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Above-ground production and response to defoliation on a native pasture in lowland Nepal

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Abstract

Annual above-ground production, livestock consumption, and response to experimental defoliation were measured on adjacent grazed and fenced areas of a village pasture in lowland Nepal. Grazed pasture composition was dominated by *Chrysopogon aciculatus* (45%), *Cynodon dactylon* (19%), and *Imperata cylindrica* (19%). Ungrazed pasture inside an adjacent 22 m x 22 m exclosure was dominated by *I. cylindrica* after one year of protection from grazing. Annual above-ground production of the grazed area was 8700 kg/ha, whereas production inside the exclosure was 17 000 kg/ha. Livestock consumed nearly all the annual above-ground production. An experiment examined the effect of four frequencies of defoliation on pasture production. Defoliation reduced production in a nonlinear manner: defoliation every 11 days reduced production 42%, but defoliation every 90 days reduced production 21%. A model was fitted to cumulative production measured for three defoliation treatments to estimate periodic and annual yield for 2-week, 7-week, and 13-week schedules of cutting protected pastures for stall feeding village livestock. Cutting grass on a 13-week schedule has the potential to produce 13% more fodder than continuous grazing and provides a partial solution to illegal grazing in Chitwan National Park.

Resumen

La produccion aèrea de biomasa, el consumo del ganado, y la respuesta a la defoliación experimental fueron medidas en áreas adyacentes pastoreadas y cercadas, en las tierras bajas de Nepal. En las pasturas en pastoreo predominaron las especies Chrysopogon aciculatus *(45%),* Cynodon dactylon *(19%), e* Imperata cylindrica *(19%). Las pasturas sin pastorear en un àrea de 22 x 22 m fueron dominadas por* I. cylindrica, *después de un año sin pastoreo. La producción anual del àrea pastoreada fue 8700 kg/ha, mientras que la producción en el àrea sin pastorear fue de 17 000 kg/ha. El ganado consumió casi toda la producción aérea. El efecto de cuatro frecuencias de defoliación en la producción de la pastura, fue examinado en un experimento. La defoliación redujo la producción no linealmente: la defoliación cada 11 días redujo la producción 42%, pero la defoliación cada 90 días redujo la producción 21%. Se ajustó un modelo a la producción acumulada, medida en tres tratamientos de defoliación (cada 2, 7 y 13 semanas), para estimar el rendimiento periódico y anual de las áreas sin pastorear, usadas para la alimentación del ganado estabulado de la villa. La defoliación a intervalos de 13 semanas tiene el potencial para producir 13% más alimento que el pastoreo continuo y además que constituye una solución parcial para el pastoreo ilegal en el Parque Nacional de Chitwan.*

Introduction

Feeding livestock in rural lowland Nepal is an enduring problem for villagers. Common grazing pastures that surround agricultural land are heavily overgrazed, as are forest reserves within a day-trip of villages and around remote grazing camps. High demand for fodder imposes constant pressure on grasslands protected within wildlife reserves and national parks, such as the Royal Chitwan National Park in south-central Nepal (Mishra 1982, 1984; Sharma 1991). Grass fodder is scarce in pastures adjacent to the Park during the hot dry season from March to May, whereas ungrazed tall grasslands on primary floodplains in the park are lush and highly productive during that time because of a high water table (Lehmkuhl 1989). Consequently, many people illegally enter the Park to cut grass or let their cattle wander into the Park to graze.

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Strategies to improve village pastures and increase fodder supplies outside the Park are necessary to reduce conflicts with villagers who require healthy productive livestock (Mishra 1982, 1984; Sharma 1991). Stall feeding and pasture improvement have been suggested as solutions to reduce livestock encroachment in national parkland, reduce overgrazing in forest reserves, provide for better husbandry of fodder resources, and increase livestock production (Carson *et al.* 1986). Moreover, stall feeding has become important where common grazing grounds owned by the central government have been fenced to establish fuelwood and tree-fodder plantations, but still allow grass cutting (Sharma 1991). Very little published information is available on the composition, productivity, and response to defoliation of village pastures to serve as a basis for pasture and livestock management.

The goal of this research was to do a case-study of production and guidelines for fodder management on pastures adjacent to the Royal Chitwan National Park, Nepal. Specific objectives were: (1) Describe composition and estimate annual above-ground production; (2) Observe changes in composition and productivity with protection from grazing; and (3) Assess impacts of different levels of clipping on production to develop grass-cutting recommendations for stall feeding. Secondary objectives were to test the grazing optimisation hypothesis, i.e., determine if production was optimum at some intermediate level of defoliation (McNaughton 1979, 1986; Belsky 1986, 1987), and to provide insight into the dynamics of similar grazing lawns (McNaughton 1984) in the Park that develop under heavy grazing by wild, large-mammalian herbivores.

Methods

I conducted studies from April 1986 to March 1987 on the 8 ha Hattisar (elephant camp) pasture near the lowland Terai village of Sauraha, Chitwan District, Nepal. Elevation of the site is about 120 m. The climate is subtropical with a summer monsoon. Annual precipitation usually exceeds 2000 mm, with 80% falling from June to September (Lehmkuhl 1989). Mean maximum temperature is 37 °C during April, and the mean minimum temperature is 7 °C during January (Lehmkuhl 1989).

I erected a 22 x 22 m exclosure with a 5-wire electric fence on the pasture to measure ungrazed production and observe compositional changes with protection from grazing. A comparable unfenced area adjacent to the exclosure was used to measure grazed production. I estimated composition of the grazed area during April 1987 by point-frame sampling along eleven 20-m transects. Five point hits were recorded at each of 10 stations systematically located along each transect from a randomly chosen starting point.

I measured above-ground biomass in the grazed area by the caged-plot method (Milner and Hughes 1968) using temporary barbed-wire exclosures. The prostrate growth form of the grasses and very close cropping by livestock made it impossible to clip with shears to collect all above-ground biomass. I therefore removed herbage by scraping with a trowel-like device, commonly used by villagers for that purpose, at ground level or <0.5 cm below the soil surface, then washed soil away prior to weighing. The problem with this procedure was that scraping collected a small amount of below-ground biomass, and thus more herbage than was available to livestock.

I randomly sampled biomass in the grazed area from four rectangular 0.5 m^2 caged plots and four uncaged plots to estimate production by the caged-plot method at ten 5-weekly intervals over one year. Different plots were measured at each sample period. Forage consumption by livestock was estimated from caged-plot data by Linehan's formula (Linehan *et al.* 1952; Sharrow and Motazedian 1983). I counted livestock grazing the pasture within a day of clipping to provide a rough estimate of grazing intensity. I estimated standing biomass inside the exclosure concurrently by clipping four 0.5 m^2 rectangular plots, then scraping residual biomass at ground level as done in the adjacent grazed area. Both green and dead material were included in the sample biomass. Samples were dried at 60-70 °C for 2 days in a laboratory oven before weighing. All reported biomass estimates are of dry weight.

I conducted an independent experiment inside the exclosure during the same period to study the effects of four levels of defoliation frequency on above-ground production. The effects of defoliation every 11, 22, 45 and 90 days on production in 6 replicate plots were compared to undefoliated controls for one year. Plots of 0.5 m^2 were arranged in a randomized block design with blocks aligned across a gentle slope. Biomass was clipped with shears at ground level according to the treatment schedule, then dried and weighed.

I examined the effect of defoliation treatments on cumulative yield by one-way analysis of variance. Orthogonal comparisons (Sokal and Rohlf 1981) of adjacent treatment means were made at an error probability of $P = 0.05$. *Post hoc* comparisons were evaluated by adjusting the overall error probability $P = 0.05$ by the Bonferroni procedure (Wilkinson 1988) to account for multiple comparisons. I fitted cumulative yield of three clipping frequencies at each sampling period to the model,

$$B = a * (1 - \exp(-b * T^c))$$

where B = cumulative biomass, T = Julian date, and a, b, and c are model parameters, with the Quasi-Newton nonlinear algorithm (Wilkinson 1988).

Results

Pasture composition

Chrysopogon aciculatus was the dominant grass with 37% ground cover in the grazed area, followed by *Cynodon dactylon* (20%) and *Imperata cylindrica* (19%). No other species recorded more than 3% ground cover. Dead biomass gave 16% cover and 4% was bare ground. *I. cylindrica* grew to about 0.5 m height and dominated the ungrazed area inside the exclosure within one year. A few formerly suppressed *Saccharum spontaneum* plants (0.1/m^2), released from grazing inside the exclosure, rapidly grew to 3–4 m height within a year.

Production on grazed and ungrazed sites

Above-ground production. Annual production in the ungrazed exclosure during the first year after protection was estimated by combined clipping and scraping as 17 000 kg/ha, the difference between initial April biomass and peak October biomass (Figure 1). Clipped production alone was 13 400 kg/ha. Samples taken from November to March were excluded from the analysis because of human intrusion during November. Annual production on the grazed area from April to October was 8700 kg/ha. Grazed and ungrazed production both peaked during October.

After an autumn dormant season, production resumed on grazed plots during January, when mean daily temperature began to increase (Lehmkuhl 1989). Total grazed production during that time (Jan.–Apr.) was 1880 kg/ha. These data indicated some production occurred from January to April before the experiment had begun, so a better, although speculative, estimate of annual production on grazed and ungrazed sites would add 1880 kg/ha to yield 10 580 kg/ha grazed production and 18 880 kg/ha ungrazed production.

Consumption by livestock. Livestock density was high on the 8 ha pasture. An average of 198 head of livestock (25/ha) per day were found grazing the pasture, with a maximum of 410 head counted on one day. About 70% of the stock were cattle and 12% were water buffalo. Stock were not kept in the pasture all day, but were moved along a daily grazing circuit, probably spending an hour per day on the pasture.

The rate of biomass consumption by livestock roughly paralleled grass production throughout the year (Figure 1). Production and consumption estimates in Figure 1 suggested that livestock consumed nearly all the annual production, which is not to say that 100% of the standing biomass was utilized. Rather, standing biomass remained relatively constant while livestock removed new production.

Defoliation response. Defoliation by clipping significantly depressed production of shoot biomass ($P = 0.001$) (Figure 2). Orthogonal comparisons of adjacent treatment-pairs revealed a significant difference only between the 45-day and 90-day defoliation regimes. *Post hoc* comparison of the combined 11-, 22- and 45-day treatments against the 90-day treatment indicated a significant treatment effect (Bonferroni $P < 0.025$) but the 11- and 22-day treatments together were not different from the 45-day treatment.

Biomass on the control plots should be slightly higher than pictured in Figure 2. A few cows got into the exclosure for a few minutes one morning during September and ate grass from some control plots, and villagers later removed a small amount of grass under cover of night as evidenced by clipping. Control biomass could have been as high as 18 000 kg/ha based on production estimated from immediately adjacent undisturbed

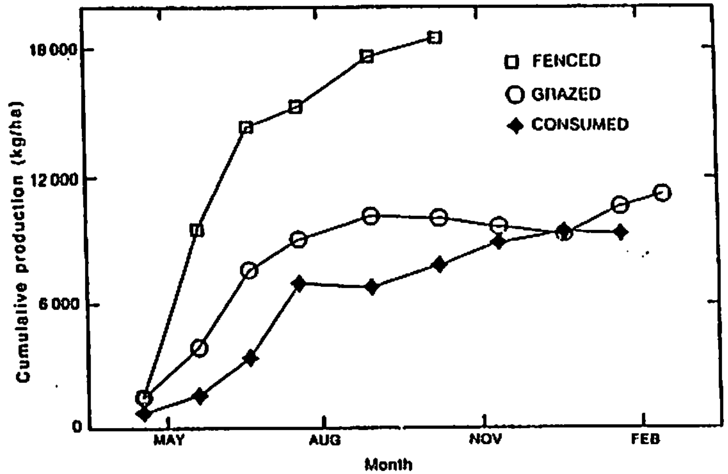

Figure 1. Annual above-ground production and livestock consumption on a native grazed pasture, and annual above-ground production in an adjacent ungrazed exclosure on the Hattisar pasture near Sauraha village, Nepal, during 1986–87.

plots inside the exclosure (Figure 1). No other plots were disturbed.

Production models were fitted for three cutting schedules to estimate grass production for stall feeding. Data from 11- and 22-day clipping treatments were not significantly different, and were pooled to estimate a model for a 2-week cutting schedule. Curves were fitted for the 45-day and 90-day treatments to estimate 7-week and 13-week cutting schedules. Although total yield for the 45-day treatment was not significantly different from yield from more frequent clipping treatments, I fitted a model to these data to give estimates of yield for an intermediate cutting schedule.

Residual error was small, with models slightly

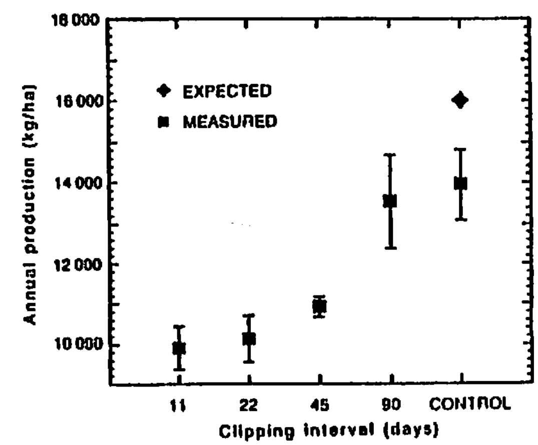

Figure 2. Annual above-ground production under experimental defoliation intervals of 11, 22, 45 and 90 days, compared with production on undefoliated control plots ($n = 6$) on a native pasture in lowland Nepal, 1986–87. The expected value for control production was estimated from the immediately adjacent non-experimental area (see text). Bars show the standard error of the mean.

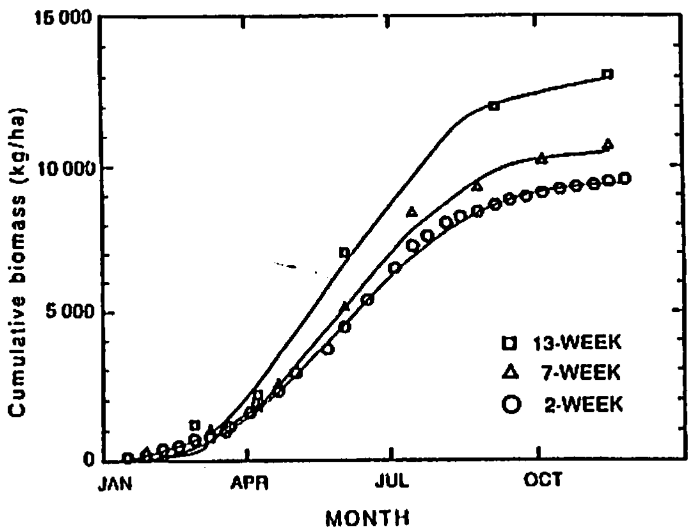

Figure 3. Cumulative biomass of a native mixed-species pasture in lowland central Nepal from 2-week, 7-week and 13-week cutting schedules. Points are original data, and lines are model estimates.

underestimating production early in the year and during the summer (Figure 3). Production was most rapid between April and September for all cutting schedules. Annual yield was an estimated 9400 kg/ha, 10 440 kg/ha and 12 970 kg/ha for the 2-week, 7-week and 13-week cutting schedules. Estimates of annual yield and yield during each cutting interval can be calculated with the model using the following coefficients: 2-week schedule, a = 472.5, b = 4.938 × 10^{-7}, c = 2.757; 7-week schedule, a = 524.5, b = 2.746 × 10^{-7}, c = 2.876; 13-week schedule, a = 650.6, b = 7.013 × 10^{-7}, c = 2.705.

Discussion

Composition

Composition of the pasture establishes it as a disturbance phase of the floodplain *S. spontaneum* association identified by Lehmkuhl (1989). The composition conforms somewhat to a disturbance phase in the commonly cited successional sequence for a heavily grazed *S. spontaneum* floodplain association described by Dabadghao and Shankarnarayan (1973; referred to as DS below). Under the DS scheme, undisturbed swards are dominated by tall *S. spontaneum*, with the shorter *I. cylindrica* as an understory species. Heavy cutting and grazing result in the decline of *S. spontaneum* and dominance of the more resistant *I. cylindrica*. Continued heavy grazing eventually leads to dominance by annual grasses. Protection from grazing and cutting reverses the trend.

The change in pasture composition with protection follows the DS sequence, but the paucity of annuals deviates from DS. Annuals formed a small part of the pasture flora, which was dominated by the grazing-resistant perennial *C. aciculatus*. Sampling and examination of heavily-used wildlife grazing lawns inside the Park and pastures suggest that *C. aciculatus* dominates sites on secondary floodplain terraces with rich soils. Similar sites on primary floodplains with sandy soils more closely follow the DS scheme with a diverse flora of up to 20 species of annual and perennial grasses (J.F. Lehmkuhl, unpublished data). Production dynamics of pastures on secondary floodplains, such as the one in this study, would be a relatively poor model for understanding the production dynamics of most grazing lawns, which occur mainly on primary floodplain.

Production

The difference in annual production between grazed and ungrazed areas appeared largely the result of changes in composition with protection. Protected plots were dominated by 0.5 m-tall *I. cylindrica*, whereas the grazed plots were a mix of prostrate grasses and suppressed *I. cylindrica* and *S. spontaneum* not more than 2 cm tall.

The topography and soils at the site are similar to other pastures on secondary floodplains in the area, so the results of this study should be generally applicable to those pastures (but not grazing lawns). Annual production of *I. cylindrica* measured by clipping inside the exclosure after one year of protection (13 400 kg/ha) was similar to production of another *I. cylindrica* sward 10 km distant in the Park that was protected from grazing (12 000 kg/ha) (Lehmkuhl 1989).

Defoliation

The defoliation experiment indicated no grazing optimisation (McNaughton 1979, 1986) or overcompensation (Belsky 1986, 1987) of production. Clipping, however, may not adequately simulate the manifold effects of grazing: experimental clipping has been shown to have a greater negative effect on production than grazing (Stroud *et al.* 1985; Johnson and Parsons 1985). Nevertheless, production experiments in the Park with protected *I. cylindrica* swards and swards grazed by wild herbivores did not involve clipping and also suggested undercompensation (Lehmkuhl 1989). Also, different results may have been produced using a longer clipping interval.

Grass cutting management

The defoliation experiment and model suggested that grass cutting at 2-week intervals yields amounts of forage for livestock roughly equal to that consumed by them during grazing. The quality of 2-weekly cut forage should be similar to grazed forage because phenology is similar and compositional changes with short-term protection would be small. However, stall feeding cut grass could result in higher livestock production per unit forage by elimination of the energetic costs of grazing. Stall feeding would have the additional benefit of retaining for crop fertilization manure that would ordinarily be deposited on pastures, but elimination of manure on pastures may reduce production. Other potential

problems with stall feeding are the labour required to cut fodder daily for livestock, prevention of unauthorized cutting, and the practicality of keeping livestock out of fenced areas. However, grass cutting in fenced pastures or new fuelwood plantations has been successful in Chitwan during recent years, and is considered a primary tool for increasing local fodder supplies (Sharma 1991).

The 7-week schedule would produce only a nominal 10% increase in forage above the 2-week schedule, but cutting every 13 weeks could potentially produce 30% more forage than grazing. However, the quality of 13-week cut forage is lower than continuously grazed forage, and may negate potential benefits of higher yield. Grazed forage has an estimated 80% more crude protein than 13-week old *I. cylindrica* (13.4% *vs* 7.3%), 47% more digestible cell solubles (28% *vs* 19% by the detergent fibre technique), and 14% less indigestible lignin (5.8% *vs* 6.7%) (E. Dinerstein, unpublished data). However, crude protein of 13-week old *I. cylindrica* is above maintenance levels of digestible crude protein for working bullocks (6% for 600 kg animal) and for maintenance, pregnancy and lactation of cattle and buffaloes (5% for 600 kg animal) (Ranjhan 1980, pp. 256, 269). Research on the interactive effects of forage yield and quality on livestock production should be an element of stall-feeding programs.

Fencing pastures for grass-cutting would release suppressed *S. spontaneum*, which would present a problem for maximizing herbaceous fodder production. The stout woody culms of *S. spontaneum* are little used by livestock other than domestic elephants, and shading by tall culms would reduce the vigour and cover of more palatable prostrate grasses. *S. spontaneum*, however, does have value as a dry season fodder before extensive woody growth occurs. Regrowth begins during January and shoots are 15-30 cm tall in the Park 3 months later during the hot dry season, when pasture biomass is low and extensive cutting of *S. spontaneum* by villagers indicates its value as fodder. In addition to high palatability, new *S. spontaneum* foliage is highly nutritious with about 10% crude protein (E. Dinerstein, unpublished data). Management of some pastures or tree plantations for *S. spontaneum* could provide a good dry season fodder source outside the Park.

The seasonal trend of abundant biomass during the summer and low availability during the winter suggests that some form of fodder conservation is desirable. Making hay and silage are little practised in the subcontinent, but may have potential for increasing fodder availability during the dry season and maintaining healthy village livestock (Ranjhan 1980; Pathak and Jakhmola 1983).

These data are based on a case study and provide preliminary guidelines for managers. Several years data on defoliation might show declines in productivity under heavy cutting schedules. Also, these data probably do not represent the full range of pasture productivity for the district, and should be cautiously applied to other sites outside the immediate area. Plans for pasture management should include preliminary sampling and monitoring of forage and livestock production over several years.

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