Wildlife Harvest in Integrated Conservation and Development Projects: Linking Harvest to Household Demand, Agricultural Production, and Environmental Shocks in the Serengeti

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ABSTRACT. *This paper develops a model coupling wildlife population dynamics to endogenous human consumption and poaching behavior in an environment of imperfect labor and product markets and static agricultural production technology subject to environmental shocks. Using a model of the Serengeti wildebeest herd, we simulate how long an integrated conservation and development project based on managed wildlife harvest might effectively delay biodiversity loss by preempting poaching. Alternative interventions that more directly tackle the problem of time-varying returns to peasant agricultural labor appear to offer more durable solutions to the challenge of wildlife conservation in the midst of endemic rural poverty.* (JEL Q26)

I. INTRODUCTION

Integrated conservation and development projects (ICDPs) are widely promoted as a solution to the problem of biodiversity loss in developing countries. ICDPs involve quasi-contractual arrangements wherein communities on the periphery of protected areas curtail the illegal offtake of native species in exchange for material consideration, often in the form of alternate sources of income or sustenance. Wildlife ICDPs often compensate local people from a managed harvest under the assumption that this will discourage poaching, increase local peoples' valuation of wildlife, and elicit their aid to maintain noncatastrophic harvests (McNeely 1995; Munasinghe 1994; Wells 1993; Western, Wright, and Strum 1994). But some have questioned the sustainability of ICDPs that rely on wildlife harvest, pointing out potential pitfalls in alternative ICDP designs, and emphasizing the need for monitoring programs to test ICDPs' critical assumptions and to allow managers to respond adaptively to avoid program failure (Barrett and Arcese 1995; Salafsky 1994; Sinclair and Arcese 1995b). While generally quite sympathetic to the ICDP concept, we have concerns about particular designs, especially those that do not attend sufficiently to the underlying socioeconomic pressures that drive excessive and untimely exploitation of environmental resources, including wildlife.

This paper develops a simulation model to explore the interactions of wildlife populations and human consumption and poaching behavior under alternative ICDP designs in a situation where labor and product markets are imperfect, and where agricultural production is static and subject to environmental shocks. These circumstances reflect conditions in many regions of Africa where ICDPs rely heavily on wildlife harvest (Mbano et al. 1995; McNeely 1993). We consider first the effects of introducing only a game meat distribution system based on managed culls, and then the effects of adding other potential interventions. This stylized approach permits us to isolate the effects of wildlife harvest and to demonstrate that while it does indeed discourage poaching, as its proponents emphasize, it nonetheless aggravates pressures

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on the herd. Some alternative interventions show considerably greater promise. In particular, a combination of policies oriented toward, on the one hand, increasing agricultural productivity and, on the other hand, providing state contingent employment options may be especially potent.

We do not model all the changes prospectively induced by ICDPs. In particular, we ignore the potential for markedly more cooperative (and less myopic) individual behavior, both because there is no broad-based evidence of such changes occurring in African wildlife ICDPs (Barrett and Arcese 1995; Gibson and Marks 1995), and because this would entail a notably more complex, game theoretic modeling strategy which would overtax the limited empirical evidence presently available to parameterize and calibrate a simulation model. Moreover, in our experience durable goodwill and cooperative behavior among parks' peripheral populations are built largely by attention to the fundamental economic challenges they face, not by more superficial interventions like wildlife harvest. If this hypothesis is true, and community cooperation were to increase as we proceed through the successively more fundamental interventions we model, this would reinforce our qualitative findings with respect to the relative durability of different ICDP designs for wildlife conservation in Africa.

The key potential flaws in ICDPs based on wildlife harvest are three. First, human populations are growing in areas with ICDPs, while wildlife populations slated for harvest typically are not. Thus, at some point, ICDP managers must expect to either reduce distributed meat volumes per capita or increase harvests above sustainable levels (Barrett and Arcese 1995; Campbell and Hofer 1995; Sinclair and Arcese 1995a). Second, there might not be a positive, noncatastrophic wildlife harvest available when environmental shocks, such as droughts, greatly increase natural mortality (Pascual and Hilborn 1995). However, because environment shocks frequently coincide with the greatest levels of human need, demand for wildlife harvest is often greatest at these times, creating conjunctural pressures that may overwhelm the ICDP. Third, increased income per capita associated with development may lead to increased demand for wildlife products among very poor populations (Barrett and Arcese 1995; Salafsky 1994). Therefore, we suggest that a central problem in ICDPs that link local development to wildlife harvest is that, in the absence of ancillary interventions such as those we introduce in Section V, protected area managers (PAM) will at some time be forced to choose between (1) breaching their contract with local communities in order to maintain a viable herd size, or (2) risk the collapse of herds by allowing a potentially catastrophic harvest. We label this decision point a "crisis" for the PAM and for the ICDP as a whole.

Our simulations rely on a model of population dynamics for the well-studied wildebeest (*Connochates taurinus*) population of the Serengeti ecosystem of East Africa. We link this to a model of household demand for game meat, a crucial feature of which is that the price of game meat and the wage rate for labor are both endogenous. We then simulate the median time to crisis in wildlife harvest-based ICDPs under alternative assumptions about human population growth and management interventions, and about the correlation between agricultural productivity and wildlife population shocks. We then rerun the simulations after introducing alternative interventions designed to affect the fundamental structure of the rural economy.

II. BACKGROUND ON WILDLIFE AND THE SERENGETI REGIONAL ECONOMY[1]

The Serengeti ecosystem is defined by the wildebeest's migratory range, covering some 25,000 km^2 in northern Tanzania and southern Kenya. Tanzania's Serengeti National Park comprises more than half the ecosystem's land area. It is UNESCO's first World Heritage Site and part of one of the world's largest Biosphere Reserves. Serengeti contains the world's largest ungulate herds. It lies on the high interior plateau of East Africa, experiences marked seasonality in rain-

[1] This section draws extensively from Sinclair and Arcese (1995b) and Sinclair and Norton-Griffiths (1979).

fall, and rests on volcanic soils of varied age. Environmental, spatial, and temporal heterogeneity underlie the herbivore migrations that organize the ecosystem and help make Serengeti one of the world's most unique and valuable natural resources.

The Serengeti has experienced significant perturbations this century. Ungulate populations, especially buffalo and wildebeest, declined dramatically after the introduction of rinderpest in the 1880s, then grew sharply after its control in the 1960s. Most recently, there has been rapid growth in human settlements, especially along the western boundary of the park. The region comprises more than one million people and has been growing about 3.0 percent annually (Campbell and Hofer 1995; World Bank 1993). This coincides with a marked increase in the number of poachers arrested in the park (Arcese, Hando, and Campbell 1995). As a result, Sinclair (1995, 24) states that "the illegal killing of the migrant ungulates by poachers is potentially the most serious threat to the Serengeti system. Since the migration determines the structure and function of the system, overharvesting of the migrants with a collapse of their populations will result in the collapse of the whole system."

The primary reason for poaching in the Serengeti is endemic poverty (Arcese, Hando, and Campbell 1995; Campbell and Hofer 1995). The World Bank lists Tanzania as the world's poorest nation, with a per capita income of US$90 in 1993 (World Bank 1995). Recent estimates indicate that 59 percent of Tanzanian agriculturalists fall below Tanzania's poverty line of TSh31,000 (roughly US$150) annual income per capita (World Bank 1993). Moreover, poverty in the mainly agricultural Serengeti region is more widespread and severe than the national average. Mara region, on the park's western boundary where most poaching occurs, had an income per capita of only TSh 9,380. Food represents 77 percent of rural households' expenditures, divided almost evenly between home production and market purchases. Meat is the least likely food group to be consumed out of own-farm production. Killing wildlife for meat is the most widespread form of poaching that occurs in Serengeti (Arcese, Hando, and Campbell 1995; Campbell and Hofer 1995; Magombe and Campbell 1988–89).

The Serengeti Regional Conservation Strategy (SRCS) is a new ICDP (Mbano et al. 1995). Like many African wildlife ICDPs, SRCS aims to improve conservation through several channels, chief among them meat distribution via the managed harvest of wild ungulates, especially wildebeest. However, although the legalization of managed wildlife harvest is feasible in the short term, it is uncertain if harvests can be controlled within sustainable limits in the long term. That is the central question behind this paper.

III. MODELING WILDEBEEST SUPPLY AND DEMAND IN THE SERENGETI

A. Noncatastrophic Harvest Volumes

We adopt the most current available model of wildebeest population dynamics in Serengeti, developed by Pascual and Hilborn (1995; hereafter PH). Equation [1] details the dynamics of N_t, the number of adult wildebeest in the population at time t.

$$N_{t+1} = [N_t S_w^8 S_{dt}^4 + N_t R_t] e^{u_t} - H_t. \qquad [1]$$

Population is stochastically related to S_w, the discrete monthly adult survival rate during the eight wet season months; S_{dt}, the discrete monthly adult survival rate during the four dry season months; and R_t, the number of individuals added to the adult population per capita (the "recruitment rate") in time t, which encompasses both pregnancy and calf survival rates. Following PH, we set S_w = 0.99 based on Sinclair (1979). Demographic stochasticity, due to epidemiological shocks, for instance, enters through u_t, which are independent and identically distributed $N(0, 0.007)$. Population is reduced by the human harvest volume, H_t.

Dry season survival and recruitment rates vary with current environmental conditions. Recruitment and survival rates are increasing functions of per capita food availability, F_t, which is itself an increasing function of both area, A, and monthly grass production, G_t. G_t varies directly with average monthly dry season rainfall, NR_t.

$$S_{dt} = \frac{\psi(F_t + \delta)}{\psi F_t + \delta} \quad [2]$$

$$R_t = \beta + \alpha F_t \quad [3]$$

$$F_t = A\frac{(G_m/30)}{N_t} \quad [4]$$

$$G_t = h(NR_t). \quad [5]$$

We follow PH's specification for equations [1–5] in simulating the feasible noncatastrophic harvest volumes, setting $\psi = 0.98$ and $\delta = 2.85$. The random variables in the model are thus monthly dry season rainfall, NR_t, and the demographic stochasticity term, u_t. Furthermore, we employ PH's joint posterior probability distribution for the Bayesian estimates of α and β (PH's Table 2). Thus α, β, F, G, NR, S_d, and u all vary over time, creating population dynamics described in detail by PH. We set a starting value of N_0 at 1.0 million animals, an intermediate number between recent wildebeest population estimates ranging from 0.9–1.2 million. Harvest, H_t, is determined by human demand, as detailed in the next section.

The parameterized wildebeest population model thus takes the form.[2]

$$N_{t+1} = \left[N_t 0.99^8\left(\frac{0.98(F_t + 2.85)}{0.98F_t + 2.85}\right)^4 + N_t(\beta + \alpha F_t)\right]e^{u_t} - H_t \quad [6a]$$

$$F_t = 10^6\left[\frac{-3.62 + 0.23NR_t}{N_t}\right] \quad [6b]$$

$$NR_t = 149.3 + \sum_{i=0}^{4} a_t v_{t-i} \quad \text{with } a_0 = 1.0,$$
$$a_1 = 0.95,\ a_2 = -0.42,$$
$$a_3 = 0.17,\ a_4 = 0.30$$
$$NR_t \geq 0$$
$$u_t \sim \text{iid } N(0, 0.007)$$
$$v_t \sim \text{iid } N(0, 3600) \quad [6c]$$

The time path of N permits estimation of the maximum noncatastrophic harvest volume for each period, $H_t^* = N_t - 250{,}000$, based on an estimated critical population threshold of 250,000, the lowest on record, just as rinderpest was eliminated.

B. Endogenous Human Demand for and Poaching of Wildlife Meat

The best available data suggest that meat comprises about 14 percent of food expenditures, or 11 percent of total household expenditures, among rural Tanzanians (World Bank 1993). This implies per capita meat expenditures of about TSh1,040 (roughly US$5) per year in the Serengeti region. We assume that one-quarter of a Serengeti household's meat consumption comes from game, which may be conservative because domestic stock is much more expensive (Campbell and Hofer 1995). Thus, an average household of seven persons that takes 60 percent of game meat from wildebeest will consume about one-third wildebeest per year, based on $16/carcass (Mbano et al. 1995). This implies about 60,000 wildebeest taken annually in the region; a figure consistent with other estimates (Campbell and Hofer 1995; Pascual and Hilborn 1995; Mbano, personal communication). At a metabolic weight of 53 kg,[3] a crude estimate of the annual supply of wildebeest meat in the local Serengeti economy is 3.2 million kilograms, which coincides with other work suggesting that game meat consumption is substantial and poaching is an important activity in local communities (Arcese, Hando, and Campbell 1995; Campbell and Hofer 1995; Hilborn et al. 1995; Magombe and Campbell 1988–89; Mbano et al. 1995). Nonetheless, little is known about the dynamics of human demand for wildlife, so this section is necessarily speculative.

Following DeJanvry, Fafchamps, and Sadoulet (1991), we posit a representative Serengeti household that allocates its labor and

[2] We retain PH's MA(4) structure for NR_t but use a single scenario based on mean monthly dry season rainfall of 149.3 mm over the 1960–89 period. PH use three different scenarios for average new rainfall (100, 150, and 200 mm/month).

[3] Metabolic weight refers to the mass of muscle, organs, and blood, and is thus closer to the weight of the meat than the animal's gross carcass weight, including bone, skin, and stomach, or its live weight.

land between two different activities, sedentarized food production and poaching, so as to maximize the utility it derives from the consumption of several different goods and of leisure time. This captures the essence of the decisions made by agriculturalists operating in an environment of stochastic production and incomplete markets, and it permits us to simulate poaching and game meat consumption in communities on the Serengeti's perimeter.

The household produces ($q_i \geq 0$) traditional foods (crops and domestic livestock, $i = f$) and game meat ($i = g$) using two factors ($q_i \leq 0$): land ($i = t$) and labor ($i = l$). The household possesses a production technology $J(q; w)$ that relates factors and products, conditional on the weather and other environmental conditions (w) that are fully known to the household but may vary from year to year.[4] The household has an endowment ($e_i \geq 0$) of each commodity. The household maximizes the utility it derives from the consumption (c_i) of traditional foods ($i = f$), game meat ($i = g$), nonfood household goods ($i = h$), and leisure ($i = l$), given household size (n), and subject to a cash budget constraint that includes both proceeds from its own activities and transfers from outside (s). Perfectly competitive markets exist for traditional foods and nonfood household goods, so the household buys and sells those products freely at a given price. These are hereafter referred to as tradable commodities (the set $T = \{f, h\}$). No markets exist for game meat, labor (leisure), or land; the household must fully self-provision in these factors and products.[5] These commodities are thus labeled nontradables (the set $NT = \{g, l, t\}$).

Given these characteristics, the household solves the following problem:

$$\max_{\mathbf{c},\mathbf{q}} U(\mathbf{c}; n) \qquad [7a]$$

$$\text{s.t.} \quad \sum_{i \in T} p_i(q_i + e_i - c_i) + s \geq 0$$
$$\text{tradables' cash budget constraint} \qquad [7b]$$

$$q_i + e_i - c_i \geq 0 \quad \forall\, i \in NT$$
$$\text{nontradables' availability constraint} \qquad [7c]$$

$$J(q; w) = 0$$
$$\text{production technology constraint.} \qquad [7d]$$

The constraints [7b–7d] represent the production technologies and market conditions prevailing in the region, which are presumed static. The associated Lagrangean is thus:

$$\mathcal{L} = U(\mathbf{c}; n) + \lambda\left[\sum_{i \in T} p_i(q_i + e_i - c_i) + s\right] + \sum_{i \in NT} \mu_i(q_i + e_i - c_i) + \phi J(q; w). \qquad [8]$$

Nontradables' prices are endogenous in this problem, with $p_i^* = \mu_i/\lambda\ \forall\ i \in NT$, while tradables' prices are exogenous by assumption, $p_i^* = p_i\ \forall\ i \in T$. Assuming an interior solution,[6] the first-order necessary conditions for an optimum can be written as:

$$U_i = \lambda p_i^* \quad \forall\ c_i \qquad [9a]$$

$$\phi J_i = -\lambda p_i^* \quad \forall\ q_i \qquad [9b]$$

$$\sum p_i c_i = \sum p_i(q_i + e_i) + s \quad i \in T \qquad [9c]$$

$$c_i = q_i + e_i \quad \forall\ i \in NT \qquad [9d]$$

$$J(q, w) = 0. \qquad [9e]$$

[4] An interesting extension would be a more general, stochastic dynamic formulation that recognizes intertemporal demand patterns and the effect of stochastic technology on consumption and production patterns. Allowing for multi-period optimization, either individually or collectively (perhaps via a super-game), would also accommodate the prospect for increasingly cooperative behavior amongst PAMs and the human communities on parks' peripheries.

[5] The absence of markets captures the autarkic nature of the village economy in these commodities. While there is probably trade in labor, land, and meat among households within Serengeti villages, there is little intervillage trade. Moreover, agricultural households in the region surely do not face perfectly elastic demand or supply schedules for these commodities, hence, the simplifying assumption of complete markets failure. They probably do not face perfectly inelastic schedules, either, but moving from our limiting case to an intermediate one would necessitate a general equilibrium modeling approach with heterogeneous agents in the local economy and a clear empirical understanding of the parameters of the relevant markets, for which there are unfortunately no good data. We therefore opt for the simpler, stylized structure.

[6] Equivalently, assume $U(\cdot)$ is strictly increasing. While perhaps game meat becomes an inferior good as people become wealthy (and substitute beef for game), this assumption is reasonable in the context we examine—the current generation of a very poor population.

Manipulation of equations [9a–e] produces a generalized profit function, $\pi^*(p^*,w) = \sum p_i^* q_i$; a system of input demand and output supply equations, $q^* = q(p^*, w)$; a function defining full income, $y^* = \pi^* + \sum p_i^* e_i + s$; and a system of demand equations, $c^* = c(p^*, y^*)$. Human demand for and poaching of wildlife meat are endogenous to the model.

We need to specify functional forms to operationalize the model. A parsimonious specification makes sense given the lack of information on the behavior of peasant agriculturalists in the Serengeti. We employ a Stone-Geary utility function to economize on parameters and to incorporate subsistence needs explicitly. The specific model for [7a] is thus:

$$U(\mathbf{c}; n) = \Upsilon \prod_j \left(\frac{c_j - k_j}{n}\right)^{\theta_j} \quad \text{for } j, = f, g, h, l \qquad [10]$$

where Υ and the k_j's are positive constants, with the k_j's representing subsistence minima. We set k_f at one half kg per capita per day of maize, the staple food in the region; k_h—representing medicines, cooking fuel, building materials, tools, etc.—at 30 percent the expenditure level of k_f; k_l at 5 percent of household labor time; and $k_g = 0$. Without loss of generality, let $\sum_j \theta_j = 1$ and $\theta_j \geq 0$ $\forall\ j$. Based on household expenditure data (World Bank 1993), we set $\theta_f = 0.5$, $\theta_g = 0.15$, $\theta_h = 0.3$, and $\theta_l = 0.05$.

Similar concerns for parsimony motivate a Cobb-Douglas specification of technologies:

$$q_g = b_g(-q_{lg})^{\gamma_1} \qquad [11]$$

$$q_f = b_f(-q_{lf})^{\gamma_2}(-q_{tf})^{\gamma_3} e^w \qquad [12]$$

$$w = z + dv = z + \left[\frac{\rho\Omega}{(1-\rho)\xi}\right]^{1/2} v \qquad [13]$$

where $q_l = q_{lf} + q_{lg}$, z is an $N(0, \Omega)$ exogenous shock to agricultural yields that is independent from v, the $N(0, \xi)$ rainfall shock, and ρ is the correlation coefficient between agricultural yield and rainfall shocks. Simulations that follow in Sections IV and V proceed on the assumption that v and z are serially independent and identically distributed.[7] We set Ω to maintain a constant variance of q_f, equal to the observed variability in regional maize yields over the past twenty years, because maize is the dominant crop (USDA, various years). Because we do not know how poaching yields vary with rainfall, q_g is modeled simplistically as a deterministic function of q_{lg}. On the one hand, this is conservative because dry periods lead to greater wildebeest mobility and to longer residence times in unprotected areas west of park boundaries, nearer villages. On the other hand, poaching productivity is likely an increasing function of herd size, since a larger stock should increase poaching productivity, all else held constant. There are, however, two interrelated problems with a more complicated specification to [11]. First, the proximity and density effects appear strongly negatively correlated; as rains fail and mortality depletes the herd, the wildebeest tend to move closer to higher potential, more agricultural regions where they are more easily poached. Second, in the absence of any data on poaching inputs and output, it is impossible to establish which of these effects dominates in a given setting. We therefore opt for an obviously stylized approach, in part to call attention to the serious need for empirical work on the economics of poaching. We assume decreasing returns to labor in both agriculture and poaching as well as constant returns to scale in agricultural production ($0 < \gamma_i < 1$ for $i = 1, 2, 3$, and $\gamma_2 + \gamma_3 = 1$), with $\gamma_1 = 0.9$ and $\gamma_2 = 0.8$. The constants, b_f and b_g, were set at 10 and 1, respectively, to calibrate local maize output and game offtake volumes at $w = 0$ to the best estimates of current levels. Finally, mean land per rural Tanzanian household is 4.7 hectares (USDA), so $e_t = -q_{tf} = 4.7$.

[7] These error structures assume stationarity and homoskedasticity in climate patterns, wildebeest demographic stochasticity, and crop yields. Since the empirical limitations of the analysis preclude reliable long-run (i.e., intergenerational) analysis, this seems a reasonable assumption. But longer-run assessments of the design of such programs should probably confront directly the possibility of trend or difference stationary processes in the underlying environmental shocks.

Average household size in the Serengeti region was $n = 7.03$ persons in 1988 (Campbell and Hofer 1995). Using an intermediate estimate of 1.25 million persons in close proximity to the park in 1995, we use a base of $hh_0 = 177{,}800$ households. Let $l = n$, that is, all household members are available to work. We assume that human populations in the Serengeti continue to grow at the long-term rate, based on 1957–88 census data, of 2.9 percent per year (Arcese, Hando, and Campbell 1995; Campbell and Hofer 1995), with growth arising through increased numbers of households, such that $hh_{t+1} = 1.029hh_t$.

Section IIIA deferred definition of the harvest volume, H_t. Let gross game meat demand be $D_t = c_{gt}\, hh_t = (e_{gt} + q_{gt})hh_t$. We assume a constant 60 percent proportion of poaching (q_g), game meat sonsumption (c_g), and SRCS meat distribution (e_g) are wildebeest, based on existing data (Arcese, Hando, and Campbell 1995).[8] Our decision rule is thus that as long as $0.6D_t \leq H_t^*$, that is, as long as human demand does not threaten the sustainability of the wildebeest herd, then the PAM will honor the ICDP quasi-contract and deliver $0.6e_{gt}$, so that $0.6\, D_t = H_t$. Thus, the point we defined earlier as a crisis arrives when $0.6D_t > H_t^*$.

C. Behavior of the Household Model

A key feature of our household model is that the price of game meat and the wage rate for labor are both endogenous, which induces households to reallocate their time between labor on the farm, poaching, and leisure. These endogenous prices are a function, in part, of agricultural productivity, which is subject to external shocks. Thus, in years with adverse production conditions, the marginal product of agricultural labor declines and the marginal opportunity cost of leisure increases. These effects make poaching more attractive, capturing the propensity of peasants to poach as a survival strategy in the face of crop failure.

Endogenous prices and wages are also a function of endowments that partly or fully satisfy demand for game meat or leisure, including meat received from SRCS. Thus, to prevent poaching completely, SRCS must provide game meat such that $e_g = c_g$. This relaxes constraint [7c], reducing its associated multiplier, μ_g, driving p_g^* and the marginal returns of poaching to zero. At the same time, however, y^* increases with e_g, and this stimulates game meat consumption via income and substitution effects. This has often been overlooked in ICDP design. PAMs assume that meat distribution from managed culls can reduce or eliminate poaching but do not recognize that this also stimulates game meat consumption. This has the potential to undermine ICDPs that rely on wildlife harvest, and to do so rapidly if the demand for game meat is more price and income elastic. Thus, harvesting animals for distribution to human populations that would otherwise poach carries with it a risk of increasing the total offtake volume.[9]

The e_g, necessary to induce peasants to quit poaching is endogenous and depends on the realization of environmental shocks, w, to agricultural production. Thus, even if PAMs could accurately estimate households' willingness-to-accept value for cessation of poaching in one year, (i.e., the e_g that yields $q_g = 0$), conditional on known w, the amount needed to elicit acceptance in following years will change with probability one. As a

[8] A referee suggests that because harvest is independent of current period natural mortality in the model we use, this might understate the feasible noncatastrophic harvest. If the PAM could undertake selective harvesting to cull animals for meat before they would otherwise die of natural causes, harvest might endogenously reduce the natural mortality rate, enabling an increase in game meat harvest during those drought periods when the meat is of greatest value to local human populations, and slowing the movement toward a conjunctural crash in the wildebeest population. While we find this proposition intriguing, there is no empirical foundation in the ecology literature on the region with which one could adjust the PH wildebeest population dynamics model to accommodate such a hypothesis. Furthermore, this invests considerable faith in the selective harvesting ability of poachers and the PAM and presumes that selective culling is the optimal PAM activity in periods of high mortality risk.

[9] This result follows automatically from the assumptions that game meat is (1) nontradable ($c_g = e_g + q_g$), and (2) a normal good ($\partial c_g/\partial e_g > 0$). Combined, these yield $\partial q_g/\partial e_g > -1$, that is, there is less than a one-for-one trade-off of PAM-distributed meat for poached game.

result, where game poaching and consumption behaviors are endogenous, PAMs must be prepared to renegotiate the ICDP contract every year if they wish to eliminate poaching for good.

The effects are only slightly different if PAMs provide income transfers in another form, such as contributing to s instead of e_g. In this case, the transfer again produces positive income effects on c_g, but now the substitution effects are negative because cash transfers reduce λ. The net effects on game meat consumption are ambiguous, but the returns to poaching are increased by raising the relative price (p_g^*) of game meat. Thus, the more fungible the asset transferred, the less will be the effects of the transfer on game meat demand, but poaching and game meat consumption could increase nonetheless.

IV. SIMULATIONS OF TIME TO CRISIS

We generated an empirical distribution of the time to crisis by replicated simulations of the model in Section III. In each period of each simulation, we randomly drew with replacement the three exogenous variables (u, v, z) from their specified distributions and the α, β parameters from PH's published joint distribution. Based on these realizations of the time-varying exogenous variables, we solve the household's constrained optimization problem, computed the wildebeest population size, and determined whether $0.6\, D_t > H_t^*$. If not, we let N and hh grow according to the laws of motion specified above, then began the next period by resampling u, v, z, α, and β. Each simulation was replicated 300 times. We repeated this process 27 times, to account for alternative assumptions about: (1) the correlation between shocks to rainfall and to agricultural productivity (ρ), (2) the contractual volume of wildebeest meat given each household by the PAM (e_g), and (3) the rate of human population growth (m).

A. Base Model Results

In each of 27 scenarios, the median time to crisis was between 9 and 14 years, with standard deviations averaging about one-third of the estimates (Table 1). Time to crisis ranged from 2 to 58 years. Thus, if our parameterization of household behavior is at all accurate, this model suggests ICDPs that reduce essentially to game cropping are likely to collapse in less than one generation in the absence of other interventions to mitigate game meat demand and poaching. In Section V we resimulate the model to explore the effects of approaches to ICDP design that move well beyond game cropping.

The concentrated period of collapse is highlighted graphically in Figure 1, which also portrays the effects of a sensitivity anal-

TABLE 1
SIMULATION DESCRIPTIVE STATISTICS

Median (std dev)	$e_g = 0.33$	$e_g = 0.50$	$e_g = 1.00$
A: Human Population Growth = 2.9% (m = 0)			
$\rho = 0.3$	14 (3.4)	12 (3.3)	11 (3.6)
$\rho = 0.5$	12 (3.7)	11 (3.5)	10 (3.5)
$\rho = 0.7$	11 (3.5)	10 (4.1)	9 (2.9)
B: Human Population Growth = 3.4% (m = 0.005)			
$\rho = 0.3$	12 (3.6)	11 (3.2)	10 (3.3)
$\rho = 0.5$	11 (3.8)	10 (3.4)	9 (3.3)
$\rho = 0.7$	10 (3.3)	9 (3.0)	9 (3.0)
C: Human Population Growth = 3.9% (m = 0.01)			
$\rho = 0.3$	11 (3.3)	10 (3.3)	9 (3.4)
$\rho = 0.5$	10 (3.4)	9 (3.4)	9 (3.4)
$\rho = 0.7$	9 (3.0)	9 (3.2)	9 (3.0)

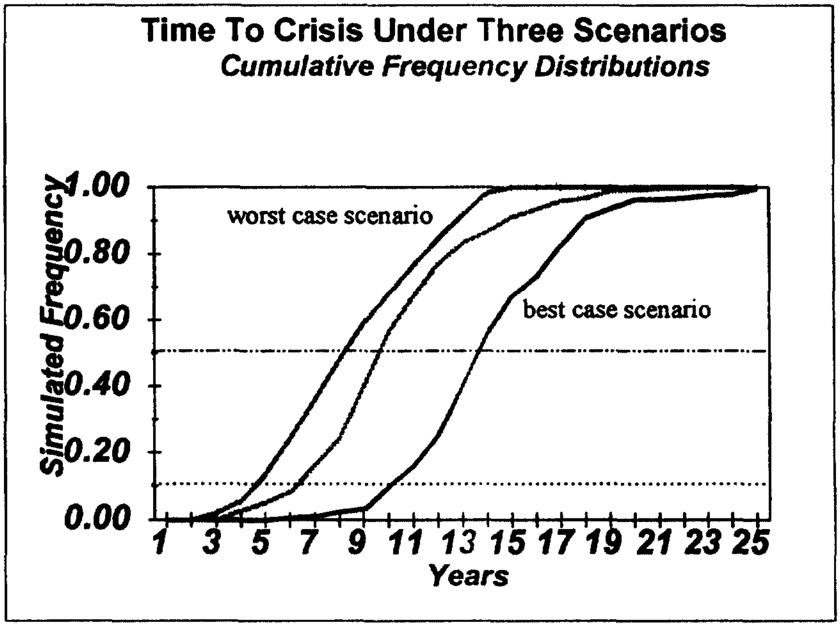

FIGURE 1
TIME-TO-CRISIS DISTRIBUTIONS

ysis performed with respect to e_g, m, and ρ. In the best case scenario, corresponding to the upper left cell in Table 1A, the PAM has a 50 percent probability of facing crisis within 14 years, and a 10 percent probability of crisis within 10 years. An intermediate scenario, the central cell from Table 1B, has a cumulative frequency distribution lying entirely to the left of the best case scenario distribution: 10 percent of crises occur within 6 years, 50 percent within 10 years. Most alarming is the worst case scenario, corresponding to the lower right cell in Table 1C. Here, the 10 percent and 50 percent probability levels for time to crisis are 5 and 8 years, respectively.

A second major result is that poaching remains common under a static distribution volume; that is, in the case of no renegotiation of contractual compensation under the ICDP. The percentage of periods in which $q_g = 0$ was 11.1 percent with $e_g = 0.33$. This increased to 17.3 percent with $e_g = 0.5$ and 28.8 percent with $e_g = 1.0$. Poaching occurred in most periods because the transfer level was constant over time, but demand for game meat and the relative returns to alternative activities changed in response to variability in the returns to agricultural labor.

Finally, although higher distribution rates, e_g, discourage poaching, they stimulate game meat consumption via income and substitution effects, and thus decrease the time to crisis (Table 1). The qualitative effects of increasing game meat distributions are similar to those resulting from an increase in the correlation between environmental stochasticity, wildebeest survival and recruitment rates, and agricultural production—which heightens the risk of a conjunctural crisis. An important difference, however, is that while PAMs have only limited and indirect influence over agricultural production via support for research and extension, they have direct control over e_g. This suggests that smaller distributions of game meat may help preserve the herd even though they do not eliminate poaching. This result is in contrast to the design of some wildlife ICDPs that depend heavily or, as in this simulation, exclusively on game meat distribution.

B. Modifying the Assumption of Constant Human Population Growth

To this point we have assumed that the introduction of an ICDP that provides income transfers to residents has no effect on the local rate of population growth. This is a conservative assumption because population growth rates in the Serengeti region are historically lower than in the rest of Tanzania and Kenya, probably as a result of greater emigration, lower immigration, and higher local mortality due to the region's severe poverty. However, amelioration of these conditions, as a result of improved incomes and nutrition via local development and enhanced availability of game meat, may increase the population growth rate in the near term.[10] Thus, it is worthwhile to explore the effects of increased human population growth on our results to this point.

To do so, we generalized the earlier formulation of human population growth to $hh_{t+1} = (1.029 + m)hh_t$, where m is the endogenous component of the local human population growth rate. Our baseline simulations set $m = 0$. We then reran the model under two less conservative estimates, $m = 0.005$ and $m = 0.01$, which correspond to local population growth rates of 3.4 percent and 3.9 percent, respectively.[11] As expected, the larger the human population drawing on wildebeest for food and income, the larger the harvests will be on average. Thus, our model predicts that more rapid human population growth will lead to greater pressure on the ecosystem and an earlier collapse of the ICDP. This is seen as a declining median time to crisis as m increases, holding e_g and ρ constant, as one looks down the panels in Table 1.[12]

V. THE SIMULATED IMPACT OF SOME ALTERNATIVE INTERVENTIONS

Examination of a representative simulation illustrates that crisis typically occurs at conjunctural moments of upward pressure on human poaching activity and natural wildebeest die-offs (Figure 2). This suggests some interventions that might improve the durability of the ICDP relative to a design that relies solely on game meat distribution. We explore four of these in more detail. First, we consider agricultural production technology improvements that increase the mean and reduce the variance of crop yields. Second, we explore the consequences of infrastructure improvements to facilitate access to and from the park. Third, we model the effects of increasing state-contingent public employment and antipoaching enforcement. Fourth, we combine the first and third strategies by imagining state-contingent public employment for capital improvements that change agricultural productivity, such as irrigation, agroforestry for wind breaks and erosion control, or water retention landscaping (e.g., bunding, ridging). These simulations are highly speculative because we have no empirical estimates for the model parameters we introduce. But such interventions are being actively considered in African wildlife ICDPs with which we are familiar, so tentative exploration of alternatives may assist policy analysis and guide further empirical work.

A. Ameliorating the Risk of Crop Failure

Poaching serves as income insurance against the risk of crop failure. In this case, the stronger the correlation between rainfall and agricultural productivity, the more dam-

[10] Long-term declines in human fertility rates associated with improved standards of living exceed time horizons of interest here.

[11] Increases in game meat demand that result from higher human population growth might be muted if a large part of growth came from expanding household size, but the evidence available suggests that the most recent growth in the region has come from an increase in the number of households (Campbell and Hofer 1995; World Bank 1995).

[12] Table 1 shows that the median time-to-crisis changes nearly symmetrically over variation in the three parameter values: e_g, m, and ρ. This may be a modeling artifact or a reflection of proximity to the biologically maximal harvests predicted by PH. At this point, any increase in total offtake leads to collapse in a few years.

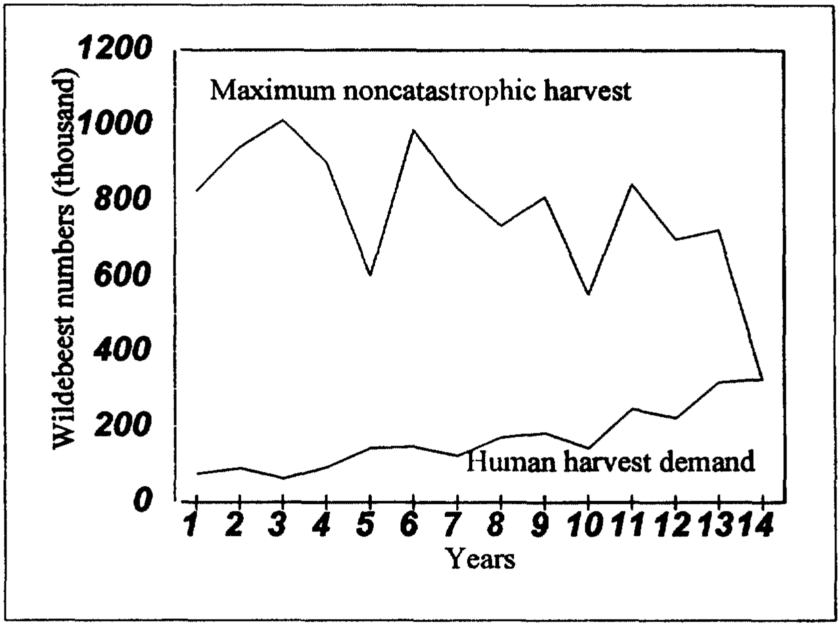

FIGURE 2
SAMPLE TIME PATHS FOR H_t AND H_t^*

aging is the insurance activity of poaching because covariate shocks to the wildebeest herd and crop yields induce greater human dependence on wildlife when the herd can least withstand increased harvest. The adverse effect of covariate environmental stochasticity on the durability of ICDPs is evident in the declining median time to crisis associated with increases in ρ (Table 1). This suggests that technology improvements that increase crop yields and reduce their variability may facilitate conservation, as might be achieved, for example, by introducing small-scale irrigation projects. To explore this possibility, we reran the base model ($e_g = 0.33$, $m = 0$, and $\rho = 0.3$) after increasing expected food crop yields (b_f) by 25 percent and reducing the variance of q_f by the same amount. These are ambitious targets for irrigation interventions exclusively (FAO 1986; Moris and Thom 1990), but may be attainable if combined effectively with research and extension efforts to control pests and soil erosion and to introduce improved seed varieties and better water retention through landscaping. Improved crop yield and consistency extended the median time to crisis from 14 years in the base scenario to 21 years under enhanced conditions. It also more than doubled the fraction of periods with no poaching ($q_g = 0$). Thus, improved agricultural technology may ameliorate drops in labor productivity caused by environmental shocks and thereby reduce the number of people that switch to poaching in bad growing years.

B. Improvements to Park Infrastructure and Access

Ecotourism advocates often favor infrastructure projects to improve park accessibility. However, roads and other infrastructure improvements may also facilitate the illegal transport of game meat and trophies out of protected areas, rendering these commodities more tradable. In Serengeti, for example, anecdotal accounts suggest that poached game meat is trucked to urban centers like Musoma, Mwanza, Kisumu, and, perhaps, Nairobi. Infrastructural improvements that further link these markets to Serengeti could increase the consumer population markedly.

Moreover, infrastructural improvements that reduce the cost of transporting game meat may also exacerbate the problem of poaching in response to crop failure if there are no new opportunities for local people to earn incomes that are independent of wildlife harvest.[13] In terms of our model, the returns to labor spent poaching in bad years, when people abandon low-return farming, will diminish with poaching volume more slowly in integrated than in isolated economies. This is because the price component of the marginal revenue product of labor is constant for tradables but is declining for nontradables when increasing output relaxes the availability constraint [7c] and thereby reduces μ_g and p_g^*.

To explore these ideas, we reran the base scenario with game meat classified as a tradable commodity as an assumed result of infrastructural improvements. As predicted, this reduced the median time to crisis by 5 years, from 14 years to 9. It also reduced the percentage of periods with no poaching by a third, to only 7.3 percent.

A referee points out that tradable game meat might, however, make it feasible for the PAM to sell meat on the market and distribute cash instead of game meat to the populations involved in the ICDP. As discussed in Section IIIc, a contribution to households' income transfers, s, instead of to game meat endowments, e_g, has ambiguous effects on demand. So we also resimulated a scenario under which tradable game meat permits the distribution of cash rather than meat. Replacing the positive baseline endowment of $e_g = 0.33$ with its cash equivalent, the median time to crisis was 13 years, essentially unchanged from the original model. While local demand for game meat is less under a cash distribution system, the returns to poaching are higher when game meat is tradable, thereby generating game meat exports from the region and the same fundamental problems with the sustainability of the ICDP design.

C. State-Contingent Employment and Antipoaching

Periods when environmental shocks induce peasants to poach are also those in which PAMs most need to conserve herd size to allow noncatastrophic harvests in the future since wildlife natural mortality rates rise. One mechanism for reconciling conservation and food security goals may be to use low rainfall as a trigger for state-contingent public employment schemes that provide wages in the form of cash or food that exceed the returns of poaching. Employment in support of antipoaching enforcement may also reduce the expected returns to poaching.

To explore this further, we modified our model to make labor tradable at an exogenous wage equal to the marginal revenue of labor spent poaching in periods of rainfall less than, or equal to, one standard deviation below the mean, assuming an aggregate annual poaching offtake of 30,000 head (about half the historic level).[14] This creates a wage labor option during periods of environmental stress into which households rationally self-select before choosing to poach beyond the noncatastrophic harvest volume. However, because there are no reliable estimates of the deterrence effect of added personnel on subsistence poaching (Arcese, Hando, and Campbell 1995), we assume for modeling purposes that the impact of added personnel

[13] A referee asks whether improved infrastructure might render labor tradable. While better roads could increase the elasticity of labor demand and supply, both through lower cost migration opportunities and additional, nonagricultural employment related to ecotourism, we doubt there would be a marked impact and thus retain the stylized limiting case of nontradable labor. Moreover, if labor and game meat both become tradable, the qualitative results of this scenario would be the same unless the parametric market wage rate was high—significantly higher than that modeled in Section V.C—because the shadow price of tradable game meat would no longer decrease with poaching volume.

[14] We implement this iteratively, representing the marginal revenue product of poaching labor time (i.e., also the wage in the employment scheme) from the marginal product of labor in [11], evaluated at $q_g = 30{,}000/hh_t$, and an estimate of p_g^* derived from an initial solution to the households' optimization problem without a wage labor market.

simply reduced b_g by 20 percent. Making these changes to the model more than doubled the median time to crisis, to 30 years, which may be the far horizon of reasonable prediction for our model. On average, the state-contingent employment scheme was invoked 2.6 times before reaching the crisis point, so this would not be a one-off intervention, but rather a program repeatedly activated. The percentage of periods in which there was zero poaching remained approximately 11 percent. These schemes have no significant effect on poaching frequency; rather, they limit episodic expansion in the volume of poaching activity at a time when the herd cannot withstand sharp increases in harvest volumes. State-contingent employment schemes that create an effective floor to the returns to poaching might not only mitigate human suffering during crop failures but may also enhance the sustainability of wildlife ICDPs. Episodic employment programs can effectively substitute for wildlife poaching in offering income insurance to peasant populations.

State-contingent public employment schemes could have even greater effect if used to improve the productivity of the underlying agriculture—for example, through labor-intensive capital improvements in small-scale irrigation, landscaping to reduce erosion and improve water retention, or revegetation to provide windbreaks and reduce soil erosion. The temporary effect of diverting peasant labor out of poaching could thereby be made (at least partly) permanent effects by increasing the productivity of agricultural labor in future periods. To demonstrate this, we resimulated the baseline model, this time increasing expected food crop yields and decreasing food yield variance, each by 5 percent for each period following the activation of the employment scheme. There can thus be several agricultural productivity improvements made over a period of years. This is a hybrid approach designed to address two core threats to wildlife in the midst of low-income agriculture: low labor productivity that limits agriculture's ability to absorb local labor and the threat of crop failure that induces episodic labor reallocation into poaching. The median time to crisis under this new scenario increased to 41 years, showing the value added by tackling jointly low agricultural productivity and the labor allocation problems posed by episodic crop failure. Moreover, the mean number of times the state-contingent employment scheme was activated prior to reaching the crisis point fell from 2.6 times (with an average time to crisis of 30 years) to 2.2 times. Using the state-contingent employment program to improve the underlying productivity of local agriculture thus lengthens the average interval between activations of the scheme (by almost two-thirds in these simple simulations), thereby decreasing the average labor cost of the interventions. This sort of design seems promising enough to merit more careful study and experimentation.

These modifications to the baseline model suggest the importance of moving ICDP design beyond a narrow construction designed to reduce poaching—for which game meat harvest and distribution might be appropriate—and toward one targeted at the fundamental economic causes of peasant wildlife poaching: low agricultural labor productivity and episodic crop failure. Technical changes, capital improvements, and state-contingent interventions to ensure a safety net can substantially relieve the pressures of food insecurity and poverty that prompt much poaching by agriculturalists in low-income areas like the Serengeti.

VI. DISCUSSION AND CONCLUSIONS

Pascual and Hilborn (1995) estimated the probability of collapse in the Serengeti wildebeest population under an exogenous harvest, assuming that human demand and poaching were under the control of protected area managers. However, experience shows these assumptions are probably false (Arcese, Hando, and Campbell 1995; Campbell and Hofer 1995; Hilborn et al. 1995; Mbano et al. 1995). In this paper we present a model that extends the work of PH by including elements of endogenous human behavior, using the nonseparable agricultural household modeling technique of DeJanvry et al.

(1991). Our model suggests that ICDPs that rely on wildlife harvest to reduce poaching are unlikely to be sustainable, particularly where game meat is tradable and environmental shocks reduce agricultural labor productivity episodically. This reinforces existing suggestions that more careful analytical and empirical modeling are urgently needed to help clarify the assumptions and improve the design of wildlife ICDPs (Barrett and Arcese 1995). By doing so, managers can be given better tools for identifying and monitoring potential pitfalls and adapting management tactics to prevent program failures.

Perhaps the central contribution of this exercise is to highlight that the conceptualization of the problem of wildlife conservation as one of reducing poaching—a common view among biological scientists in the field—leads to ICDP designs based on unsustainable approaches like game harvest. The central problem instead relates to poor rural households' allocation of labor time and the lack of sufficiently remunerative activities, especially in times of environmental stress, to keep peasants out of protected areas. Successful ICDPs will combat poverty, risk, and food insecurity by changing the capabilities and incentives facing human populations on parks' peripheries, not through handouts. One particularly promising approach combines improvements in agricultural productivity with state-contingent employment programs.

A. Model Assumptions

Our model enormously simplifies the interaction of wildebeest population dynamics with patterns of human demand for and poaching of game meat. However, it also captures some key features of these understudied interactions. Wildlife poaching is an important source of food and income for poor human populations under nutritional stress in the Serengeti-Mara region, and interviews of people arrested in the park suggest that the decision to poach is affected by the opportunity to earn income elsewhere (J. Magombe, S. Mduma, and P. Arcese, unpublished results). For example, anecdotal reports suggest that the recent liberalization of laws governing the sale of gold in Tanzania has led many young men from the Serengeti and Mara districts to leave poaching in the Serengeti for mining opportunities elsewhere. Peasant farmers respond to climatic or epidemiological shocks that depress farm labor productivity by altering their time allocation (Fafchamps 1993). We expect, therefore, that the mechanisms we model have some generality. If so, careful research on the effects of local economic development and agricultural production will help to validate and improve our model and permit practical application in conservation and development planning.

Nevertheless, in the absence of research results on most of the relationships we model, our parameterization of human demand patterns rests mainly on guesses. To try and insure these did not bias the baseline model toward collapse, we kept our assumptions conservative. For example, we assumed that wildebeest harvests did not exceed 60 percent of total number of animals poached in the system, that the human population base for game meat demand was strictly local, and that there was no recurrence of the prolonged dry season experienced in Serengeti during the 1960s (Sinclair and Norton-Griffiths 1979). Our sense, therefore, is that our simulation results are as likely to overstate as to understate the risk of near-term collapse of the various ICDP designs we model. This both highlights the precariousness of schemes that depend heavily on game meat distribution and the promise of those that address squarely the more fundamental causes of human predation on wildlife: low agricultural labor productivity caused by rudimentary production technologies and a meager capital base, and episodic crop failures for which there are few alternative insurance mechanisms other than poaching.

Finally, it is important to note that ICDPs are, in principle, assumed to foster cooperative efforts between project staff and local populations; and that this will facilitate the success of programs via voluntary reductions in activities that might otherwise undermine program sustainability. Indeed, instances of success in ICDPs do appear to depend on strong cooperation among parties to the quasi-contracts (Brandon and Wells 1992; Wells 1993). Our model, however, ignores the possibility of cooperative action and assumes instead that individuals act in myopic self-interest. This does not imply that we believe local communities in Africa or elsewhere are incapable of cooperation or self-policing. Instead, in the absence of relevant research results on the topic, it is simply not possible to speculate about the degree to which such cooperation might develop or deteriorate based on human population size, game meat distribution rates, enforcement effort, agricultural production, and environmental conditions. Moreover, cooperation might be uncommon under conditions of severe poverty, given the imperfect ability of authorities to control illegal harvest. Cooperation would also be relatively more difficult over wildlife with a large migratory range, like the wildebeest of the Serengeti, because the level of repeated interaction necessary to achieve a self-enforcing cooperative equilibrium may be hard to achieve over large spaces. Nevertheless, significant cooperation could counteract some of the incentive effects we find in the baseline model. This possibility highlights the urgent need for careful research on the development and durability of cooperation between ICDP managers and local people under a range of environmental, economic, and social conditions. Unfortunately, few such projects appear to be under way or planned (Kremen, Merenlender, and Murphy 1994; McNeely 1995; Western, Wright, and Strum 1994).

B. Alternatives to Wildlife Harvest as a Key Benefit in ICDPs

Static agricultural production technologies and market conditions, insufficient insurance mechanisms against natural risk, and human population growth are the crux of the threat to harvested species in our stylized game harvest ICDP. Thus, when few or no alternative sources of food or income exist, local people can be expected to kill protected species, especially when climatic or epidemiological shocks depress the productivity of farmwork. Given that the state of wildebeest and other wildlife populations varies with rainfall (Pascual and Hilborn 1995; Sinclair 1979), strong correlations between rainfall and agricultural yield can be expected also to result in a correlation between rainfall and poaching pressure, such that poaching will be most severe when herds can least sustain added harvest. This suggests that the development of mechanisms to obviate such pressures should be a priority in ICDP design. While wildlife harvest, at least on its own, does not appear a durable solution, alternative intervention strategies show more promise.

Obvious but challenging avenues include agricultural research aimed at improving yield, pest control and drought resistance for crops, epidemiological control for domestic livestock, and the stimulation of competitive, year-round rural labor markets to provide a competitive wage floor above the returns to poaching. These improvements enhance the viability of ICDPs because they provide higher and more stable incomes than can be expected from the harvest of wildlife. Moreover, by deemphasizing wildlife harvest as an element of ICDPs, managers may succeed in decoupling human demand, which clearly will grow, from the harvest of wildlife populations, which must remain stable or decline if they are to remain sustainable. By reducing the probability of confrontations in periods of stress, this decoupling could also help foster goodwill that would support the superior, cooperative solutions envisioned in much of the rhetoric about ICDPs but not commonly found in practice.

In contrast, infrastructural improvements to increase the accessibility of wildlife areas—a goal of many ICDPs that seek to increase ecotourist revenue—could expand the market for poached goods and hasten collapse of ICDPs if they do not simultaneously achieve increases in agricultural labor productivity or the creation of nonagricultural employment opportunities at satisfactory wage rates. First, roads or other improvements may facilitate the illegal transport of game meat and trophies out of protected areas and render them more tradable. In Serengeti, if game meat were regularly trucked to urban centers like Musoma, Mwanza, Kisumu, and Nairobi, the size of the consumer population might increase by an order of magnitude. Second, direct transfers of cash or equivalent benefits to local communities may have the unintended effect of increasing demand for game meat via income (and, in some designs, substitution) effects, and may also increase the rate of population growth inside the area participating in the ICDP via immigration. Growth in human demand for game meat, due to both income and human population growth, poses a threat to wildlife populations slated for harvest. ICDPs that provide income transfers to local people may therefore hasten their own collapse in the absence of complementary measures to improve antipoaching enforcement and the availability of other foodstuffs and consumer goods.

A final alternative is to increase the risks to poaching via enforcement, as suggested by SRCS (Mbano et al. 1995). Our model suggests this should discourage peasants from reallocating their labor time to poaching. By itself, however, increased antipoaching effort will probably not decouple rural livelihoods from poaching, and it may exacerbate conflicts between local people and PAMs unless viable alternatives to poaching are made more available.

In summary, the degree of promise shown by ICDPs is conditional on their design. There remain serious challenges ahead in the design of enforceable, durable contracts between protected area managers and community leaders and members. Although some of these are foreseeable (Barrett and Arcese 1995; Brandon and Wells 1992; Kremen et al. 1994; Salafsky 1994; Sinclair 1995b; Wells 1993), few proponents or administrators of ICDPs that rely on wildlife harvest discuss them at length, and perhaps as a result, few ICDPs with a wildlife harvest component have established monitoring programs that are sufficiently detailed or funded to be able to detect the kinds of pitfalls we outline here. We therefore predict that wildlife harvest in many ICDPs will become unsustainable in the near term if there are not strong ancillary efforts to address underlying structural problems that cause peasants to rationally allocate labor to poaching, and episodically in devastatingly large volumes. Wildlife conservation in the midst of low-income agriculture depends fundamentally on increasing average agricultural labor productivity and on providing a safety net in the form of alternative labor demand when crops fail. This highlights the potential role for larger organizations (e.g., states, international agencies) in supporting ICDP initiatives and, in particular, in sustaining them in bad times. ICDPs must be embedded in a larger political-economic framework since local agencies are generally unable on their own to develop and disseminate improved technologies, to deepen and broaden rural labor or financial markets, or to access funds necessary to buffer shocks. More durable approaches than game harvest must be identified and followed if we are to meet the challenge of wildlife conservation in the midst of endemic rural poverty.

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