A Game Theory Model of Parental Care and Desertion

Ethology and Behavioral Ecology

I. Why is desertion an option and when should it be one?
The Concord fallacy.

A. From the moment of fertilization one question should be asked by each parent -- should I stay or should I go. The answer to this question should always be determined by what best serves lifetime RS.

B. If this is the case, notice that whatever past investment has been made is largely irrelevant (but see below). Thus, the question is from this moment on, what action should I take that will maximize my remaining lifetime RS? The answer to this question is not directly contingent on past investment.

C. If instead I answer based on previous investment I have committed the **Concorde Fallacy** named after the French-British SS airliner. (By the late 60s all projections showed that the investors would **very unlikely to be able to recoup their investment** yet they continued to develop the plane based on the argument that they had invested so much that they had to continue. So instead of just accepting their already high loss, they added to it. A similar thing happened in Viet Nam with the US.

1. Thus, it is better to cut your losses by not adding more to them if it is unlikely that you will actually benefit from some behavior.

2. The rationale is often seen in business as "I don't care about what you did for me in the past -- what are you doing for me now and in the future".

3. Thus only the present as it affects the future matters; the past is dead.

D. We would expect animals not to commit the Concorde Fallacy - there should be strong selection against it. Is that the case?

1. Brockmann and Dawkins and digger wasps.

a. The value of nest is determined by the number of paralyzed insects put in it -- they can be put in by several females.

b. A given female's investment is often different -- how many did she bring in?

c. Sometimes conflicts arise when two females arrive at the same nest at the same time (one presumably the initial founder and the other enterer who may or may not have added some provision to the nest).

d. According to predictions, females should fight over a nest depending on the total provisioning. In fact, what they seem to do instead is fight in accordance with how much they have provisioned the nest. You would predict that they should fight in proportion to the overall size.

II. To Desert or not to Desert:

A. Where reproductive success is largely determined by parental care

1. This would be either via defense or provisioning of young

2. Assume that:

survivors = 0 if both desert
= V_1 if one deserts

= V_2 if neither desert
all of these are independent of the size of the offspring at hatching
3. If one deserts and finds a new mate

$$RS = V_1 + pV_2$$

where ***p*** is the probability of setting up a second household and we assume that the animal remains with his second mate. It gets V_1 because we assume that the deserted mate does not desert the young.

Therefore, to select for desertion as an ESS, the fitness of a deserter must be greater than one that stays, i.e.,

$$V_1 + pV_2 > V_2$$

So clearly desertion will be favored if there is a high probability of obtaining a second mate, or if it is relatively easy for one parent to raise young. Note that there is no reason to also assume the other mathematical possibility that V_2 is low -- it is far more reasonable to assume that V_2 is close to V_1.

A number of strategies can be adopted to prevent desertion:

(a) **Synchronize breeding** (as long as operational sex ratio is near 1.0 this will be in the interest of the sex likely to be deserted -- notice that it does not necessarily require cooperation, simply doing what the others are doing within the constraints of season etc. will be good enough.

(b) **Require long courtship** and thereby also **reduce *p***.

Notice that we do not talk about changing V_1 vs. V_2 as a strategy -- we assume that this is largely set by other characteristics that can be changed but are more difficult to change.

B. A Model that Depends on Pre- and Post-Birth PI:

Maynard Smith's 1982 model of parental care systems. This is a model that looks at the number and sex of the parents as potential ESSs. In the payoff matrix below, the columns correspond to female behaviors of caring or desertion as to the rows for males. Each cell of the matrix gives the formula for determining the payoff to female (top right) and male (lower left) for when both sexes play a particular strategy, for instance, both care or male cares and female deserts.

Payoffs are calculated for a single breeding cycle; considerations for iteroparity are not part of this model in the sense that decisions are made for one breeding bout (a season a subdivision of a season) and do not take into account decisions that an individual makes in light of past or future reproduction. Thus, it is best to regard all individuals of one sex as being of the same age and condition and having the same expectations for future reproduction (whether they be some form or iteroparity of semelparity).

Let the following be defined:

P_0*, *P_1*, and *P_2 are the probabilities of an offspring surviving with 0,1, and 2 parents, such that:
$P_0 \leq P_1 \leq P_2$
Notice that it is possible in some species for instance that parental care would have no effect on survival of offspring.

W is the <u>number of eggs or offspring a female produces **if she deserts**</u>
w is the <u>number of eggs or offspring from a female **if she cares**</u>
where:
$W \geq w$
Notice that a female potentially is expected to be able to lay more eggs if she deserts; the reason is that she does not need to save energy for rearing the offspring. It is assumed that she does not plan to have a second clutch and so clearly this model ignores the case of a female who plans to desert and have several clutches and therefore puts fewer eggs into each nest than a female who plans to care. However, this is a reasonable assumption since the other condition is essentially one of polyandry and is rather rare; a female would usually be better off to wait for the next breeding season.

p is the <u>probability that a male mates with a second female</u> (whom we will assume has not mated already) <u>**if he deserts**</u>

As in any ESS, what one player (sex) does determines what is in the other player's (sex's) best interests.

Female

Male	**Stay**	**Desert**
Stay	wP_2 / wP_2	WP_1 / wP_1
Desert	wP_1 / $wP_1(1+p)$	WP_0 / $wP_0(1+p)$

First let's look at the cells for the male. Why w in each case? The answer is that w is the reproduction a male gets with a single female. If he might mate a second time he will get $w + p*w$, i.e., $w(1+p)$ where p is the chance he finds a second mate. For the females, the benefit of a second mate is the difference between W and w.

In most cases would you expect W or $w(1+p)$ to be larger if $p = 1.0$?

With these assumptions, there are four possible ESS solutions:

1. Bi-parental care:

$wP_2 > WP_1$ or the female deserts

$wP_2 > wP_1 (1 + p)$; i.e., $P_2 > P_1 (1 + p)$ or the male deserts

<u>In plain English</u>: **if W is not greatly larger than w and if $P_2 > P_1$ (two parents better than one) <u>and</u> if p is not large (no especial advantage in extra matings for the male with desertion) both parents will care.**

2. Neither cares:

$WP_o > wP_1$ or female cares

$wP_o(1 + p) > wP_1$; i.e., $P_o(1 + p) > P_1$) or male cares

In the remaining two cases, things are more complex:
In general single parent guarding is favored if $P_2 \approx P_1 >> P_0$.

However, **male desertion will be favored if p > p'**
female desertion will be favored if V > v
In both cases, whether or not desertion occurs will be the result of the relative values of p or V to P.

3. Uniparental female care (common in mammals):

$wP_1 > WP_0$ or female deserts

$wP_1(1 + p) > w P_2$; i.e., $P_1(1 + p) > P_2$ or the male cares

4. Uniparental male care (many fish):

$WP_1 > wP_2$ or female cares

$wP_1 > wP_0(1+p)$; i.e., $P_1 > P_0 (1 + p)$ or male deserts

In mammals, female lactation makes female desertion a difficult strategy -- it is interesting to speculate as to why male lactation has not evolved in at least some species -- strategy #4 would certainly seem to be an option in many species.

Birds: monogamy in altricial species, #3 in precocial species.