National Energy Authority

Discussion on a Simulation Model for the Þjórsárver Area

by Laufey Hannesdóttir

Reykjavík
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1. Course.

A course on simulation modeling was held March 5-7 1973 in The University of Iceland, Reykjavík, conducted by Dr. G.M. Van Dyne from The United States. Others to take part were few biologists, engineers, a mathematician, geologist, meteorologist, and a hydrologist. An attempt was made to make a simulation model of the biological system of the Þjórsárver area in Iceland.

2. Þjórsárver Area.

The Þjórsárver area is situated in the mid highlands of Iceland, just south of the Hofsjökull glacier in the Þjórsá river basin. The Þjórsárver area is like an oasis, 120 km^2 of vegetated land, in the sands and glaciers that surround it. It is grazed in the summer by migrating geese (pink-footed), other birds and sheep. The vegetation consists mostly of mosses, sedges and shrubs. The area has not been used by man, except for sheep grazing until now that plans have been made for a hydroelectric reservoir that would inundate part of the Þjórsárver area.

3. Model in General.

The model is a simulation model for the biological system of the Þjórsárver area. The geese are selected for central flowing element as they are of high concern. The main objective of the model is to provide a framework for the biological system but also to measure the effect of man, to qualify already obtained research data, and to make suggestions for further research on the biological system. Other flowing elements are sheep, insects, predatory animals and five plant groups. A graphical representation of the model is shown on graph. 1. It is divided into two areas, Þjórsárver and Great Britain, because the geese migrate to Great Britain in the winter. The flowing elements come from an infinite source the flow being controlled by flowgates which in turn are controlled by driving variables and flowing elements. The flows end in a sink except the migrating geese. Abbreviations on the graph are the following:

Flowing Elements:

PG1	Plant Group 1 Palatable Herbs
PG2	Plant Group 2 Medium Woody
PG3	Plant Group 3 Medium Herbs
PG4	Plant Group 4 Unpalatable Woody
PG5	Plant Group 5 Unpalatable Herbs
IG1	Goslings in Þjórsárver
IG2	Non-breeding geese in Þjórsárver
IG3	Breeding geese in Þjórsárver
I	Insects in Þjórsárver
S	Sheep in Þjórsárver
Pred.	Predatory animals in Þjórsárver
GBG23	Breeding and non-breeding geese in Great Britain coming from Þjórsárver
GBG4	Other geese

Driving Variables:

climate: temperature, precipitation, snow cover, etc.

reser. elev.: elevation of hydroelectric reservoir

fertiliz.: fertilization of the open highlands by man

time: days of the year

hunt. G.B.: goose-hunters in Great Britain.

Below there are more detailed descriptions of the flowing elements.

4. Individual Flows

The biomass flow divided into the five plant groups can be treated as a whole. It is measured in gr/m^2, grammes of dry weight per meter square of area.

The flow-in is obtained by multiplying an initial biomass Bi (t) (by controlling factors or functions), where i stands for plant group i and t for time.

$$Bi = Bi(t) \quad Mi \cdot Ni \cdot Wi \cdot Ti(t) \cdot Gi$$

where Mi : maximum growth rate = 14/100 $\frac{gr/m^2/d \text{ growth}}{gr/m^2 \text{ biomass}}$,

Ni : nutrient factor : not defined,

Wi : waterlevel factor, flooding effect : function on graph (4),

Ti(t): temperature factor : function (t) on graph (2), and

Gi : Goose droppings : function on graph (3).

The flow out is found by the following function:

$$Bi = \sum_{j=1}^{5} [Nosj \cdot pcd \cdot wtj] + Bi(t) \cdot Ci$$

where the js are the five different herbivore groups [IG1, IG2, IG3, I and S],

Nos : numbers of herbivores,

pcd: proportional weight consumed per day, table 1,

wt: weight per individual herbivore, table 1,

Ci: cold killing factor, graph 5.

TABLE 1. - Grazing of Herbivores.

Herbivores		Plant groups 1	2	3	pcd $\left\{\frac{gr/m^2d}{gr/m^2}\right\}$	wt (kg)	average stocking (gr/m^2)
IG1		1	3	2	%=f(t)[2]	0.8	0.15
IG2	d≤180d	1	2	3	8%	2.3	0.05
IG3	d>180d[1]	1	3	2	8%	2.3	0.41
I		2			30%	$5x10^{-6}$	0.05
S		3	1	2	3%	< 50 ad.[3] 25 lam.	0.15
		preference table					

1) After the 180 day of the year adult geese prefer plant group 3 to plant group 2.

2) On 1st July goslings consume 17% kg weight
On 15th July goslings consume 12% kg weight
On 1st Aug. goslings consume 10% kg weight
On 15th Aug. goslings consume 8% kg weight

3) 1/3 of total sheep population is adult and
2/3 of total sheep population is lambs.

The total biomass in each plant group is not eaten;there is always some standing crop left that can be estimated as a certain percentage of total biomass.

The herbivores have preference for plant groups. For example, goslings, like plant group 1 most and eat it while available down to standing crop and turn then to plant groups 3 and 2, but anytime they find plant group 1, they take that. Plant groups 4 and 5 are not eaten by herbivores but they have importance as the other plant groups may change into them, perhaps by overgrazing. Sawflies only eat plant group 2 and sheep only plant groups 1, 2 and 3 (see table 1).

If G_j is the grammes needed per day for herbivore group j, this is compared to biomass of plant groups in preference order, where B_1 is biomass of plant group in first preference above standing crop, B_2 in second preference, etc. The diet would depend on the availability of biomass in the different plant groups. The calculation procedure could be as follows:

Preference	Check	Diet
1	$G_j < B_1$	(G_j of B_i)
2	$G_j > B_1$ $(G_j - B_1) < B_2$	
3	$G_j > B_1$ $(G_j - B_1) > B_2$ $(G_j - B_1 - B_2) < B_3$	(B_1 of B_1)+(B_2 of B_2)+(($G_j-B_1-B_2$) of B_3)

If B_3 is not enough to satisfy the last need the herbivores will migrate out or die.

This calculation procedure simplifies the actual grazing. It assumes, for example, that only one plant group is eaten at a time but actually the herbivores are eating the most abundant plant group most of the time but when they find a plant group of higher preference they take that.

<u>The herbivore flows</u> are measured in total number of herbivores in each group and have to be treated one by one as they are different for different herbivores.

The number of new goslings (IG1) is controlled by the number of eggs laid, and hatching success, which are in turn controlled by climate, reservoir elevation, predatory animals, number of breeding geese, eggs/par, and food biomass. That is,

$$IG1 = clim \times res.el. \times pred. \times IG3 \times eggs \times Bi$$

but the functions have not been defined exactly, except the eggs a/par function, graph 6.

The loss of goslings or flow-out is controlled by climate, predatory animals, time, nós geese and food biomass. The time enters the migration function, graph 10. The other functions are undefined. The migrating goslings now become breeders in Great Britain and belong to the total winter population (TWP) in G.B.

The flow of non-breeding geese and breeding geese is connected in a cycle, is a continuous flow.

The number of breeding geese arriving in Þjórsárver is a certain percentage of TWP, their arrival being controlled by a time function, graph 7 and their numbers by biomass. Breeders (IG3) can turn into non-breeders (IG2) in Þjórsárver according to the following rules:

> Death of one breeder --- one breeder to non-breeding population, 2% of breeders die in 60 days.
> Loss of one nest --- two breeders to non-breeding population, nós nests lost is a function of density, nós nests = (eggs laid/4.6).

The time distribution of transfer (breeders to non-breeders) is laged 20 days behind egglaying.

The number of non-breeding geese arriving in Þjórs-árver, like the breeders, is a percentage of TWP, their arrival being controlled by a time function graph 8 and their number by biomass.

The flow out of IG2 and IG3, migration to G.B., is a time function graph 10, but their loss in Þjórsárver is 2% of their total number in 60 days.

In G.B. all geese are considered as a whole, TWP. TWP is then IG1, IG2, IG3 and geese coming from other places than Þjórsárver, i.e. other places in Iceland, Greenland, etc. Some loss occurs to TWP by hunting in Scotland and by natural death (25%). Then a certain percentage of the remaining TWP migrates to Þjórsárver as described above.

The insect flow-in is probably only controlled by plant group 2, Graph 12, and the outflow by time of pupation, graph 11. Very little is known about other insects than sawflies and their behavior has to be estimated from that of the sawflies.

The sheep flow-in is a constant, 500 sheep are driven in to the area according to a time function. The outflow is time and climate dependent, the sheep go out of the area faster if the weather is bad, graph 9. The loss is 1% of total sheep population in 60 days.

The predatory animal flow is probably only controlled by number of goslings, their food. The ratio, number of breeding geese to number of predatory animals is constant except when the number of geese changes rapidly. The change of predatory animal numbers will follow behind perhaps lagged 2-3 years.

5. Driving Functions and Relations

The exact functions that show the relationship between a driving variable or a flowing element and a flowing element are not known in many cases but those that are known or some estimations there of are shown in graphs 2-12. Below is a list of functions only approximately known or unknown.

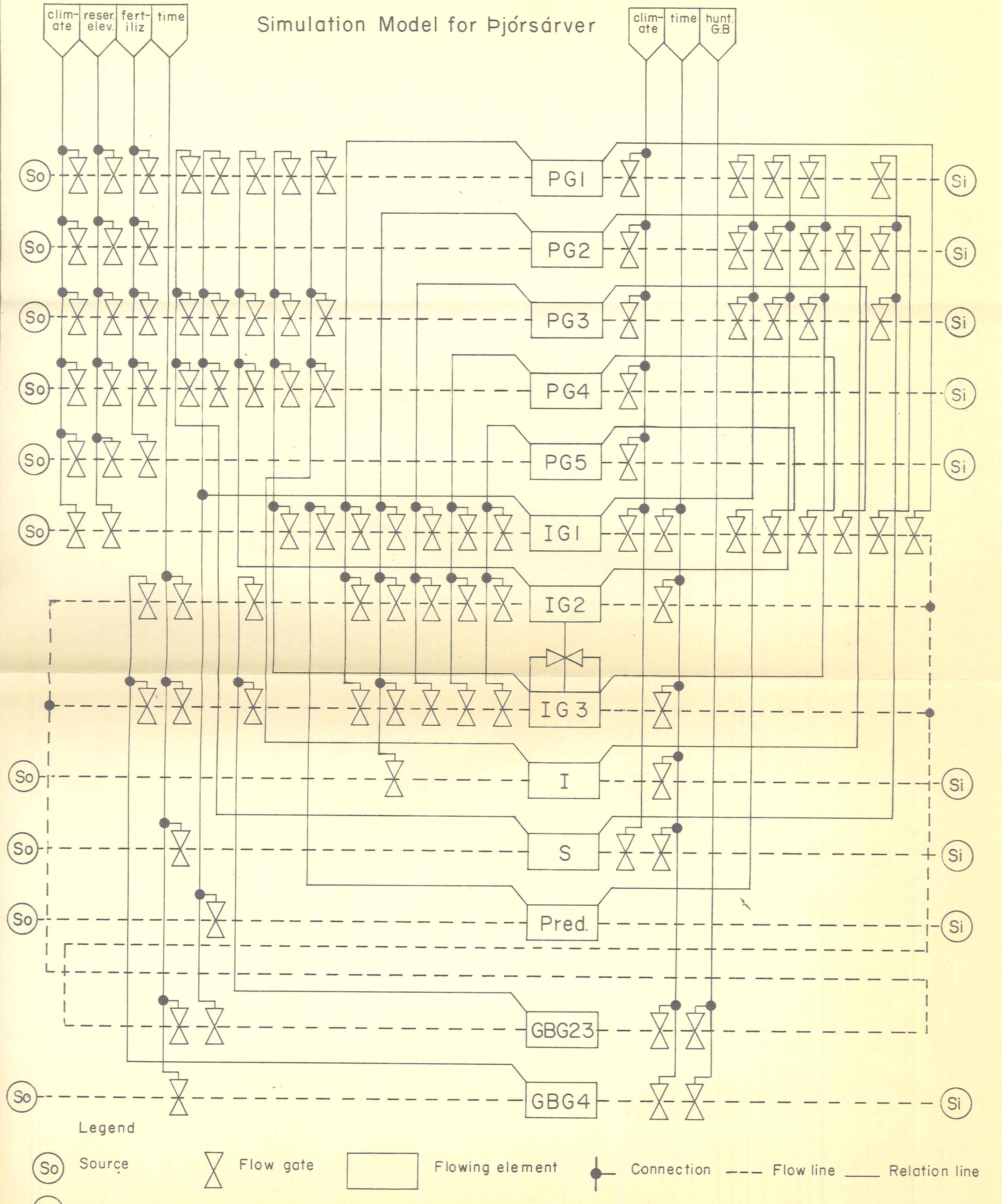
fertilizing factor,	i	=	f(fertilization) for each plant group,
water level factor,	i	=	f(water level in reservoir) for each plant group,
climate,	temp	=	f(days), known for Hveravellir,
hatching %,	i	=	f(no´s geese)
" ",	i	=	f(climate)=f(temp, precip, wind)
" ",	i	=	f(water level)
" ",	i	=	f(no´s predatory animals)
fledging %,	i	=	f(climate)=f(temp, precip, wind)
" ",	i	=	f(no´s geese)
" ",	i	=	f(no´s predatory animals)
killing of goslings,	no´s	=	f(food availability)
" " ",	no´s	=	f(climate)
" " ",	no´s	=	f(predatory animals)
killing of insects,	no´s	=	f(?)
Loss TWP,	no´s	=	f(nós hunters in G.B.)

There might be more functions that have to be estimated than here are listed in order to have the model running; these will be obvious when the model is worked on in more detail.

6. Limitations of Model

This simulation model is limited in many ways. It is a point model rather than a spatial model; the Þjórsárver area is taken as a whole so distributions within the area are not considered except the five plant group spacings. The quality of the food biomass dosn´t come forth except in the five plant groups, no nutration balance (phosphorus balance, etc.) but the food biomass is measured in gr/m^2 that is quantity. The vegetation in the model must never go to zero because the growthrate is taken as % of total vegetation. Estimations of initial flows have to be made, for example, April 1 each year.

Simulation Model for Þjórsárver



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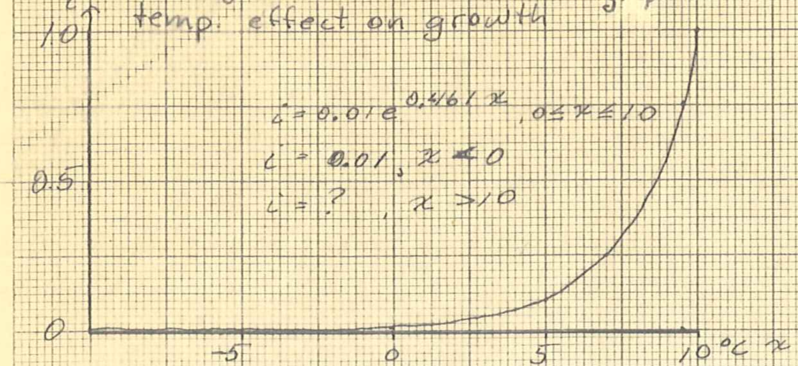
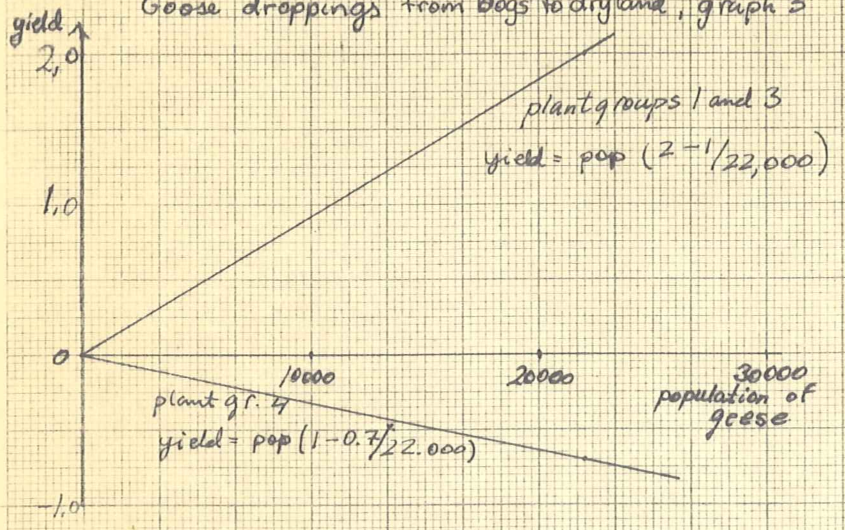
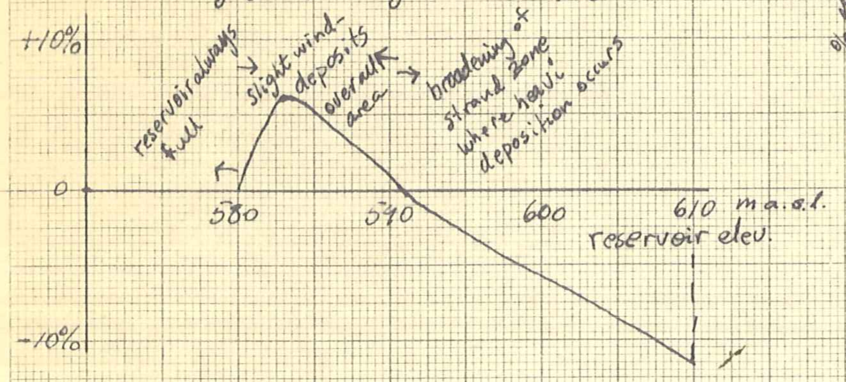


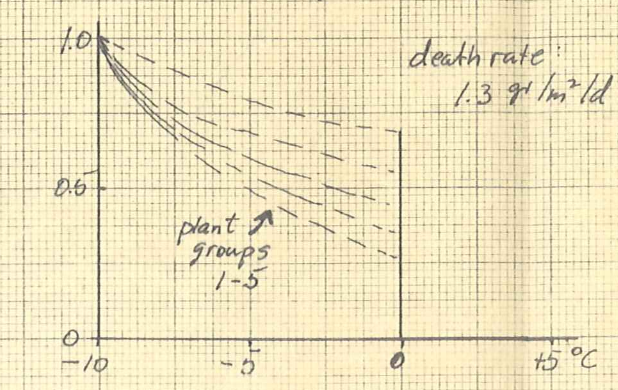
Driving variable, climate temp. effect on growth graph 2



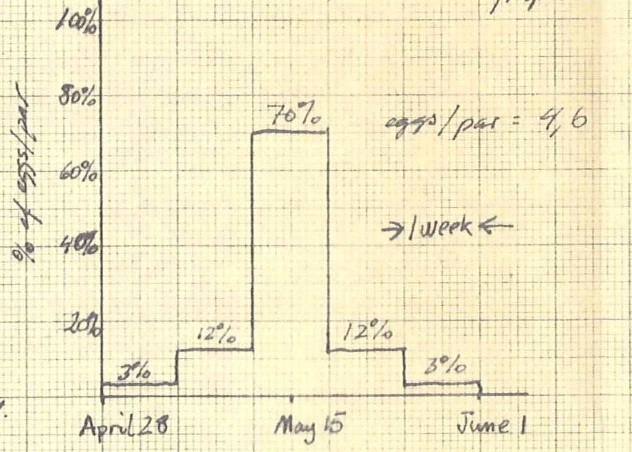
Goose droppings from bogs to dryland, graph 3



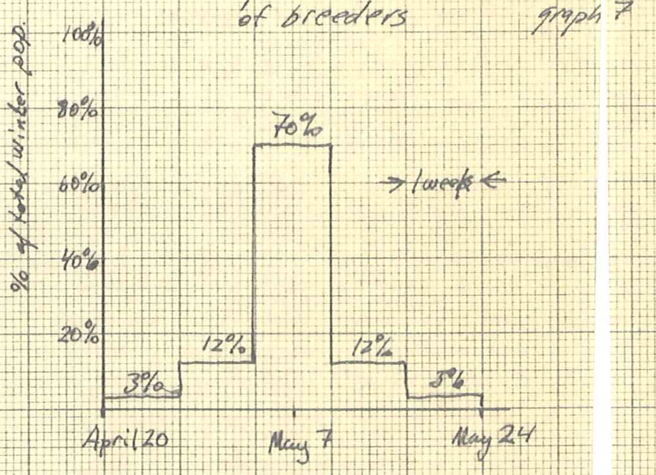
Deteriorating effect of wind deposits on growth in general, graph 4



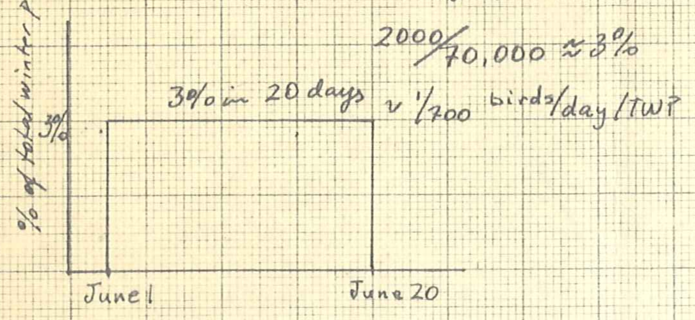
Cold killing effect on plant growth graph 5



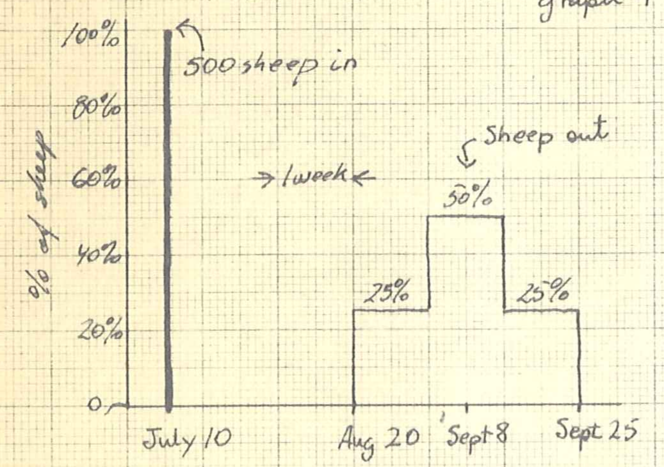
Egg laying, geese graph 6



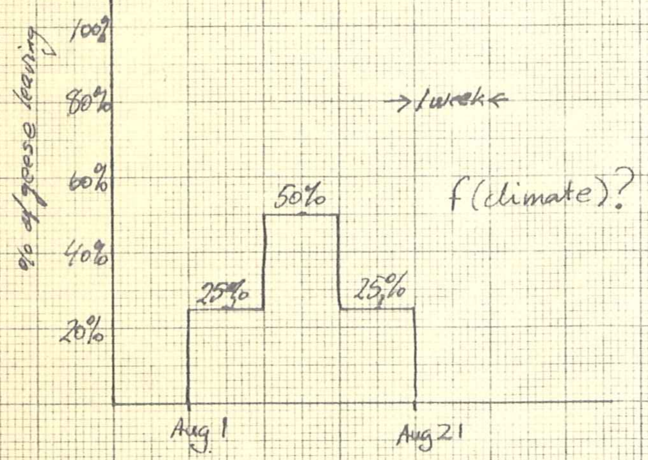
Migration to Þjórsárver of breeders graph 7



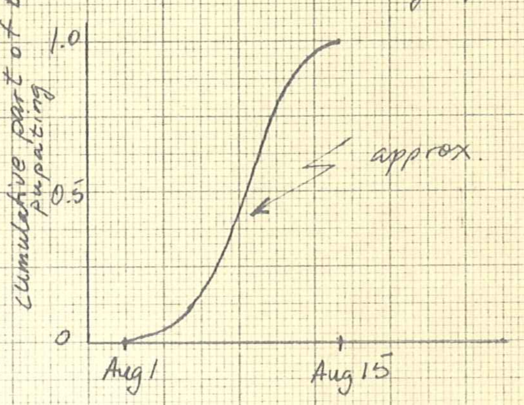
Migration to Þjórsárver of non breeders graph 8



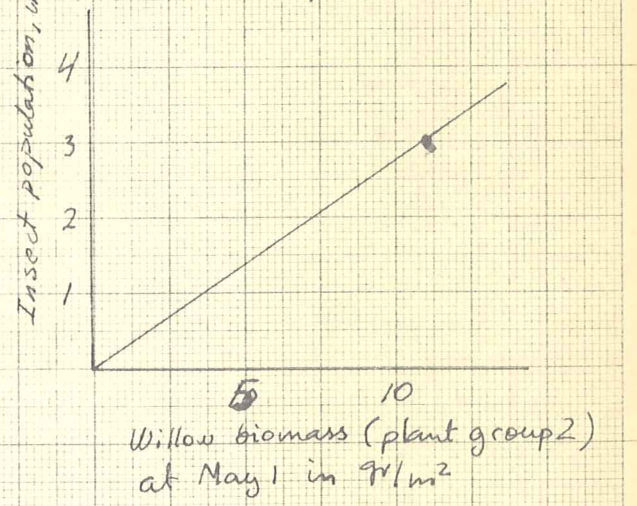
Migration of Sheep graph 9



Migration from Þjórsárver of geese graph 10



Insects pupating graph 11



Insect population

Other insect grazing factor on all vegetation $= 1.5 \times$ (willow grazing effect)?