

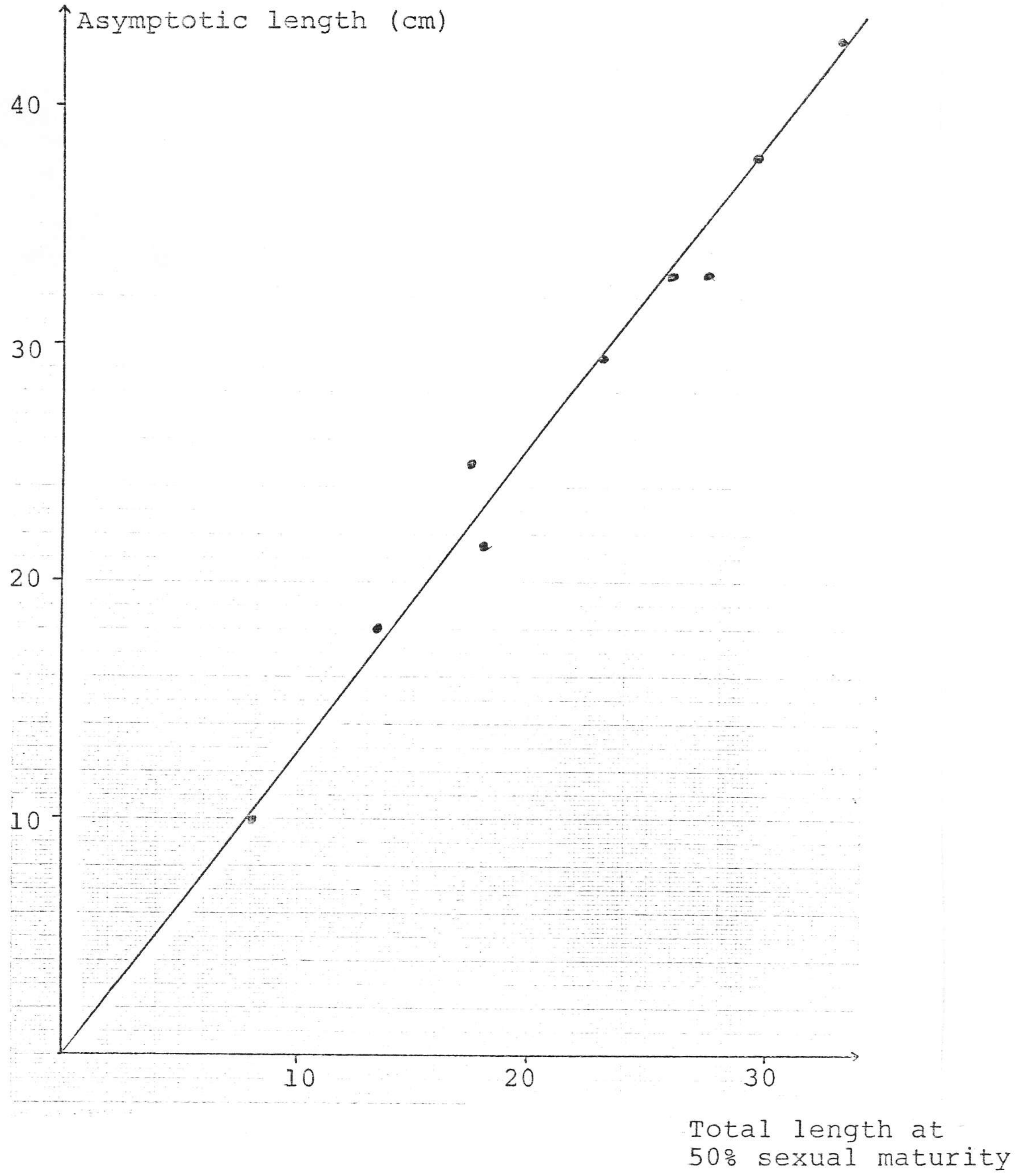

Figure 8. Relationship in size at sexual maturity and asymptotic length in arctic populations in north Iceland, localities 1 to 6.