

A Common Pool Resource Experiment with a Dynamic Stock Externality *

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Abstract

The common pool resource environment introduced by Ostrom, Walker and Gardner may be interpreted as the steady state of a fully dynamic model in which rent-maximizing fishermen exploit biomass which evolves according to a logistic growth function. We conduct a laboratory experiment to compare observed behavior in such a dynamic environment with behavior in the static environment that is its steady state. We focus on the effect of free form, non-binding communication in the two environments. We hypothesize that the complexity of the dynamic environment will reduce the ability of fishermen to cooperate in reducing fishing effort.

We run 12 sessions with groups of eight subjects in a 2x2 design crossing two levels of communication with two model formulations (static and dynamic), supplemented with three dynamic, communication sessions which ran for longer time intervals. To enhance comprehension we present the scenario in an economically meaningful context. We examine observed appropriation, resulting stocks and aggregate rent levels over time and compare with benchmarks of static and dynamic efficiency, Nash equilibrium, and open access (zero profit) equilibrium. Contrary to our expectations, subjects in some of the dynamic sessions were clearly able to restrain harvest and build up stocks.

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1 Introduction

A common pool resource (CPR) is an economic resource which is both *subtractable* (in the sense that one person's use of the resource diminishes its value for other users) and *non-excludable* (in the sense that it is difficult to control access to the resource). Examples of open access resources are road networks, fisheries, and the global atmosphere. Because exclusion is costly, management of the resource is often difficult. Frequently CPRs are managed as *common property*, that is, property which multiple individuals have the right to use. In the extreme case of *open access* resources, this right of use is essentially unlimited.

It is well known that open access to CPRs causes overcrowding and degradation. Hardin (1968) calls this "The Tragedy of the Commons". However, not all CPRs suffer this fate. Social institutions may evolve which explicitly or implicitly restrict access to the CPR, thus preserving its value (Feeny, Berkes, McCay & Acheson 1989). Thus factors facilitating social coordination, such as communication among users, may be important in determining the extent of overexploitation.

There are two ways of modelling the tragedy of the commons: as a static externality or a dynamic one. In a static model users of the resource diminish the value of the resource to those using it at the same time, but the future value of the resource is undiminished. Formal analysis of these models in the case of the fishery goes back at least to Gordon (1954). In general the conclusion is simple: fishermen will enter the industry until the value of their average product equals the opportunity cost of fishing. At this point all rents are exhausted and (under extreme assumptions) the fishery is worthless. In a dynamic model current users of the resource reduce the stock of the resource and thereby harm future users of the resource. Such models typically require integration of an economic model of human behaviour with a underlying model of resource dynamics. Clark (1990) was a pioneer in this literature. Munro (1982) provides an early and elegant exposition of these models, showing

how Gordon's static model can be interpreted as the steady state of a fully dynamic model in which rent-maximizing fishermen interact with an underlying Schaefer (1957) logistic growth model.

The static CPR model has been extensively studied in the laboratory. A particularly influential research program was initiated by Walker, Gardner & Ostrom (1990). They implemented the basic CPR game as a laboratory environment and convincingly demonstrated over-harvesting in the basic environment. They also showed that subjects were willing to incur private costs to punish excessive effort and that a combination of non-binding communication and costly punishment was sufficient to create much higher efficiencies.

A natural question is whether the results of static CPR experiments carry over to a dynamic environment. It is natural to expect that it will be even harder to coordinate behaviour in the dynamic case, partly because the benefits of immediate cooperation are deferred in the dynamic case and partly because the computation of an optimal strategy is so much harder. The evidence here is very sparse. A few experiments have investigated dynamic CPRs. Herr, Gardner & Walker (1997) and Bru, Carera, Capra & Gomez (2003) are two examples, but neither explored a specific fishing model.

The purpose of this experiment is to begin a systematic comparison of the properties of static and dynamic CPRs in a laboratory context. We focus on comparing a behaviour in a dynamic fishery environment with behaviour in a static environment that is the steady state of the dynamic environment.

2 Static and Dynamic Fishery Models

2.1 A Static Model

The classic CPR model, as developed by Gordon (1954), contemplates an industry of price-taking fishermen who in aggregate supply e units of fishing effort at an opportunity cost of

w per unit. The catch of fish (*i.e.* the yield, y) is a quadratic function of the rate of effort, e .

$$y = ae - be^2, \quad a, b > 0 \quad (1)$$

Industry profits are

$$\begin{aligned} \pi &= py - we \\ &= p(ae - be^2) - we \end{aligned} \quad (2)$$

where p is the exogenously determined price of fish. Under these circumstances social welfare is maximized by maximizing π . This occurs at the efficient effort level

$$e^* = \frac{a - w/p}{2b} \quad (3)$$

Under an open access regime, however, new effort enters the industry until all fishermen earn zero profits. This occurs at the open access effort level

$$e^{oa} = \frac{a - w/p}{b} \quad (4)$$

2.2 A Dynamic Model

The yield-effort curve (1) may be interpreted as the steady state of a dynamic system in which the fish stock grows according to a logistic growth function and the harvest is proportional both to effort and to the biomass of the fish stock (Munro 1982). Let the natural rate of growth (in the absence of harvesting) be

$$g = F(x) = rx\left(1 - \frac{x}{k}\right) \quad (5)$$

where g is the rate of growth in tons per period, x is the stock of fish in tons, k is the carrying capacity of the fishing ground (also measured in tons), and r is the intrinsic rate of growth (i.e. the growth rate in an unconstrained environment).

As before, the stock of fish is exploited by an industry of price-taking fishermen who in aggregate supply e units of fishing effort at an opportunity cost of w per unit of effort. In the dynamic case the rate of harvest, h , depends on the rate of effort, e , and the current stock of fish x :

$$h = qex \quad (6)$$

Here q is a “catchability” coefficient which may be interpreted as the fraction of the stock harvested by one day’s fishing effort. The evolution of the stock is described by the stock equation

$$\begin{aligned} \dot{x} &= g - h \\ &= rx\left(1 - \frac{x}{k}\right) - qex \end{aligned} \quad (7)$$

The value of the harvest is ph where p is the price of fish. Fishing effort is supplied by fishermen at an opportunity cost of w so that the rate of profit in the fishing industry is

$$\pi = pqex - we \quad (8)$$

Under conditions of open access fishermen increase or decrease effort according to whether their profits are positive or negative. We may model this by specifying

$$\dot{e} = \mu\pi \quad (9)$$

where $\mu > 0$ is an adjustment coefficient. Equations (7) and (9) characterize the dynamic behaviour of the system.

2.3 The Static Model as a Steady State of the Dynamic Model

The system of Equations (7) and (9) will be in steady state if the stock and effort levels are both unchanging over time, *i.e.* if $\dot{x} = \dot{e} = 0$. By (7)

$$rx\left(1 - \frac{x}{k}\right) = qex \quad (10)$$

Solving (10) we obtain the steady-state stock, x^s , as a function of sustained effort

$$x^s = k - \frac{qke}{r} \quad (11)$$

Substituting into (6) yields the steady-state harvest, y , as a function of the steady-state effort.

$$y = qke - \frac{q^2k}{r}e^2 \quad (12)$$

Equation (12) is the sustained yield-effort curve. Note that it is of the same form as (1) with

$$a = qk \quad (13a)$$

$$b = q^2k/r \quad (13b)$$

For future use we note

$$q = \frac{a}{k} \quad (14a)$$

$$r = \frac{aq}{b} \quad (14b)$$

In the next section we describe how we implemented these models in a laboratory environment.

3 Experimental Design

3.1 Laboratory Environment

Using z-Tree (Fischbacher 2002) we created a laboratory environment in which groups of eight subjects faced repeated opportunities to choose a level of appropriation from a CPR. To facilitate understanding we chose to present the decision problem in a natural context. Subjects were told they represented villagers who could spend 25 days per month either fishing or farming. Each day spent farming yielded a fixed return of 5 laboratory dollars (L\$). Each day spent fishing yielded a proportionate share of the total catch of fish. The total catch was a function of the total fishing effort and the stock of fish.

Each decision period represented one month. In each period subjects were first presented with a calculator screen in which they could compute the consequence of any combination of their own and others' fishing effort. After all subjects had finished with the calculator each was required to state an actual effort level. The outcome of the period was computed and reported to the subjects and a new period began. Each session began with three practice rounds which did not affect payoffs. Following the practice session the experiment was re-initialized. Each session then ran for a further fixed and known number of periods. At the end of the session subjects' earnings were totalled, converted to local currency and paid privately in cash.

The experiment was conducted under four conditions created by crossing a communication factor (No Communication / Communication) with a model specification factor (Static / Dynamic). In the No Communication sessions subjects were not permitted to communicate at any stage of the experiment. In the Communication treatments subjects were permitted up to five minutes of free form communication before each group of four paid rounds beginning with the fifth. Communication was restricted only by the requirements that side payments not be discussed, that there be no threats of violence, and that subjects were not

permitted to view each others' screens.

The Static and Dynamic sessions differed in the the nature of the externality, as described below.

3.2 The Static Environment

The static environment, introduced by Walker et al. (1990), is an adaptation of the Gordon (1954) model to a fishery with a finite number of identical fishermen. Let there be $J = 8$ individuals. Let d_j be each individual's time endowment, measured in days per month. We assume $d_j = d \forall j$. Let e_j be the j -th individual's fishing effort in days per month and let $e = \sum_{j=1}^J e_j$ be the total fishing effort of all members of the group. In the static model the fishery output follows the static yield function (1) modified to exclude negative returns.

$$h = \max(ae - be^2, 0) \quad (15)$$

The payoff for individual j is

$$\pi_j = w(d - e_j) + p \frac{e_j}{e} (\max(ae - be^2, 0)) \quad (16)$$

Assuming that the harvest is strictly positive, *i.e.* that $0 < e < \frac{a}{b}$, three benchmark equilibria can be easily computed. The socially optimal solution (or efficient) equilibrium maximizes joint profits and can be expressed as

$$\{e_j^*\} = \operatorname{argmax}_{\{e_j\}} \left(\sum_{j=1}^J \pi_j \right) \quad (17)$$

with solution

$$\sum_{j=1}^J e_j^* = \frac{a - w/p}{2b} \quad (18)$$

Note that (18) restricts only aggregate effort; any set of $\{e_j\}$ satisfying (18) will be an efficient outcome.

The Nash equilibrium satisfies

$$e_j^N = \underset{e_j}{\operatorname{argmax}}(\pi_j) \quad \forall j \in \{1..J\} \quad (19)$$

Equation (19) gives rise to the J first order conditions

$$-w + ap - 2bpe - bpe_j = 0 \quad \forall j \in \{1..J\} \quad (20)$$

Equating any two members of Equations (20) shows that the solution is symmetric, *i.e.* $e_i^N = e_k^N \quad \forall i, k$. Summing Equations (20) over all j yields the Nash equilibrium aggregate effort

$$e^N = \frac{J}{J+1} \frac{a - w/p}{b} \quad (21)$$

and because the solution is symmetric, each agent's effort is

$$e_j^N = \frac{1}{J+1} \frac{a - w/p}{b} \quad (22)$$

A third benchmark is the open-access equilibrium characterized by $\pi_j = 0 \quad \forall j$. This corresponds to Gordon's (1954) original formulation in which individual fishermen are assumed to ignore their own impact on the average product of fishing effort. The open-access equilibrium is

$$e_j^{oa} = (a - w/p)/b \quad \forall j \quad (23)$$

In this experiment we adopt the parameters chosen by Walker et al. (1990), as shown in the first column of Table 1.

symbol	item	static	dynamic
d	endowment of effort per month	25	25
p	price of fish	1	1
w	opportunity cost of effort	5	5
a	linear coefficient in harvest function	23	23
b	quadratic coefficient in harvest function	0.25	0.2035
k	carrying capacity of fishery		10000
q	catchability coefficient		0.0023
r	unconstrained growth rate		0.26
e^*	socially optimal aggregate effort	36	44.23440
e^N	Nash equilibrium aggregate effort	64	78.63894
e^O	Open Access equilibrium effort	72	88.46881

Table 1: Parameters and Benchmarks

3.3 The Dynamic Environment

The dynamic environment is the same as the static environment except that the harvest now depends explicitly on the stock of fish at the beginning of the period, x_t .

$$h_t = qe_t x_t \quad (24)$$

where the subscript refers to decision period. Note that the marginal and average products of fishing effort, qx_t , are equal and independent of output any period.

The stock evolves according to a discrete approximation to (7)

$$\begin{aligned} x_{t+1} &= x_t + g_t - h_t \\ &= x_t + rx_t \left(1 - \frac{x_t}{k}\right) - qe_t x_t \end{aligned} \quad (25)$$

We chose parameters $k = 10000$, $q = 0.0023$ and $r = 0.26$ so as to make the steady state of the dynamic model correspond approximately equal to the static yield - effort curve of the static model. The corresponding benchmarks for the steady state of the dynamic model are

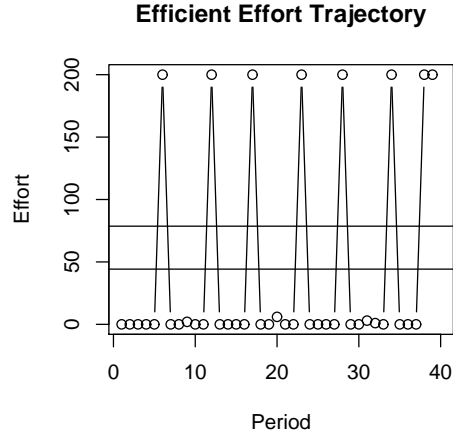


Figure 1: Efficient Effort in the Dynamic Model

reported in Table 1.¹

It is important to note that the steady state benchmark values in Table 1 are not the predicted or optimal values for effort in the dynamic model. In the dynamic model the efficient trajectory of effort solves the following control problem.

$$\begin{aligned} & \max_{\{e_{jt}\}} \sum_t \sum_j \pi_{jt}(x_t, e_{jt}, e_t) \\ & \text{subject to} \\ & x_{t+1} = x_t + rx_t \left(1 - \frac{x_t}{k}\right) - qe_t x_t \end{aligned} \tag{26}$$

We solved this problem by brute force, restricting attention to integral values of effort and stock. The trajectory of efficient effort is shown in Figure 1. Note that the optimal strategy calls for pulse fishing. Stocks are built up by abstaining from harvesting for four or five periods. Then maximum effort is exerted for one period, after which stocks are allowed to rebuild.

¹For $a=23$, $b= 0.25$ and $k = 10000$, Equations (14) imply $q = 0.0023$ and $r = 0.2116$. Due to a clerical error, the dynamic sessions actually used a value of $r = 0.26$. These imply $a = 23$ and $b = 0.2034615$. Consequently, the steady state benchmarks are 44.23440, 78.63894, and 78.63894 for efficiency, Nash equilibrium and open access respectively.

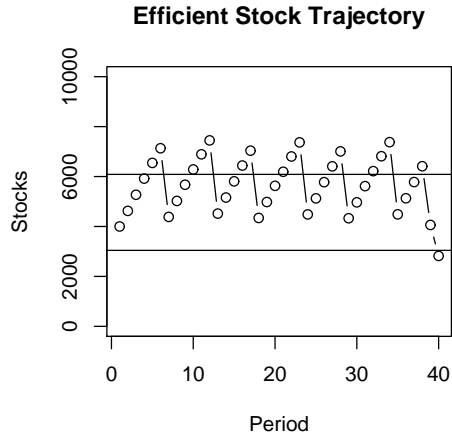


Figure 2: Efficient Stock in the Dynamic Model

The corresponding stock levels are shown in Figure 2. Under the pulse fishing strategy the stock gradually builds to a maximum somewhat above the static benchmark, then is reduced rapidly to a level well below the static optimum but still above the Nash Equilibrium benchmark.

Subjects were informed of the nature of the growth function in the Instructions. In addition, the calculator screen reported current and predicted future stock and average return to effort.

4 Hypotheses

Following the results of Walker et al. (1990) we expect effort in the static, no-communication (SNC) condition will approach the Nash equilibrium benchmark of 68 reasonably quickly. at an aggregate effort level of 72 days of fishing. Because cheap talk has been shown to raise coordination in public goods games we expect to see some increase in efficiency in the static communication condition (SC) compared to the SNC condition. In addition we expect to see a clear breakdown in coordination at the end of the session, due to a strong endgame effect, and we might observe some decline over the four periods following each communication

period.

In the dynamic no-communication (DNC) environment we expect subjects to follow something of a best-response strategy leading to the static Nash equilibrium bench mark. We have not computed the dynamic equilibrium although it would be possible to do so, in principle. Instead we infer from the incentive structure of this experiment that there will be a strong tendency for subjects to allocate all their endowment according to the value of the fish caught per day (CPD). When the value of the fish caught per day is above the opportunity cost of fishing (when value of fish CPD $>$ w) then they will invest all of their endowed days to fishing. When the value of the catch per day is below the opportunity cost of fishing then subjects will allocate their endowed days to farming. If subjects followed this best response function for an infinite number of periods, the average allocation to fishing would be 73.498, the same level as predicted by the open-access equilibrium.² Since the stock begins at 4000 tonnes, we should observe the stock level rapidly decline and then oscillate around the 2173.8 tonne level. Effort levels should be either full investment or zero depending on the value of the fish caught per day.

We expect subjects to be able to achieve significant cooperation in the dynamic, communication (DC) condition but the exact nature of this increase is, of course, the focus of our investigation. *A priori* it seems more difficult to compute the optimal strategy for the dynamic model and consequently we might expect that communication would be less effective in increasing efficiency.

²TODO: I don't see how this statement follows from the model. Surely it depends upon the growth dynamics. Should we simulate?

5 Results

5.1 Overview

Figures 3 and 4 summarize the time paths of aggregate effort for all five treatments and the beginning-of-period stock of fish for the three dynamic treatments. The horizontal lines on the figures represent the open-access, Nash, and socially-optimal benchmarks. The static, no communication sessions behave as expected. Aggregate effort converges almost instantaneously to the Nash benchmark and then seems to cycle around the equilibrium value. Introducing non-binding communication has mixed results: in two sessions (SCS 2 and SCS 3) it appears to have had little or no effect, whereas in session SCS 1 subjects were successful in fishing at almost the socially optimal level in Periods 5 through 8 and again in Periods 13 through 19.

The behaviour of effort changes dramatically in the dynamic sessions. Recall that returns to fishing do not vary with instantaneous effort, so that myopic one-period profit maximization implies that fishing effort should be maximized when the stock exceeds the open access benchmark and should be zero when it falls below. Thus we expect oscillating behaviour, with fishermen alternating between maximum and zero effort. This oscillating behaviour is clearly evident in the dynamic no communication sessions. Effort begins at a high level, well above the static open access level, and declines relatively slowly until about period five, after which it clearly alternates between high and low effort levels. Interestingly enough, subjects do not fully exploit the corner solution nature of the problem: in two sessions out of three the minimum effort level is well above zero and in many cases the peaks in fishing effort are well below the maximum of 200. Figure 4 suggests, however, that net effect on the stock is very similar to open access fishing. The stock declines rapidly from its peak of 4000 and closely approaches the open access benchmark in all three sessions.

Figure 5 reveals a close interaction between stock and effort levels. Recall that at the

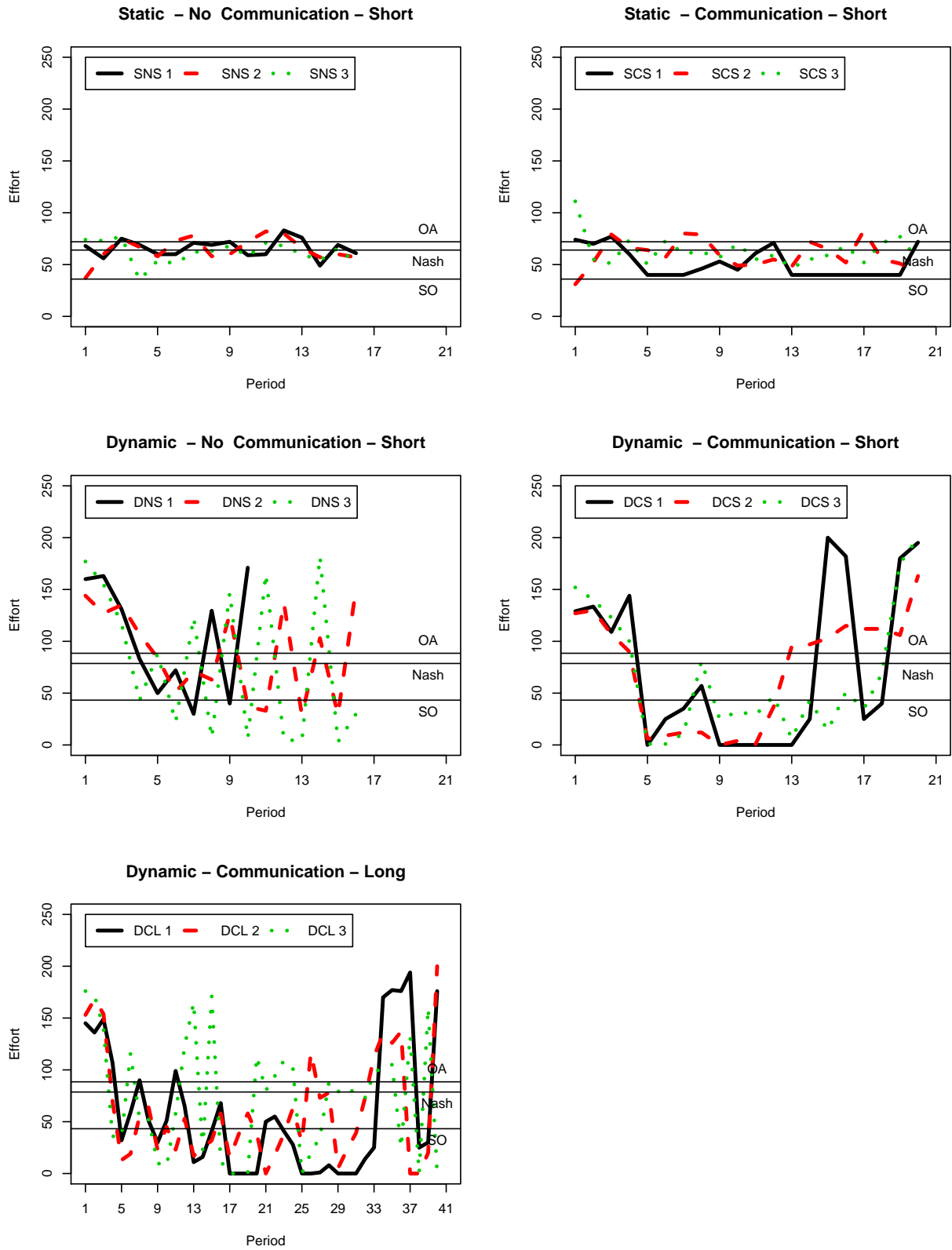


Figure 3: Effort by Session and Period

open access level of effort the average return per unit of effort is equal to its opportunity cost. Figure 5 plots the beginning of period stock and aggregate effort for each of the three Dynamic, No Communication Sessions. In all three sessions the stock begins above the open access level and declines rapidly. Aggregate effort falls over the first few periods, indicating an attempt of some subjects to restrain their fishing. Once the stock falls below open access levels, aggregate effort is cut back to a point where the stock begins to recover. As noted above, however, subjects in Sessions DNS1 and DNS2 failed to reduce their effort to zero. Subjects in Session DNS3 appear to have understood their incentives better. Figure 5 shows that these subjects reduced their contributions to close to zero as soon as the average return to fishing fell below their opportunity costs. The result is a pronounced oscillation of effort and very little deviation of stock from the open access level.

Introducing communication improved performance in most of the dynamic sessions. In general, effort falls after each communication round and then rises slowly as subjects defect in response to increased incentives to fish. There is substantial variation from session to session. Figure 6 plots stock and effort for the short communication sessions. Communication occurred at the beginning of Periods 5, 9, 13, and 17. In Session DCS1 subjects successfully coordinated on a reduction to zero effort in Period 5 but defection increased in each of the next three periods. In Period 9 they returned to zero effort and successfully maintained coordination for the next three periods. By Period 13 stock had reached close to optimal levels. Harvesting increased greatly in Period 15. It appears that subjects had decided to go for maximum exploitation. In Session DCS2, subjects maintained coordination after Periods 5 and 9, but by Period 12 stock had approached optimal levels and were unable to sustain it after Period 13. Effort increased to non-sustainable levels and the stock gradually decreased. In Session DCS3, substantial defections occurred following Period 5. Stock grew less rapidly than in the other sessions. Nevertheless, subjects exercised some restraint until the last group of four periods.

We had expected that increasing the length of the experiment would allow longer runs of cooperative behaviour before the end-game effect dominated. Somewhat unexpectedly, subjects in these sessions seemed to take somewhat longer to achieve coordination. Indeed, Session DCL3 shows almost a complete lack of coordination. Although aggregate effort was clearly reduced in a number of the communication periods, this was almost always coincident with low stocks, making zero effort consistent with myopic profit maximization. Effort rises whenever the stock exceeds myopic profit maximizing levels and consequently the stock never has a chance to grow.

Session DCL1 shows the opposite behaviour. After a slow start in Periods 5 and 9, some agreement was reached in Period 13. By Period 17 defections had been greatly reduced and the stock was building up rapidly. Indeed the stock overshoots optimal levels by Period 27 and remains at inefficiently high levels until Period 33, when subjects clearly decided to go for rapid harvest. Session DCL2 shows a pattern intermediate between DCL1 and DCL3.

[need some further discussion here]

6 Summary and Discussion

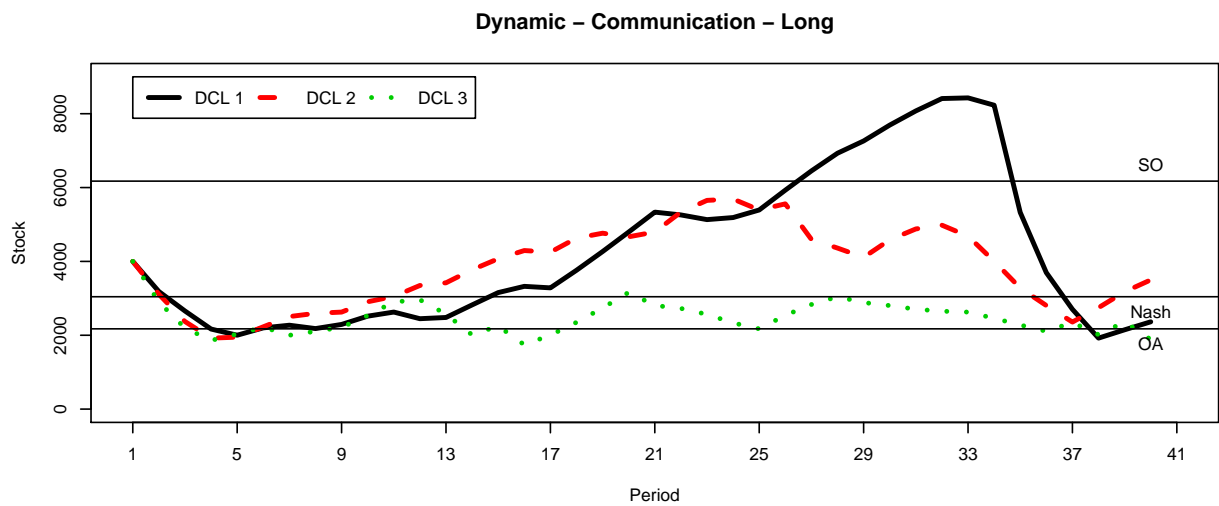
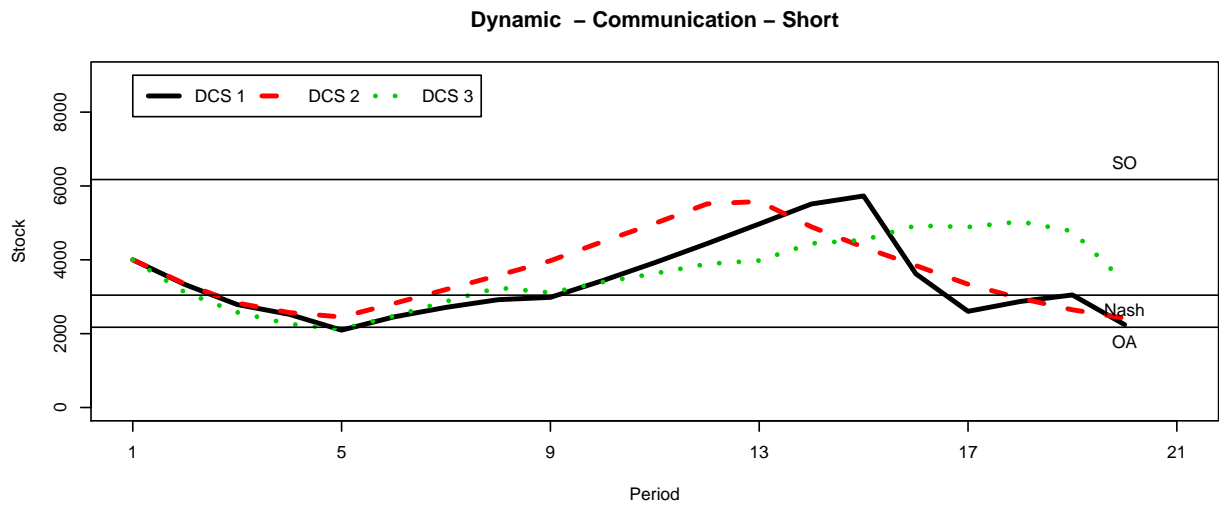
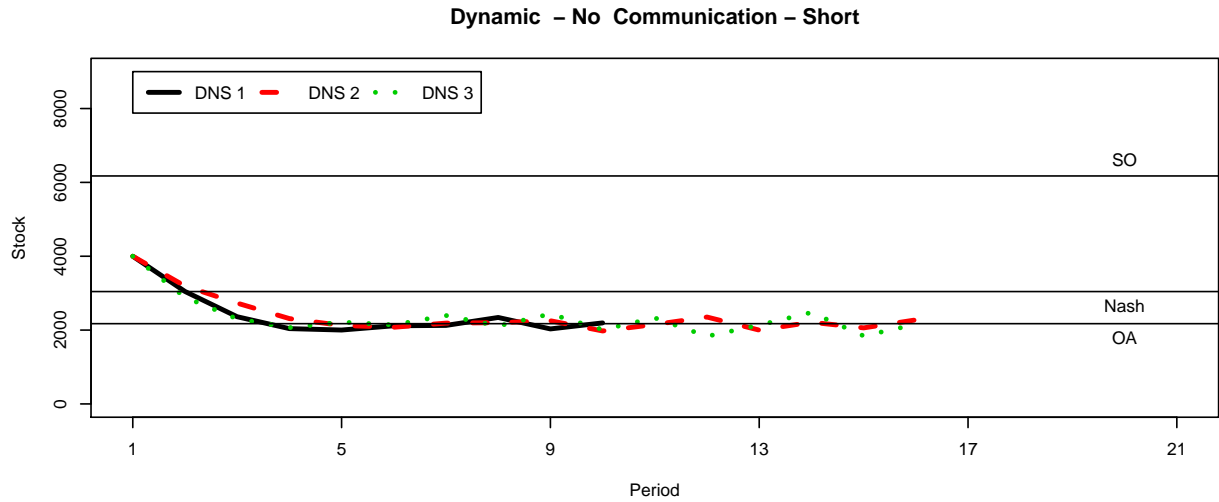


Figure 4: Stock by Session and Period

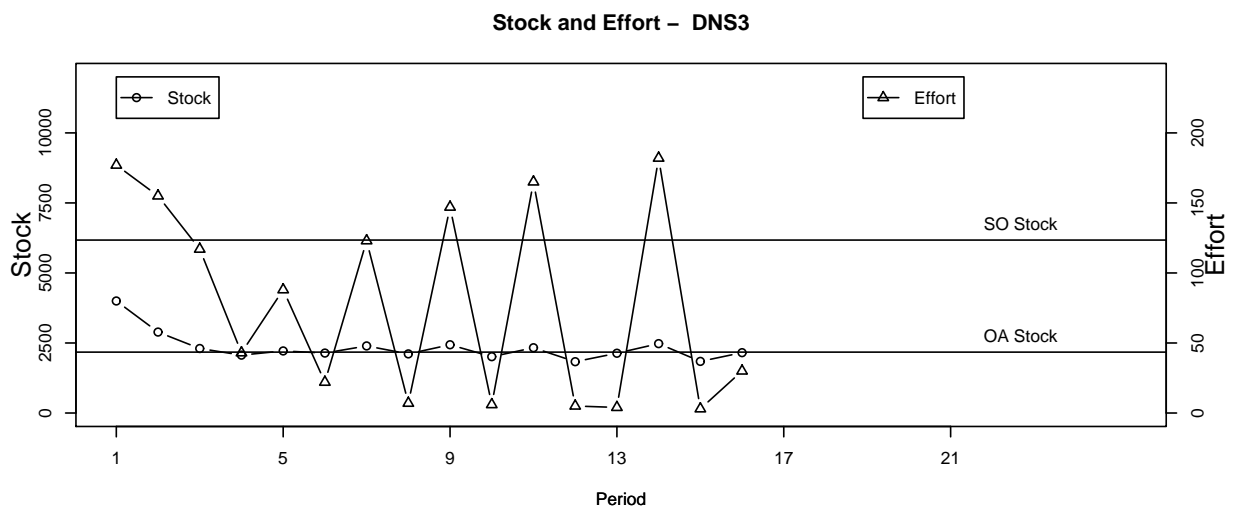
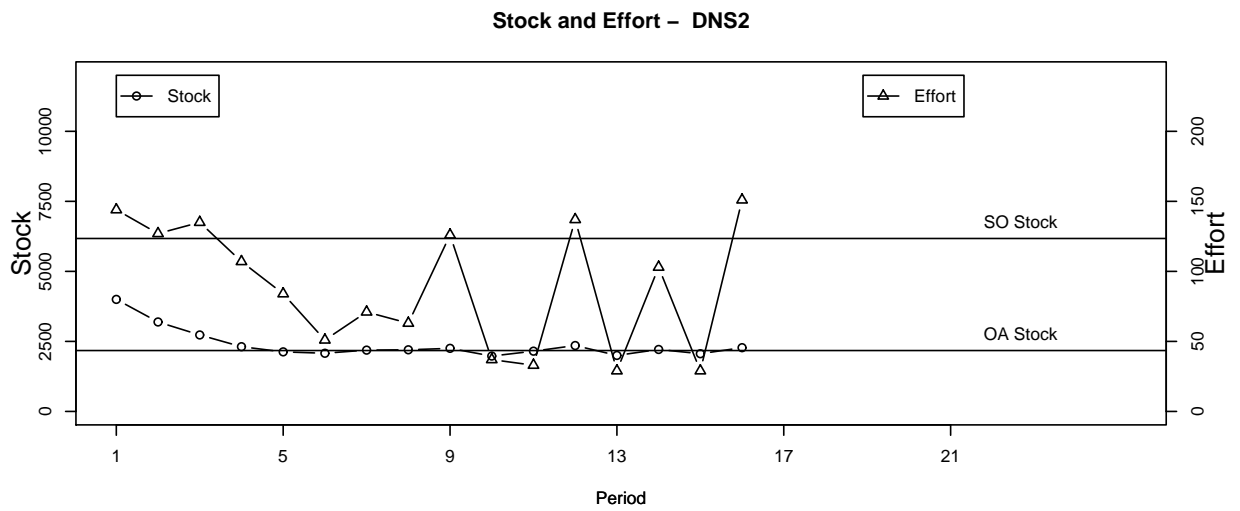
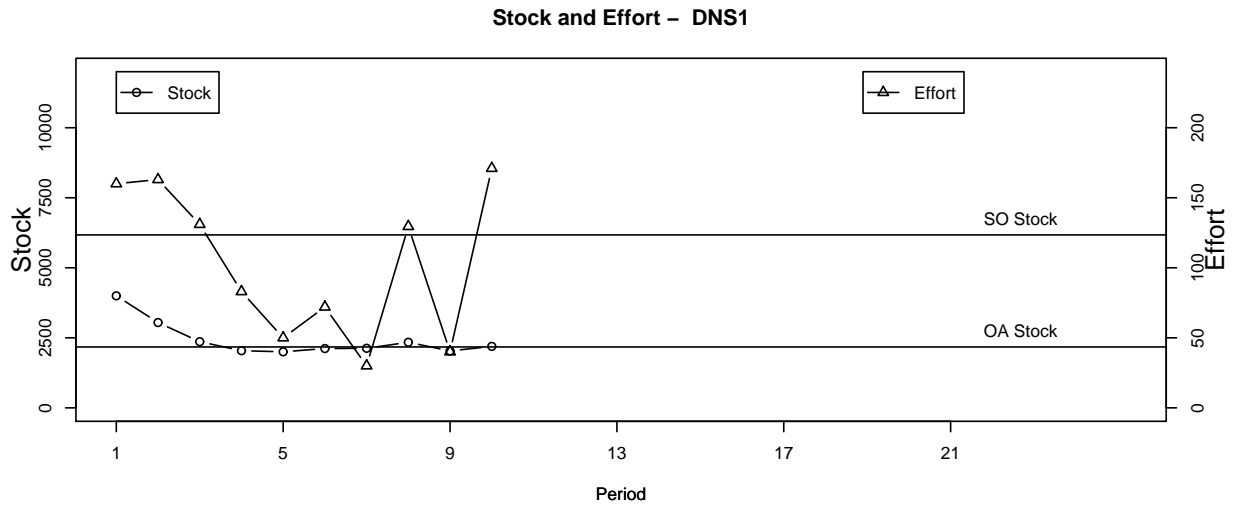


Figure 5: Stock and Effort by Session and Period - No Communication

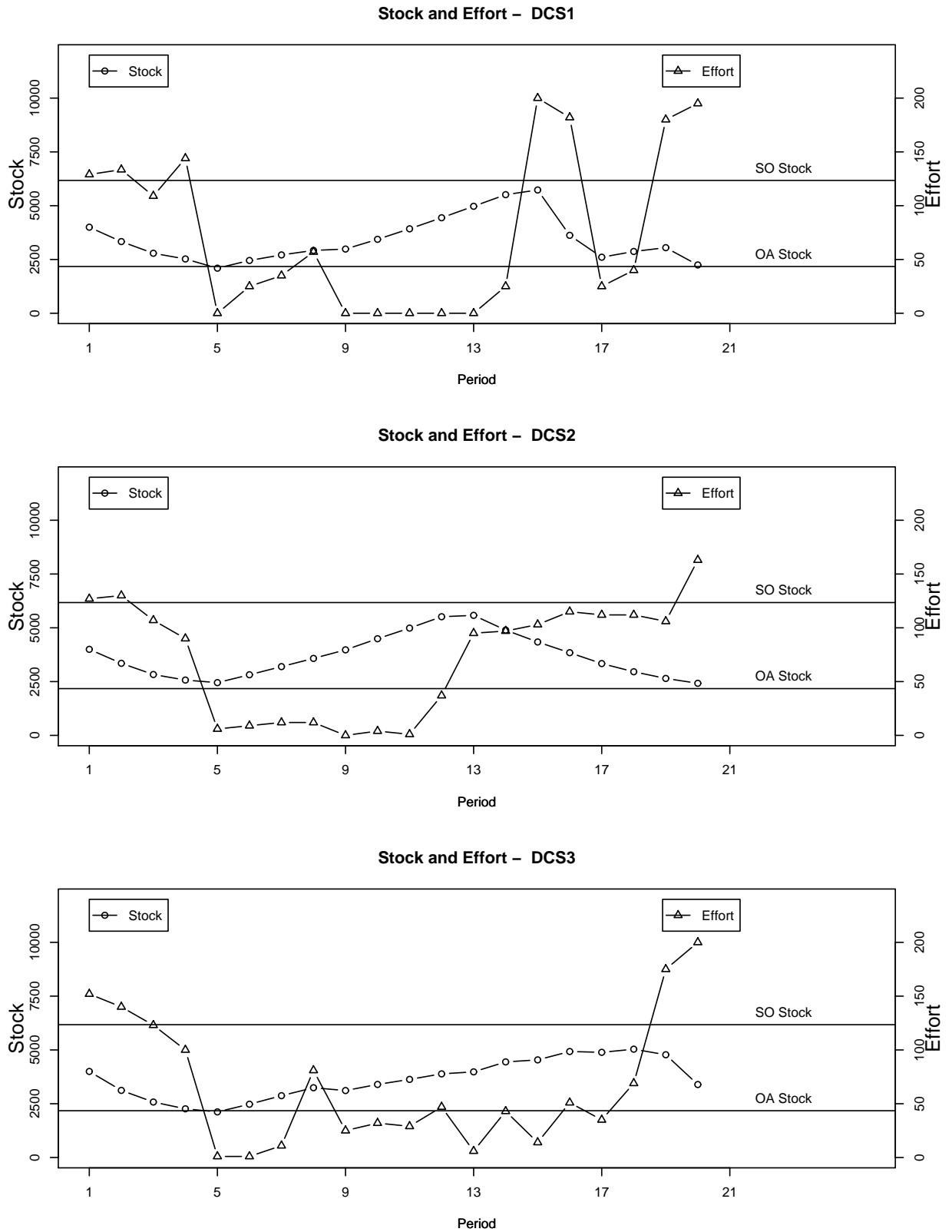


Figure 6: Stock and Effort by Session and Period - Short Communication Sessions

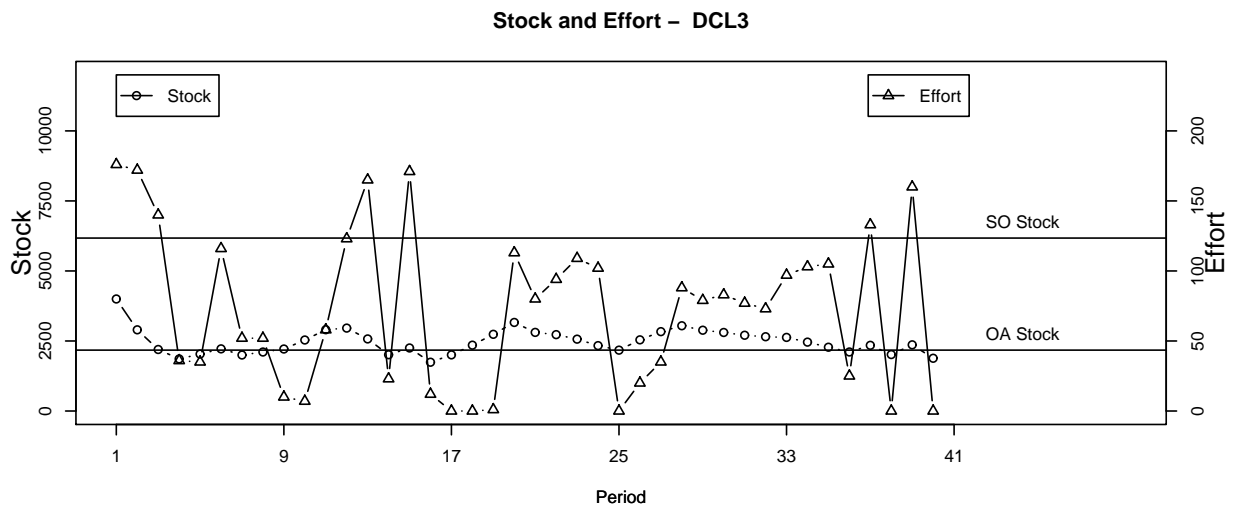
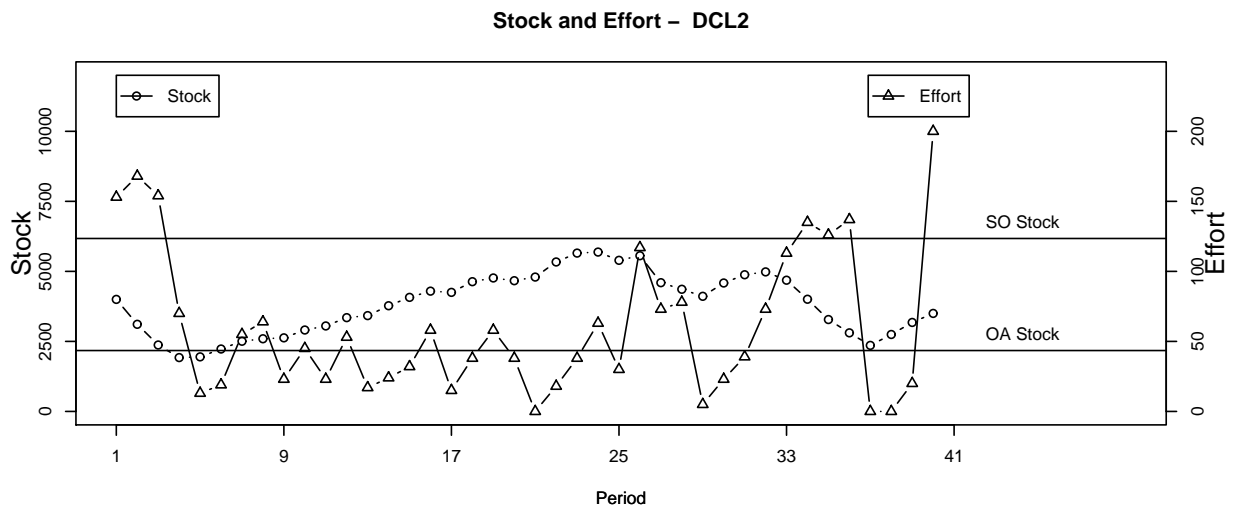
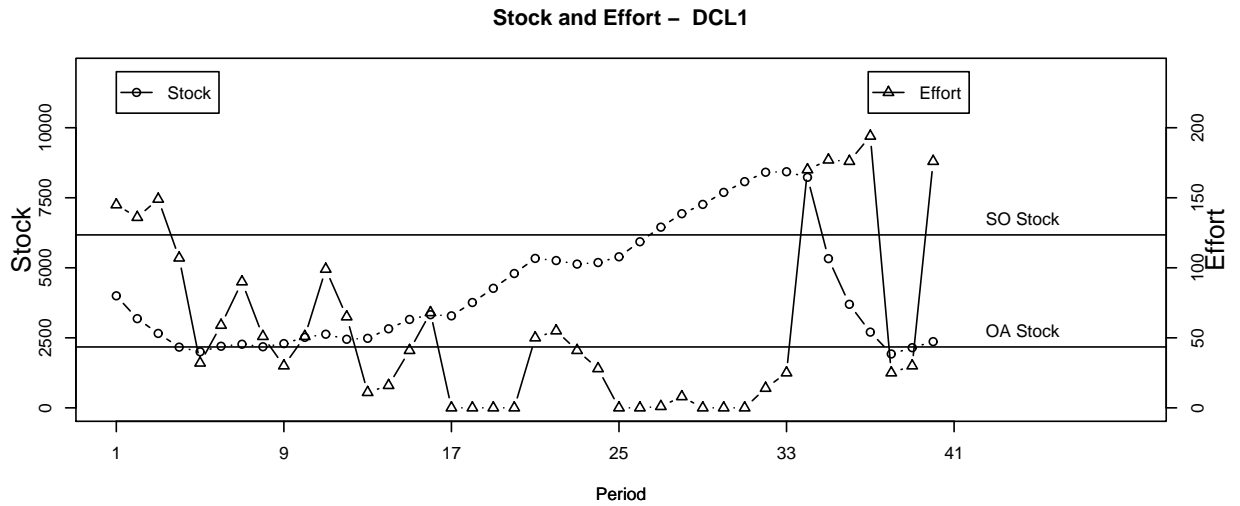


Figure 7: Stock and Effort by Session and Period - Long Communication Sessions

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A Experimental Design

We began by running a thrice replicated 2x2 factorial design in two levels of modeling (Static and Dynamic) and 2 levels of Communication (No Communication and Communication). The No Communication sessions ran for 16 periods. except for the first (Pilot) session, which ran 10 periods. The first three communication sessions ran for 20 periods, with communication rounds prior to periods 5, 9, 13, and 17. In order to examine more closely the effect of communication we ran three more communication sessions lasting 40 periods each, with communication periods before every 4th period, beginning with the fifth. The final design is shown in Table 2

Communication Treatment	Model	
	Static	Dynamic
No Communication	3	3
Communication (20 periods)	3	3
Communication (40 periods)		3

Table 2: Number of Sessions by Treatment

In effect, we have three treatment variables: Model, Communication, and Length of Session, each with three levels. We fail to have a complete 2^3 design, however, because we have no long sessions for the static-no communication (SNC), Static Communication (SC), and Dynamic- No Communication (DNC) cases.

B Data Preparation

We ran 15 sessions. Table 3 shows the treatment settings for each session. We used the data from session 20050321DNP even though it was originally intended as a pilot. Table 4 shows the variables generated by the Ztree program.

	session	dynamic	communication	pilot	nPeriods	description
1	20050321DNP/Pilot	t	f	t	10.00	dynamic pilot
2	20050531SN	f	f	f	16.00	
3	20050601DN	t	f	f	16.00	
4	20050622SN	f	f	f	16.00	
5	20050624DN	t	f	f	16.00	
6	20050627SN	f	f	f	16.00	
7	20050704SC	f	t	f	20.00	
8	20050705DC	t	t	f	20.00	
9	20050706SC	f	t	f	20.00	
10	20050707DC	t	t	f	20.00	
11	20050715SC	f	t	f	20.00	
12	20050718DC	t	t	f	20.00	
13	20060213DC	t	t	f	40.00	40 periods
14	20060214DC	t	t	f	40.00	40 periods
15	20060215DC	t	t	f	40.00	40 periods

Table 3: Treatment Variables by Session

The data from each session were stored individually in separate subdirectories named `rawdata/(filename)`. The individual session files were combined by running `data/prepdata/prepdata` and the resulting data related to relating to subjects were stored in `data/session/sessionTable.csv`.

We then ran `makeBasicDataFiles.R` to drop the practice periods and unused variables and to aggregate the data by subject within period. The resulting files were

`dataBySubjectAndPeriod.csv` , containing one observation for each subject in each period of each session.

`dataByPeriod` aggregating the data by subject within session and containing one observation for each period of each session

dataBySession.csv aggregating the data by subject and period within session and containing one observation for each session.

Variable	Description
1 session	Session Number
2 f2	Event Sequence: 1 during experiment 2 after experiment
3 Dynamic	Is model dynamic? t yes f no
4 Communication	Is there communication? t yes f no
5 TableType	Table Type: subjects or global
6 Period	Period Number
7 Subject	Subject Number
8 Group	Group Number (always 1)
9 Profit	Current Period Profit
10 TotalProfit	Accumulated Profit
11 Participate	Not used in analysis
12 K	Carrying Capacity
13 E	Endowment of Effort
14 w	Farming Wage
15 q	Catchability Coefficient
16 r	Natural Growth Rate
17 p	Price of Fish
18 Xt	Stock of Fish, beginning of period
19 eii	Individual fishing effort, previous period
20 eji	Individual farming effort, previous period
21 ttlefforts	Aggregate Fishing Effort, previous period
22 eis	Last Fishing Effort input into calculator
23 ejs	Last estimate of others effort input into calculator
24 es	Last aggregate effort input into calculator
25 harvests	Harvest from final calculation in calculator
26 fishprofits	Fishing earnings from final calculation in calculator
27 farmingprofits	Farming earnings from final calculation in calculator
28 ttlprofits	Total earnings from final calculation in calculator
29 natgrowths	Natural Growth from final calculation in calculator
30 newstocks	New Stock from final calculation in calculator
31 CpD1	Value of Catch per Fishing Day, previous period
32 CpD2	Value of Catch per Fishing Day, final calculation in calculator
33 farming	Last Farming Effort input into calculator
34 TimeDoneCalculatorOK	Time taken to press done button on calculator screen
35 TimeCalculateCalculatorOK	Time taken in the final calculation
36 ei	Individual Fishing Effort current period
37 TimeOKEffortAllocationOK	Time taken to press ok button after entering fishing effort
38 ttleffort	Aggregate Fishing Effort, current period
39 harvest	Total fish harvested, current period
40 fishprofit	Individual fishing earnings in current period
41 farmingprofit	Individual farming earnings in current period
42 natgrowth	Natural Growth of Fish Stock, current period
43 CpD	Value of Catch per Day, next period
44 farmingEffort	Individual Farming Effort, current period
45 TimeOKResultsOK	Time taken to push the final ok button

Table 4: Variables Produced by Ztree