CRISIS MANAGEMENT OF A RENEWABLE RESOURCE

by Erling Moxnes*
Foundation for Research in Economics and Business Administration, SNF
Breiviken 2, N-5035 Bergen-Sandviken, Norway

Abstract

Numerous renewable resources have been exploited beyond limits for sustainable economic development. At times over-exploitation has been observed even in cases where management regimes have been in place. Thus it seems pertinent to search for explanations beyond the theory of the commons. An experiment is performed where subjects set reindeer quotas in a district where lichen has been severely depleted by preceding overgrazing. All subjects err on the side of over-exploitation. Behaviour seems to be dominated by inappropriate, static mental models and inefficient heuristics. Hence a subtle information problem is revealed.

1. Introduction

A laboratory experiment is used to study crisis management of a renewable resource. The case is current over-grazing of lichen by reindeer in the county of West-Finnmark in Norway. The subjects are asked to set total allowable quotas for reindeer in the county over a 12 year period with the goal of maximizing infinite horizon incomes.

Several factors are likely to contribute to the mismanagement of a crisis, of which most are ruled out by the experimental design, notably the commons problem, speculation, and inappropriate incentives for the decision makers. Focus is on the remaining cognitive problems faced by the subjects. Previous research on complex dynamic management problems indicates that systematic mismanagement of the reindeer ecosystem should be expected, see e.g. Sterman (1989b), Sterman (1989a), Brehmer (1987), Brehmer (1989), Funke (1991), Paich and Sterman (1993), Diehl and Sterman (1995), and Moxnes (1996) for another case involving renewable resources. Mismanagement will be measured by the deviation between subject behaviour and optimal policies. The main purpose of the experiment is exploratory, i.e. to see if mismanagement occurs in the laboratory. A second purpose is to search for explanations, and a third one is to search for efficient pedagogical instruments. For the latter two purposes three treatments are used: Treatment 1 is meant to prevent a possible tendency

* Thanks to Magnus Hatlebakk, SNF, and Aslak Nils Sara, Bajos, for valuable discussions and comments.

to consider adjustment problems in addition to incomes, treatment 2 gives detailed information about the dynamic structure of lichen, and treatment 3 gives exact numerical information about the regrowth of lichen as a function of the stock of lichen. The treatments are organized in a three-way factorial design with 48 subjects. The experiment builds on a simulation model, Moxnes et al. (1993), and is documented in Moxnes (1995).

Figure 1 shows the time-series for quotas split on the cases with (right) and without (left) information about the regrowth curve for lichen (treatment 3). The short thick lines indicate the upper limits for the optimal policy in the two cases. None of the subjects can be said to behave optimally over the two first years. Then 10 subjects get below the limit over the next two years in the case with regrowth information, while only one gets below the limit in the other case. The majority behaves far from optimally.

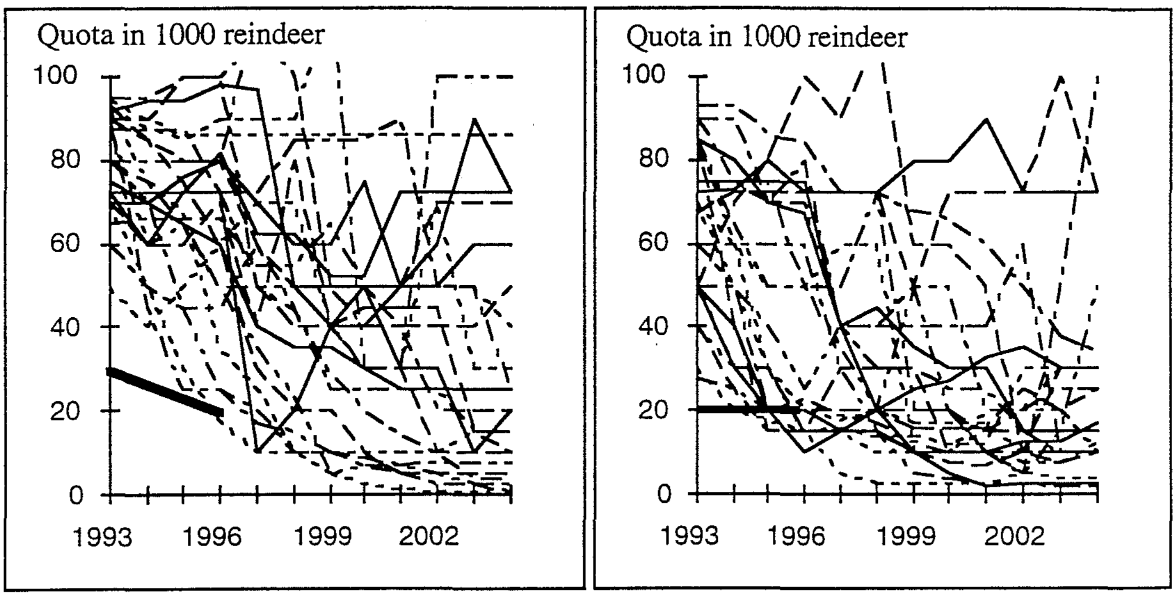

Figure 1: Quotas for the 24 subjects receiving information about the regrowth curve for lichen to the right, the 24 others to the left. Thick lines denote upper limits for optimal policies.

Figure 2 shows the corresponding developments in the lichen percentages. The optimal policy implies a lichen percentage of 59 in the final year. The results do resemble several incidents of real world reindeer management, see Scheffer (1951) and Klein (1968).

Most subjects end up with a result which is far from optimal in terms of infinite horizon incomes. The average score is NOK 342 million. This is only 29 percent of the present value for the optimal policy of NOK 1184 million. Half the subjects end up with less than 10 percent of the potential. The highest score is 7 percent below the potential.

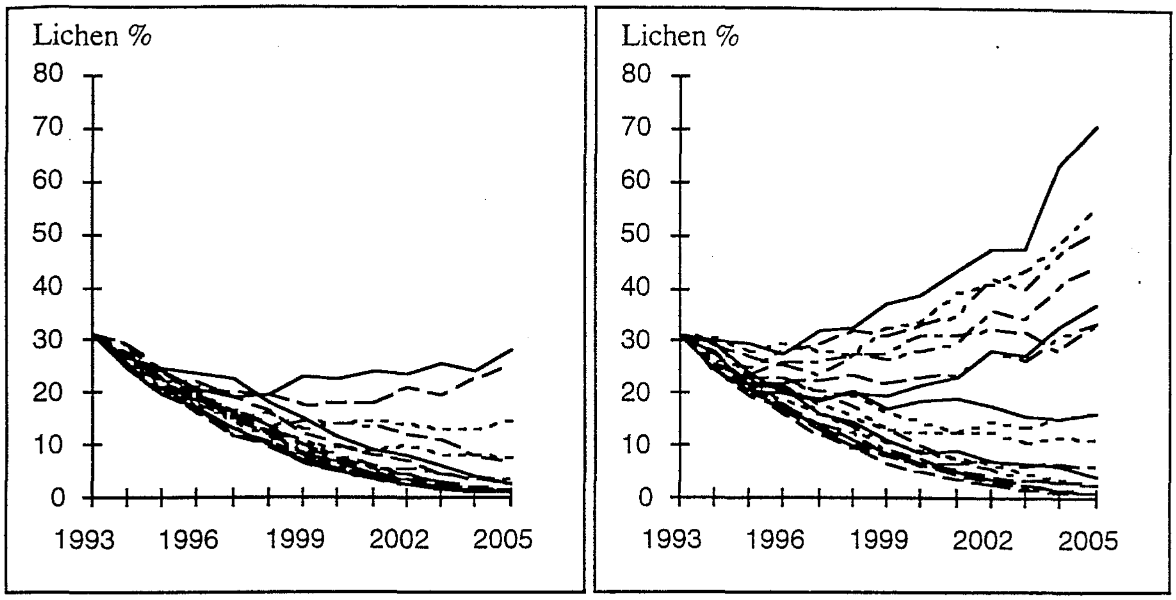

Figure 2: Lichen percentages for the 24 subjects getting information about the regrowth curve for lichen to the right, the 24 others to the left.

The only treatment to have a significant direct effect is the precise information about the regrowth curve for lichen (treatment 3), the level of significance is 0.12 percent. With this information the average present value of income is NOK 509 million, without, it is NOK 175 million. While the treatment is effective, still the subjects on average capture only 43 percent of the potential present value. There is also one negative significant interaction effect, at the 1.8 percent level. The negative sign indicates information overflow. Treatment 1 has a positive effect at the 7.7 percent level for the segment of subjects who do poorly.

Behaviour seems to be dominated by static mental models where dynamic models would have been appropriate. Static mental models can explain reported frustration, policies that go in the wrong direction, passive management, and slow quota reductions. To the extent that subjects have dynamic mental models, these are not used rationally to estimate proper quotas. Rather quotas are set according to behavioural rules, where the most likely role of possible dynamic models is to motivate changes in the correct direction. Observed behaviour for those who do better is summarized by a rule saying that reindeer quotas should be set according to the rate of change in lichen. Reductions in lichen imply reductions in quotas after a filtering delay of about 1.5 years.

The considerable amount of mismanagement implies that proper management of renewable resources requires the handling of a subtle information problem. We have shown that exact numerical information about the regrowth of lichen leads to significant improvements of the results. However, even with this treatment subjects resorted to the above mentioned behavioural rule. Regrowth information seems not to have succeed in conveying a thorough understanding of the problem. Rather, the regrowth numbers seem to have been used to adjust an anchor produced by a static mental model or a preconceived behavioural rule. For this purpose, regrowth information would probably be of less value if it were presented as highly uncertain. Another treatment, which clarified the dynamic structure of the problem, had no significant effect. Similar to the findings of other authors, it seems that the subjects were not able to figure out the policy implications from the revealed structure. Future research should investigate treatments that make clear the behavioural implications of the dynamic structure.

References

Brehmer, B. (1987). "Systems Design and the Psychology of Complex Systems." In Zunde, J.R.a.P., ed. *Empirical Foundations of Information and Software Science III*. Plenum Press.

Brehmer, B. (1989). "Feedback Delays and Control in Complex Dynamic Systems." In Milling, P. and Zahn, E., ed. *Computer Based Management of Complex Systems*. Berlin: Springer Verlag.

Diehl, E. and Sterman, J.D. (1995). "Effects of Feedback Complexity on Dynamic Decision Making." *Organizational Behaviour and Human Decision Processes* **62**(2): 198-215.

Funke, J. (1991). "Solving Complex Problems: Exploration and Control of Complex Systems." In Sternberg, R. and Frensch, P., ed. *Complex Problem Solving: Principles and Mechanisms*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Klein, D.R. (1968). "The introduction, increase, and crash of reindeer on St. Matthew island." *Journal of Wildlife Management* **32**(2): 350-367.

Moxnes, E. (1995). "Crisis management of a renewable resource." Working Paper No. 57, SNF, Bergen.

Moxnes, E. (1996). "Mismanagement of renewable resources." Working paper No. 1/1996, SNF, Bergen.

Moxnes, E., Sara, A.N., Solbakken, J.I. and Stenseth, N.C. (1993). "Reindrift og beitegrunnlag. En modellanalyse." SNF-report 35/93, SNF, Foundation for Research in Economics and Business Administration, Bergen.

Paich, M. and Sterman, J. (1993). "Boom, Bust, and Failures to Learn in Experimental Markets." *Management Science* **39**(12): 1439-1458.

Scheffer, V.B. (1951). "The Rise and Fall of a Reindeer Herd." *The Scientific Monthly* **75**: 356-362.

Sterman, J.D. (1989a). "Misperceptions of Feedback in Dynamic Decision Making." *Organizational Behavior and Human Decision Processes.* **43**(3): 301-335.

Sterman, J.D. (1989b). "Modelling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment." *Management Science.* **35**(3): 321-339.