Are advice adhered to? “Populist” versus “activist” or “systems analyst” advice.

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Abstract.

Laboratory experiments of decision making have revealed widespread misperceptions of nonlinear dynamic systems. A possible criticism of these experiments is that participants do not get the concrete policy advice they may receive in real situations. Here we repeat a previous experiment where we add two conflicting advice. A “populist” advice reflects typical misperceptions while a second and competing advice represents a near-to-optimal policy. The latter advice is in the wording of an “activist” in Treatment 1 and in the wording of a “systems analyst” in Treatment 2. The results suggest that concrete advice have some, however modest effects in complex systems. Strong allegations by an “activist” outperform stock and flow arguments by a “systems analyst”. Improper mental models of the system remain a major problem.

Keywords: expert advice, misperceptions, dynamics, system dynamics, renewable resources, heuristics, management

1. Introduction

Laboratory experiments of decision making have revealed widespread misperceptions of nonlinear dynamic systems (Brehmer, 1992; Funke, 1991; Moxnes, 1998a; Moxnes, 1998b; Moxnes, 2004 ; Sterman, 1989a, b). Typically these experiments provide participants with background information and then leave data analysis and decisions to the participants themselves. Different from many real decisions, they do not receive advice from experts. Our first question asks if it is a problem that most laboratory experiments do not include policy advice? In other words, will advice remove the effects of misperceptions? Second, does it matter how advice is worded and argued for? Third, will advice bring decisions in the direction of optimal solutions? Fourth, will advice lead to less spread in decisions or to polarization? Fifth, will the effect of advice vary with subject background? To investigate these questions we repeat an earlier experiment where we in addition to the original information include policy advice. The experiment is one of renewable resources management (Moxnes, 2004).

A possible criticism of previous experiments is that subjects are not availed with decision advice. A simple argument is that if the experimenter is able to find an optimal or near-to-optimal policy, others could be able to do the same and could give perfect advice. However, a laboratory experiment where the correct answers are provided would seem silly and lead subjects to question the purpose of the experiment. Some would follow the advice and others would not for reasons other than domain knowledge. A more realistic setting is to provide decision makers with conflicting advice. Similar to real decisions, experts or opinion leaders often give diverging advice on policy. This has certainly been the case for reindeer herding.[1]

Here we provide all subjects with both a near-to-optimal advice and an advice built on misperceptions. Here we refer to the latter as the “populist” advice. The near-to-optimal advice is either given in the wording of an “activist” in treatment T1 or a “systems analyst” in T2. Instructions to subjects used the term “expert” for all advisors.

The advice given here is different from information given in earlier studies. Here, advice say what decisions subjects should make. Previous experiments have given information to help the construction of appropriate mental models and to help subjects predict behaviour and consequences of policy interventions. The last step of figuring out the best decisions has been left to the participants. Many brief information interventions of this type have shown poor results (Moxnes, 1998b; Moxnes and Jensen, in press; Moxnes and Saysel, 2009). This may not be the case for long-lasting interventions such as group model building (Cavaleri and Sterman, 1997; Huz et al., 1997), partly because of the time spent and partly because policy advice may be given and discussed during modelling sessions. Focus here is on brief interventions that are feasible in short meetings or political debates.

Our underlying hypothesis builds on the idea that people are not likely to follow advice that are not consistent with or change own mental models. In other words, a responsible decision maker would be reluctant to follow advice that she does not believe in. Regarding advice from optimization models (Walters, 1986) comments: “...it would be

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[1] I know from debates in Norway that experts (researchers) have presented very different policy recommendations. Experience from St. Paul in Alaska shows that overshoot and collapse can happen in spite of available expert advice (from researchers and Inuit herders). Experts may be wrong and they may not be listened to.

silly to expect any real decision maker or manager to blindly plug numbers into such a function [policy linking state variables and decisions]...”.

Our main finding is that concrete and conflicting advice has limited effects on decisions. However, in both treatments results improve compared to the reference case without advice. Advice also tend to produce a wider distribution of responses.

In Section 2 we present experimental design and hypotheses. Section 3 shows results and Section 4 contains a discussion. An appendix shows the common introduction to all treatments including the reference case.

2. The experimental design

2.1. The common task

The task faced by the subjects is one of managing a renewable resource; a reindeer rangeland. They start out in a situation of overgrazing by the previous owner. The goal is to achieve the maximum sustainable yield as soon as possible.[2] As an incentive to do well, participants were told that those who did best in each treatment would receive a symbolic prize (Bolle, 1990). The task is identical to the task used in (Moxnes, 2004), where more details can be found.

The most important dynamic factor for reindeer management is lichen, the plant providing the main source of winter fodder. Figure 1 shows how the stock of *Lichen* is increased by *Growth* (total growth minus decay) and reduced by *Grazing*. *Grazing* in turn depends on a parameter for *Grazing_per_animal* and the *Herd_size*. The *Herd_size* is the decision variable, to be set once each year. The subjects are told that the herd size can be varied freely (as if animals can be sold and bought in a market). *Growth* depends on the stock of *Lichen* as described by the causal link in Figure 2.

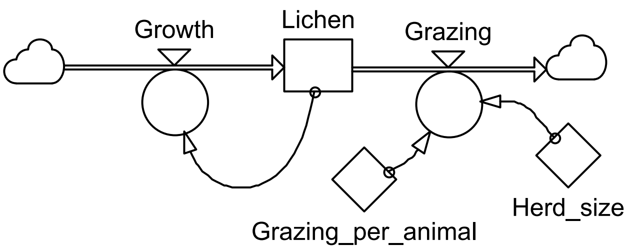

Figure 1: The stock and flow structure of the task

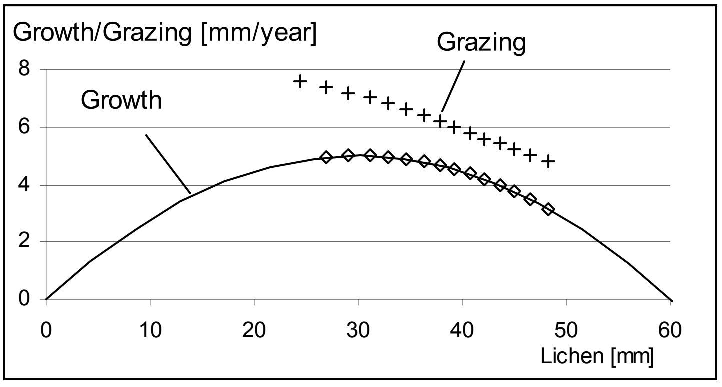

Figure 2: Growth curve with calculated data points. The + signs denote historical grazing rates.

Figure 3 shows the PC screen for the initial year. Information about the year, last year herd size and lichen thickness is shown with numbers and graphs over time. Decisions are entered in the rectangle for *Desired herd size next year*.

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[2] Alternatively one could have used a present value or some utility criterion. The chosen criterion simplifies the task and is not very different from the alternative criteria.

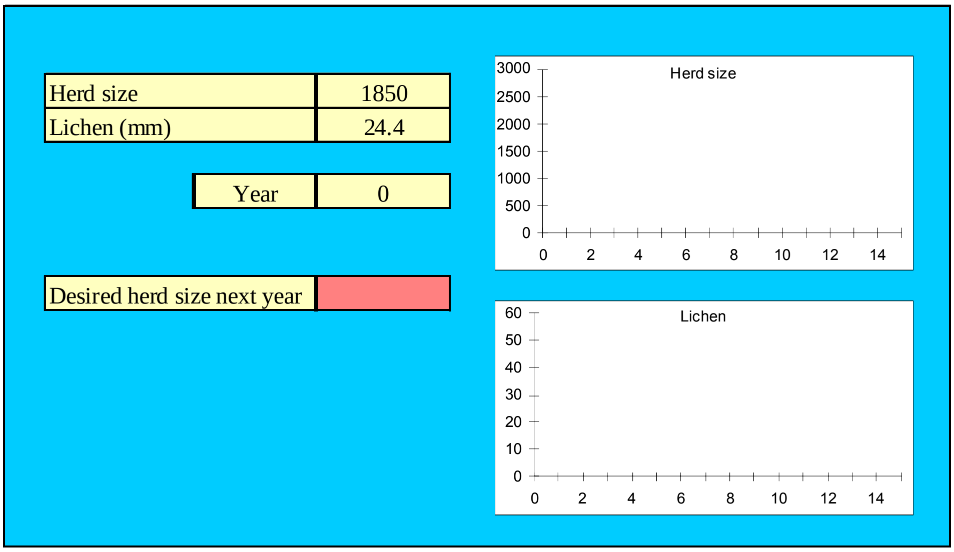

Figure 3: PC screen

Subjects do not get to see Figures 1 and 2. Rather they get verbal descriptions of the system, see Appendix. They get to know the value of the parameter *Grazing per animal* (0.004 mm/year), and they are availed with time-series data for herd size and lichen thickness (time table and time graph). These data are sufficient to calculate the data points in Figure 2 and to estimate the growth curve. From previous experiments we know that very few, if any, of the subjects will do this.

Figure 2 shows that maximum growth (5 mm/year) takes place at a lichen thickness of 30 mm, which is higher than the initial lichen thickness of 24.4 mm. The maximum growth can feed 1250 animals, which is considerably below the initial herd size of 1850 animals.

Our “populist” advice is to keep the herd size at its initial level. This will lead to an accelerating decline in lichen. If this advice is followed, outcome feedback over the first few years should cause subjects to give up on the “populist” advice. Our “activist” and “system analyst” advice, which are the same, build on the optimal policy which is to reduce the herd size to zero in the first year and increase the herd to 1056 animals in the second year. The maximum sustainable herd size will then be reached in the third year.

Importantly, each subject was granted private property rights to his or her lichen pasture and herd. Thus, the commons problem was ruled out by the design.

2.2. Hypotheses

The experiment should be seen as exploratory with no prior theory to be tested. Mainly we explore the quantitative effect of presenting optimal advice that deviates radically from status quo and from the “populist” advice. If optimal advice have strong effects, future research on decision making should consider carefully if and how advice is given. If the effects are minor, future research should consider why this is so and how advice could be made more effective. In the following we discuss possible outcomes of the experiment in light of subject mental models. We distinguish between early decisions (first couple of years) and decisions after considerable outcome feedback has been received.

Before we begin the discussion, note that the given arguments for all three advice are all imperfect, see the following sections. This is obviously so for the misleading “populist” advice, but it is also true for the “activist” and even for the “systems analyst” advice. In all cases the advice are for the near term and focus on moving the system in the right direction, without being explicit on what the final goal is. This seems to be an appropriate description for many real world advice as well. Also note that subjects were not told that one of the advice represented the optimal policy. Thus, for the participants, both policies could be misleading. Again, this should be an appropriate representation of real advice.

For the first few decisions, it is likely that subjects' mental models will dominate decisions and how the subjects interpret and make use of the advice. From previous research two different mental models seem to dominate (Moxnes, 1998b, 2004). First, many have a mental model where there is a negatively sloped and instantaneous relationship between grazing and lichen. Hence, if the herd size and grazing is kept constant, lichen will also stay constant. In this case the "populist" advice would appear appropriate, and the optimal advice will look disastrous.

Second, many subjects notice the instruction saying that that lichen growth peaks somewhere between zero and 60 mm lichen thickness. A small or nonexistent subgroup calculates where maximum growth is located and knows that grazing has to be brought below growth. The optimal advice would confirm their analysis, but may seem overly drastic. The majority will not know where the maximum is located. If they suspect that it is to the left of the initial lichen thickness (24.4 mm) and with maximum growth exceeding initial grazing, the "populist" advice would seem reasonable. If they suspect that it is to the right, the optimal advice would seem reasonable, although drastic. Since most subjects are likely to be uncertain about the location, and none of the advice says where it is, they are likely to be more influenced by the wording of the advice than the content. They are also likely to be influenced by both advice, perhaps anchoring on one and adjusting for the other. Taking the average of the advice is one concrete possibility (800 animals).

After outcome feedback has been received, the situation changes for all those that have kept high herd sizes. Lichen declines steadily and the “populist” advice seems less and less appropriate. Thus for all those that start out with high initial herd sizes, one should expect that availability of the optimal advice should lead to more rapid reductions in herd sizes than in treatments without such an advice.

The following two sections present the wording of the advice. We do not form any hypothesis about expected results. In Section 2.5 we present the subject groups. Most interesting is to see if the “systems analyst” advice works better for students with a short introduction to stock and flow diagrams and graphical integration.

2.3. Treatment T1 - advice from “populist” and “activist”

In T1 subjects get advice from both a “populist” and from an “activist”, in the introductions referred to as Expert 1 and Expert 2. The “populist” gives an advice that is far from optimal and which builds on misperceptions. The “activist’s” concrete advice is the optimal policy.

The “populist” is positive about the decisions made by the previous owner, claims that the current situation is sustainable, and uses uncertainty to justify inaction. The “populist” gives the following advice:

“The previous owner has built up the herd size carefully over the historic period. The data shows that the herd size has been increased to the current level without serious problems for the lichen and for the reindeer. Thus, drastic reductions in the herd size are not called for and would only bring the herd much below the sustainable level. In

light of the considerable uncertainty about what adjustments are needed, a very careful trial-and-error approach should be applied when making adjustments in the herd size.
Concrete first advice: In the first few years the herd size should be kept at 1800 animals, then one should observe the development before possible further adjustments to reach the maximum sustainable herd are considered."

The "activist" blames the previous owner, claims overutilization of the renewable resource only by reference to experiences elsewhere, and explains historical behaviour by greed and lack of regulation. The "activist" gives this advice:

"The previous owner has followed an irresponsible policy of overgrazing. This is yet another example of the overutilization of renewable resources that have been observed so often around the world. The reason for the overgrazing is that the owner has been greedy and that the government lacks a firm policy to regulate the use of natural, renewable resources. The only sensible thing to do now is to reduce the herd size drastically, both to protect the natural environment and to ensure the sustainable operation of the reindeer business.
Concrete first advice: Reduce the herd size to zero in the first year, then gradually increase the herd size as the amount of lichen grows towards the level that yields the maximum lichen growth."

2.4. Treatment T2 - advice from "populist" and "systems analyst"

In T2 subjects get advice from the same "populist" as in T1 and from a "systems analyst", who give the same optimal advice as the "activist". The "systems analyst" argues from a stock and flow perspective. He explains historical decline in lichen by grazing exceeding growth. To reverse the decline, grazing must be made lower than growth and to stabilize, the rates must be equalized. He gives this advice:

“Since the amount of lichen has decreased steadily under the previous owner, removal by reindeer grazing must have been greater than the natural growth of lichen in all previous years. Thus, in year zero in the historic period, the lichen growth rate must have been smaller than what is needed to feed 1150 animals. To increase the amount of lichen to a level that gives the maximum lichen growth, grazing must be reduced below the current growth rate for a while, then increased towards the growth rate again to stabilize the amount of lichen around the maximum sustainable level.
Concrete first advice: Reduce the herd size to zero in the first year, then gradually increase the herd size as the amount of lichen grows towards the level that yields the maximum lichen growth.”

2.5. Groups, subjects, and design details

For treatments T1 and T2, subjects were recruited from three different groups.
- G1 were military personnel taking a logistics course with no prior knowledge of System Dynamics (September 1 2004, N_{T1}=21, N_{T2}=21).
- G2 were students with varied backgrounds entering the Master’s program in System Dynamics at the University of Bergen. They participated in the experiment on the first day of lectures (August 24 2004 and August 25 2005, N_{T1}=12, N_{T2}=13).
- G3 had the same type students as in G2, however, they participated in the experiment after 9 to 15 hours of introductions to stocks and flows (stock and flow diagrams and graphical integration) and first order linear feedback (September 13 2006, August 27 2007, and September 1 2008, N_{T1}=31, N_{T2}=36).

-G0 had the same type of students as in G2. These were the students that participated in (Moxnes, 2004). We include these data as a reference for the case with no advice (September 3 2002 and September 2 2003, N_{T0}=33).

Subjects were randomly assigned to treatments and placed at separate PCs with no communication allowed between them.

The experiment was programmed in Excel and was identical for all groups and treatments.[3] All data (decisions about herd sizes and lichen thicknesses) were recorded in the Excel program.

3 T1 is written in Excel and is available from http://www.ifi.uib.no/staff/erling/publications.htm.

3. Results

To get an overview of the results we look at average developments of herd sizes and lichen thicknesses. The upper panel in Figure 4 shows time developments for average herd sizes for all groups with T1 (”activist” advice) as well as the reference T0 (no advice). In the first few years all average herds are considerably lower than the ”populist” advice of 1800 animals and also lower than the average herd observed in T0. Still, average herds are much higher than the ”activist” advice of zero animals (optimal). In the long run, the groups that have the highest early herd sizes end up with the lowest ones.

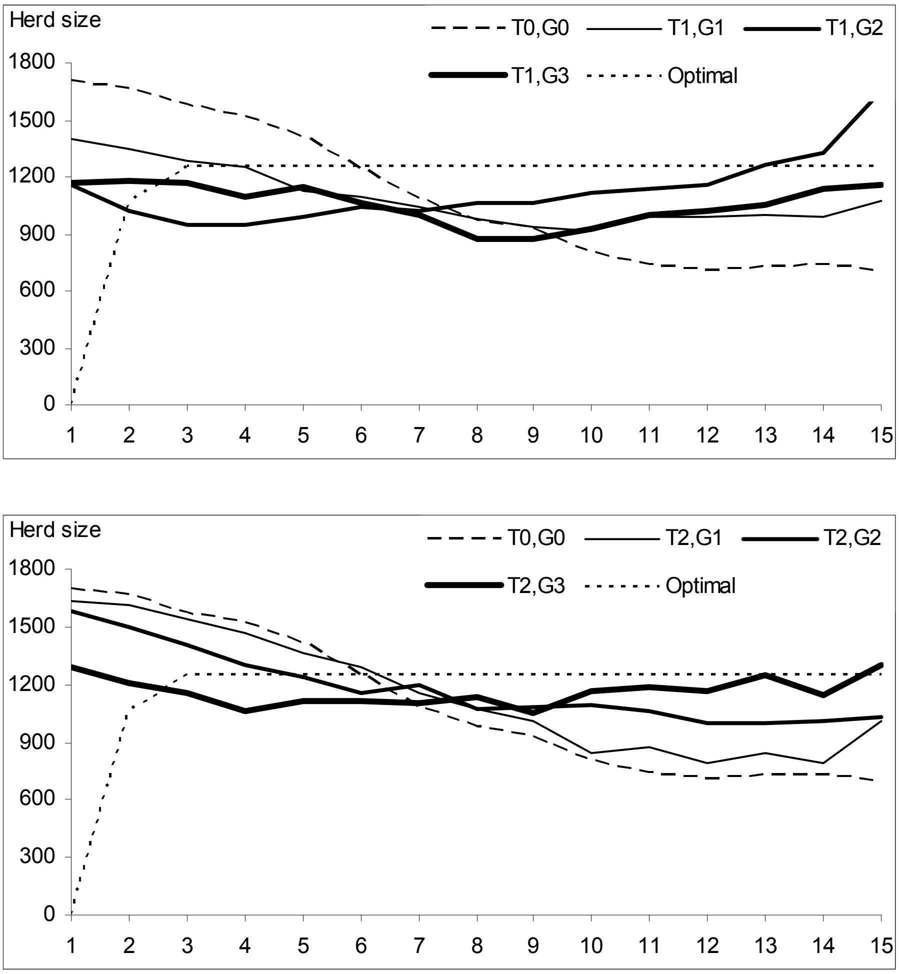

Figure 4: Average herd sizes for groups and treatments

The lower panel in Figure 4 shows average herd sizes for all groups with T2 (“systems analyst” advice) and for T0. In this case it is predominantly group G3 (stock and flow and first order system introduction) that benefits from the “systems analyst” advice. Again, in the long run, rankings are reversed compared to the early year rankings.

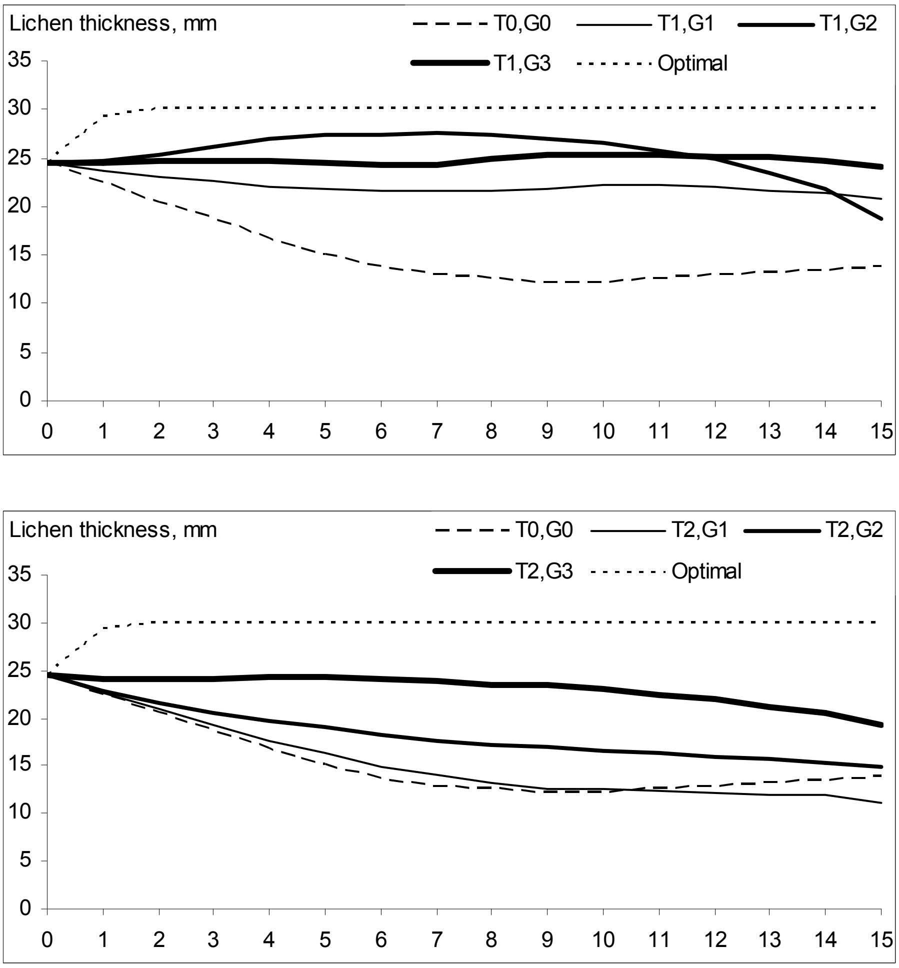

Figure 5: Average lichen thicknesses for groups and treatments

The upper panel of Figure 5 shows time developments for average lichen thicknesses for all groups with T1 and for T0. Lichen thicknesses end up between the optimal lichen thickness and that observed in T0. The ”populist” advice would have led to even lower lichen thicknesses than in T0. The lower panel with averages for all T2 groups shows that for groups G1 and G2, the results are not much better than in T0. For both treatments we see that high initial herd sizes lead to low lichen thicknesses and vice versa.

For statistical testing of effects of advice before much outcome feedback is received, we use first year herd sizes, $Herd_0$. Figure 4 shows that rankings between groups do not change over the first few years such that the first year is also quite representative of the following early years.

For longer term effects of advice, we use lichen thicknesses in year 10, $Lichen_{10}$. Using year 10 rather than the final year, we avoid a certain end game effect for a few subjects. Although the instructions say “--you should aim for the highest possible herd size that can last for ever without destroying the lichen pasture” some subjects increased herds towards the end and brought lichen below the optimal level.

All individual $Herd_0$ values fall in the range from zero (optimal) and 1800 animals (”populist” advice). Table 1 shows averages for $Herd_0$ and $Lichen_{10}$. Only the $Herd_0$ average for T0 is not significantly different from 1800 animals at the 5-percent level. All individual $Lichen_{10}$ values fall in the range from zero (”populist” with no correction after feedback) and 55 mm. Only average values in G2 and G3 for T1 are not significantly different from 30 mm (optimal).

Table 1: Average $Herd_0$ and $Lichen_{10}$.

	Herd$_0$			Lichen$_{10}$ [mm]		
	T0	T1	T2	T0	T1	T2
G0	1701#			12		
G1		1398	1635		22	13
G2		1156	1582		27*	17
G3		1166	1294		25*	23
G1,G2,G3		1240	1450		25	19

All $Herd_0$ values significantly higher than optimal values and lower than 1800 (”populist” advice) with one exception (#); t-tests at 5-percent level.
All $Lichen_{10}$ values significantly greater than zero (”populist” advice with neglect of feedback) and lower than the optimal values with two exceptions (*); t-tests at 5-percent level.

Table 2 summarizes tests of differences between treatments and groups. First we note that when we pool all groups with advice, there are significant differences between the reference T0 and both T1 and T2. In both treatments advice lead to better management with lower $Herd_0$ and higher $Lichen_{10}$. When pooling G1, G2, and G3, we find a significance difference between T1 and T2; ”activist” advice lead to better results than “systems analyst” advice. Comparing T1 and T2 for individual groups we find a significant difference only for $Lichen_{10}$ in G1.

Table 2: Results of comparisons, independent samples t-tests at 5-percent level.

Data	Herd$_0$	Lichen$_{10}$ [mm]
G0,G1,G2,G3	T0≠T1, T0≠T2	T0≠T1. T0≠T2
G1,G2,G3	T1≠T2	T1≠T2
G1	T1=T2	T1≠T2
G2	T1=T2	T1=T2
G3	T1=T2	T1=T2
T1	G1=G2=G3	G1=G2=G3
T2	G1=G2, G1≠G3, G2=G3	G1=G2, G1≠G3, G2=G3

Then we look for differences between groups. In T1 there are no significant differences between groups. In T2, there is a significant difference between G1 and G3, while G2 and G3 are only different at the 10-percent level. This suggests that students with a certain background in stock and flow thinking benefit more from “systems analyst” advice than others. Still G3 are not doing better with T2 than with T1.

As a last test of differences between treatments, we compare herd size developments after outcome feedback has been received for the three treatments. However, this time we consider only those individuals that have $Herd_0$ values of 1700 animals or higher. This group is likely to consist of subjects that either trust the “populist” advice or have mental models predicting that the optimal lichen thickness is lower than the initial. Figure 6 shows that outcome feedback has a stronger negative effect on herd sizes when subjects are availed with optimal advice. However, the effect is quite small, and it is probably not statistically significant when herd size observations are seen as dependent.

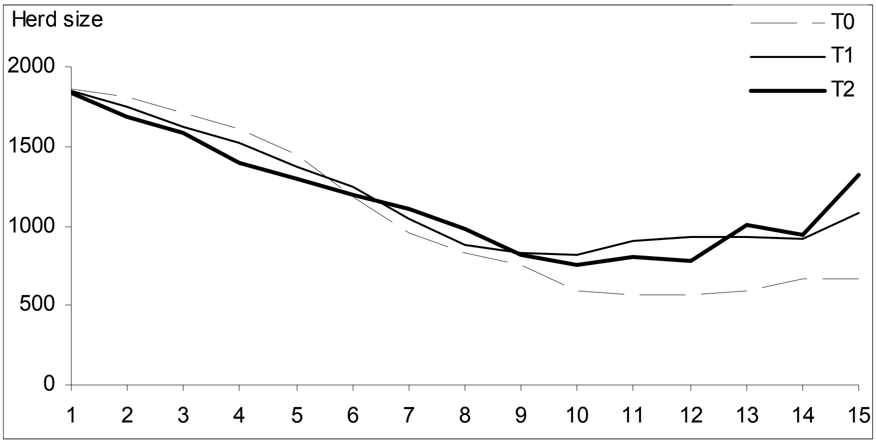

Figure 6: Herd size developments for pooled treatment observations for subjects with $Herd_0$ values of 1700 or higher.

Then we consider the effects of advice on the distribution of $Herd_0$ and $Lichen_{10}$, see histograms in Figure 7. As an overall observation we see that advice lead to greater spread and polarization. While the distribution is highly skewed for $Herd_0$ in T0, it is much more evenly spread in T1 and T2. For both T1 and T2 we see that some subjects follow the exact optimal advice and reduce the herd to zero (8 percent for pooled T1 and T2). For both T1 and T2 there is also a certain tendency that subjects cluster around the average advice of 900 animals. For pooled T1 and T2, there are 29 percent more responses in the range from 1 to 1400 animals than in T0. Still dominant however, is the tendency to cluster around the “populist” advice, that is with similar herds to those set with no advice.

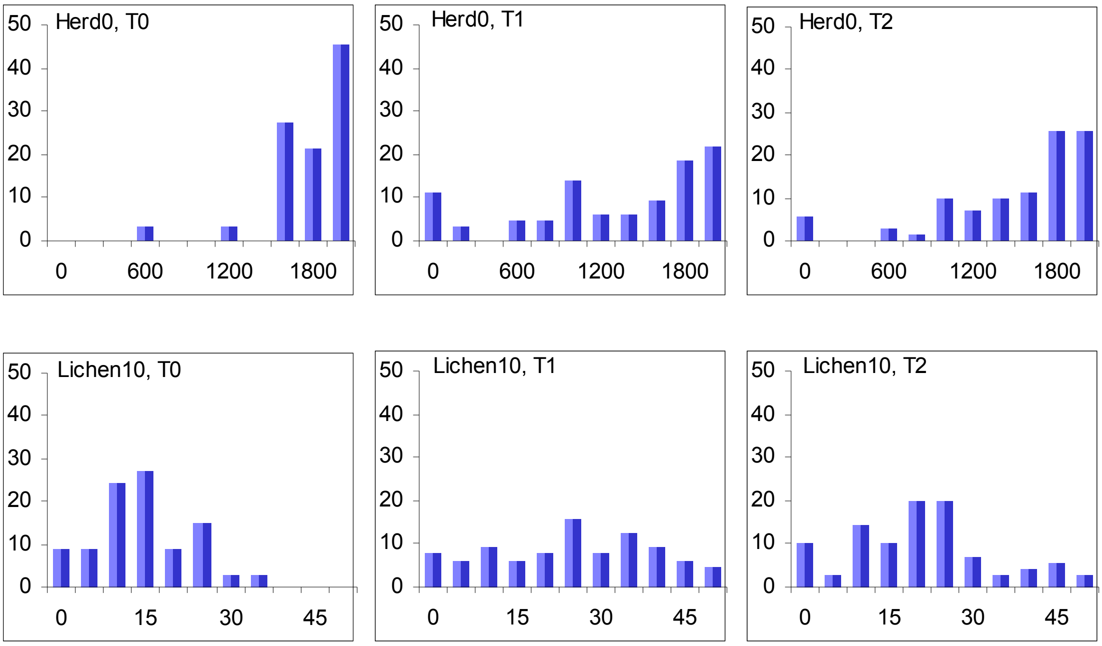

Figure 6: Histograms [%] for Herd$_0$ and for Lichen$_{10}$ (lowest category is for zero only)

Lichen$_{10}$ values show the same frequency of lichen depletion (zero thickness) irrespective of advice or no advice. This may suggest that some individuals never consider the optimal advice no matter what outcome feedback they receive. We cannot tell if this is because they are dominated by prior mental models or did not pay careful attention to the instructions. The distributions for Lichen$_{10}$ are largely consistent with the distributions for Her$_0$, since advice seems to have only minor effects on the use of outcome feedback as indicated in Figure 6. For pooled T1 and T2, there are 29 percent fewer observations of Lichen$_{10}$ below 25 mm (close to the initial thickness of 24.4

mm). Fairly high frequencies of $Lichen_{10}$ exceeding the optimal level, suggest that advice is also needed regarding the location of maximum growth.

Finally, we perform statistical tests of the spread of responses. Table 2 shows standard deviations for $Herd_0$ and $Lichen_{10}$. Significant differences at the 5-percent level are found by Levene's test for equality of variances. We observe that the variance in the reference case T0 is significantly lower than that for pooled results of G1, G2 and G3 for both T1 and T2, for both $Herd_0$ and $Lichen_{10}$, with the exception of T0 versus T2 for $Lichen_{10}$. For $Herd_0$, T1 produces larger standard deviations than T2 in G1, G2, and pooled G1, G2 and G3. For $Lichen_{10}$, T1 produces larger deviations than T2 in G3 and pooled G1, G2 and G3. Hence the general tendency is that “activist” advice leads to a greater spread than “systems analyst” advice, which in turn leads to greater spread than no advice.

Table 2: Standard deviations for $Herd_0$ and $Lichen_{10}$.

	$Herd_0$			$Lichen_{10}$ [mm]		
	T0	T1	T2	T0	T1	T2
G0	$289^{T1,T2}$			8^{T1}		
G1		$517^{T2,G2}$	$345^{T1,G3}$		15	10
G2		$775^{T2,G1}$	350^{T1}		15	12
G3		671	597^{G1}		17^{T2}	12^{T1}
G1,G2,G3		$645^{T0,T2}$	$513^{T0,T1}$		$16^{T0,T2}$	12^{T1}

Levene’s test 5-percent level: Ti and Gj denote differences from respectively treatment *i* and group *j*.

4. Discussion

The results show that even conflicting advice lead to improved performance. Compared to the case with no advice, eight percent more than zero percent follow the exact optimal advice regarding first year herd size, 29 percent more than 6 percent cluster around the average of the two advice, while the remaining 56 percent seem unaffected by the advice. Consistent with these results, conflicting advice lead to wider distributions of responses. The effect of advice after the first few years, when considerable outcome feedback had been received, is at best weak.

The average of the two advice is biased in the direction of improvement, which, hopefully, represents a general tendency for average expert advice. Otherwise one should be careful when generalizing effect sizes from our specific problem and experimental design. The optimal advice is dramatically different from the "populist" advice for maintaining status quo. This may have worked two ways: some subjects may have discarded the optimal advice as unrealistic while the decisions of others may have been pulled strongly in the direction of the optimal. It is also likely that effects of advice are sensitive to selection of subjects. For instance, while the "activist" blaming the previous owner for mismanagement may have stimulated subjects playing the role of a new owner, such blaming could provoke resistance among those who are responsible for both past and current management. To what extent our "advisors" were seen as trustworthy is a question for further research.

The concrete expert advice used in this study are not sufficient to ensure that most subjects follow the optimal policy. Mental model change is still needed. The stronger effect of the "systems analyst" advice for the group of students with some background in stock and flow thinking than for other groups, shows that mental models are important for how advice are interpreted. This is important for how advice is given. It also implies that laboratory experiments are useful and important also when concrete advice are not given.

It may come as a surprise that the “activist” wording gave better results than the “systems analyst” wording. The “activist” blamed the previous owner, classified the task as generally mismanaged, pointed to a lack of public regulations, and claimed that drastic reduction in herd size was needed to maintain sustainability. The message was clear, however no reasons were given to justify the claims for the actual case and no arguments were given to help judge the quantitative advice. The “systems analyst” used a stock and flow argument to call for herd reductions to restore the optimal condition as quickly as possible. This argument may have been more effective if at the same time the “systems analyst” had pointed out that the optimal lichen thickness was higher than the initial one. On the other hand, such an advice may have been of limited effect because of people’s difficulties with stock and flow thinking.

In the long run one would hope that general education will help develop people’s ability to understand stock and flow arguments. For the short run, “systems analysts” may rely on “activists” to get their messages out and concentrate on helping “activists” develop sound policy advice. Alternatively, “systems analysts” should strive to develop clear messages both with regard to concrete advice and with respect to conceptual change. As models become more complex than our one-stock lichen model, these advice seem increasingly important.

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Appendix: Instructions without advice

You will play the role of the owner of a reindeer herd. Your task is to produce as much reindeer meat as possible each year. Note, however, you should make sure that your operation is sustainable. This means that you should aim for the highest possible herd size that can last for ever without destroying the lichen pasture. You should also try to reach this desired state as quickly as possible. Each year your only decision is to set the desired number of reindeer for the next year. You get only 15 years to reach the desired state, and no new trial. Do the best you can. The participant who gets the best results will receive a symbolic prize.

You are the sole owner of a given reindeer pasture. Nobody else has reindeer or other animals on your pasture. In summer, there is plenty of grass and herbs. The limiting resource is lichen to support the reindeer throughout the winter. Lichen is a small plant growing on the ground. Biologically it is a combination of fungus and algae. The lichen plant grows in the summer time, growth stops in the winter, and then the plant continues to grow "on top of itself" the next summer, and so on. When there is very little lichen present, there is only little growth. When there are lots of lichen (60 mm thick), the net growth of lichen tends towards zero, what grows up is just compensating for what rots at the bottom of the plant. In between these extremes, net lichen growth reaches a maximum. When the reindeer graze, they eat the top of the plant, and the plant continues to grow on top of what is left. One can measure the average height of the plants, also referred to as the thickness of lichen.

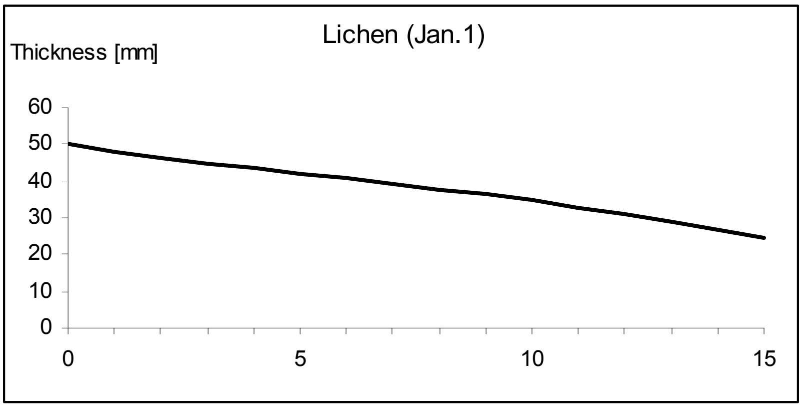
The size of the area is indicated by the following piece of information: In one year, the lichen eaten by 1000 animals is sufficient to reduce the average lichen thickness for the entire pasture by 4 mm. Lichen is vital for the survival of reindeer, if there is no lichen, all the animals will die. You can set the herd size freely, and you need not consider whether reindeer are sold or bought as a consequence of your choice.

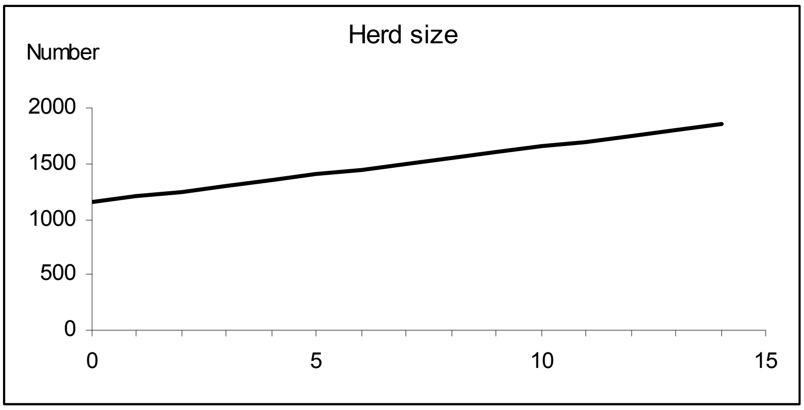
All measurements of the herd size and the lichen thickness are perfect and there are no random variations from year to year in the number of animals or the growth of lichen.

Before you take over the pasture, the previous owner has increased steadily the number of reindeer from 1150 to 1850. As a consequence, the lichen thickness [mm] has dropped from 50 to 24.4 mm. This development is shown in the diagrams and table below.

Good luck!

Historical development





Year	Lichen (Jan.1)	Herd size
0	50.0	1,150
1	48.2	1,200
2	46.5	1,250
3	45.0	1,300
4	43.6	1,350
5	42.1	1,400
6	40.7	1,450
7	39.3	1,500
8	37.8	1,550
9	36.3	1,600
10	34.7	1,650
11	32.9	1,700
12	31.1	1,750
13	29.1	1,800
14	26.9	1,850
15	24.4	