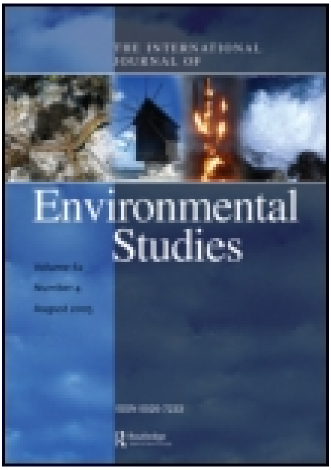

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IMPACT INDICES FOR GRAZING ACTIONS

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Proposals for animal grazing actions on federal lands in the United States are subject to both permit requirements and the environmental impact assessment (EIA) process. Such actions are often controversial due to the detrimental effects of overgrazing on vegetation, soil, riparian zones, water quality, and wildlife habitat. This paper highlights the potential negative environmental impacts of livestock grazing on rangelands in the western United States, identifies techniques or models that could be used to determine the severity of these impacts, and enumerates several indices which have been used to summarize environmental data in relation to decision-making processes. Nine such indices, along with several additional ones which could be reasonably developed, are described herein. These indices, used either individually or in a composite format, could serve as reasonable bases to identify vulnerable rangelands, provide a framework for impact prediction, target monitoring efforts to identified rangelands, facilitate the determination of sustainable grazing practices, select mitigation measures, and document decisions for new or renewal grazing permits.

Keywords: Animal grazing; environmental impacts; impact indices; impact measurement techniques

INTRODUCTION

The U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) together manage approximately 274 million acres of public rangelands [1, 2]. Both BLM and the USFS issue permits for grazing on sections of land called allotments. In general, these permits specify the type of livestock, the period of allowable use, and the

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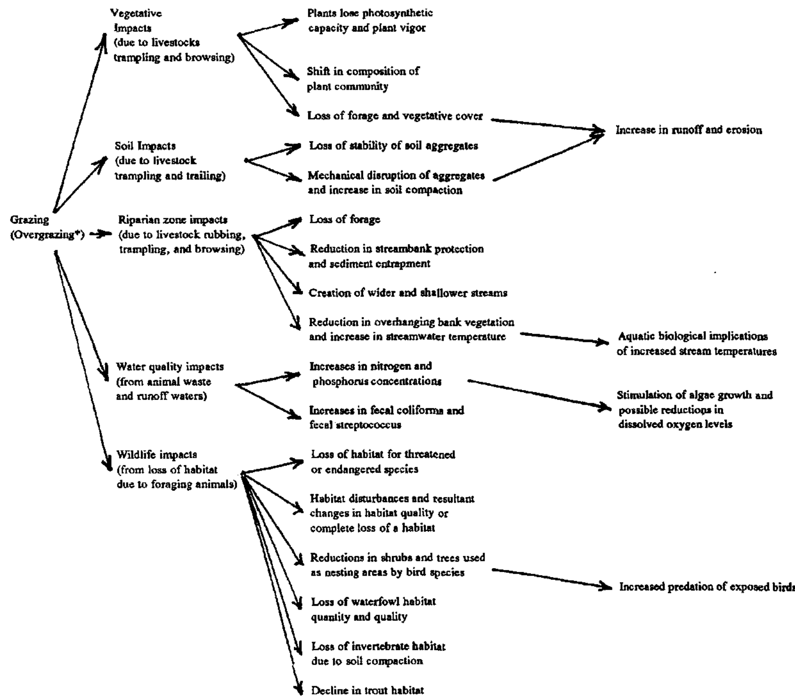
authorized level of grazing activity. As federal agencies, BLM and the USFS are also subject to the requirements of the National Environmental Policy Act (NEPA). BLM has used environmental impact statements (EISs) to determine initial sustainable grazing levels, with such EISs and/or resultant permits scheduled for review and adjustment on five year cycles. Grazing on USFS lands must be consistent with the pertinent forest management plan as well as NEPA and other federal laws and regulations [3]. However, despite these efforts, approximately 70 percent of publicly managed rangelands in the United States are in poor or only fair condition due to overgrazing or grazing mismanagement, lack of proper range management, lack of riparian habitat management programs, and inadequate monitoring [4]. Independent studies by the U.S. General Accounting Office confirm that BLM and the USFS are not performing necessary monitoring due to staff shortages and competing responsibilities [1, 2].

This paper begins by summarizing the potential negative impacts of livestock grazing on rangeland vegetation, soils, riparian zones, water quality, and wildlife. Also described are techniques that have been used to measure (monitor) the severity of these impacts. The final section summarizes several uses of indices for evaluating grazing impacts. Environmental indices, which use numbers or descriptions to categorize large amounts of data, simplify information so that it is more useful to decision makers, such as governmental rangeland managers, and various publics such as livestock owners, nongovernmental organizations, and concerned citizens. In general, indices are developed by identifying indicator factors, assigning an importance weight to each factor, establishing a method for factor evaluation, determining the numerical or qualitative aggregation approach, and applying and verifying the index [5]. The included factors may be described by qualitative, semi-quantitative, or quantitative information or data.

ENVIRONMENTAL IMPACTS OF LIVESTOCK GRAZING

Over-extensive livestock grazing can cause undesirable impacts on vegetation, soil, riparian zones, water quality, and wildlife. Figure 1



*Overgrazing can occur when the stocking rate is exceeded or when resultant negative impacts occur.

FIGURE 1 Network diagram for grazing actions on rangeland.

highlights a network diagram depicting these impacts and their interrelationships.

1. Vegetative Impacts

Livestock trampling may destroy vegetation, and thus reduce both plant cover and litter cover. Individual plants subject to foraging may lose photosynthetic capacity and plant vigor, thus decreasing their competitive ability [6]. Over time, the age structure of the plant population can become skewed to the older age classes, and the composition of the plant community can shift to favor the establishment and regeneration of toxic and spinescent woody plants, which have a competitive advantage because they are ignored by grazing livestock [7]. These woody shrubs and trees can eliminate other plants by successfully competing against them for water [8].

2. Soil Impacts

In general, overgrazing destroys soil aggregates which, depending upon the amount of moisture in the soil, results in loose dust or soil compaction [9]. The stability of soil aggregates is affected by reduced vegetative cover and livestock trampling and trailing. Since less precipitation is intercepted by vegetation, raindrops strike the exposed soil with more force and are more likely to break aggregate bonds. A decrease in vegetative cover also results in a decrease in soil organic matter and root biomass, with these components helping to form and stabilize aggregates. Extreme overgrazing may cause accelerated erosion which cannot be reversed by natural processes [9].

Livestock trampling and trailing can further reduce aggregate stability by mechanically disrupting aggregates and increasing soil compaction [9]. Soil compaction decreases the infiltration rate and can lead to increases in runoff, sediment production, and erosion. Compaction may also reduce vegetative growth and decrease soil porosity [10]. The magnitude of trampling and trailing impacts varies with soil type, soil water content, climate, and vegetative conditions; such impacts generally increase as grazing intensity increases [9]. Trampling also destroys the cryptogamic crusts formed by lichens, moss, algae, and fungi; these crusts help stabilize desert soils, fix nitrogen, and conserve soil nutrients [11].

3. Riparian Zone Impacts

Riparian ecosystems are assemblages of plant, animal, and aquatic communities whose presence is directly or indirectly attributable to stream-induced or related factors [12]. Although riparian zones are a minor proportion of the overall area of rangelands, they produce considerable biomass for animals. For example, in the arid portions of the western United States, riparian ecosystems support 42 percent of the mammals, 38 percent of the birds, 33 percent of the reptiles, and 13 percent of the amphibians [13]. In addition, 64 endangered species depend upon western riparian habitats. To exacerbate the problems, it has been found that livestock graze more heavily in riparian zones because they have flatter terrain and offer easy access to water, shade, and succulent vegetation [14].

Livestock can damage riparian vegetation by rubbing, trampling, and browsing. In general, forage loss due to trampling and treading varies from 23 to 50 percent in the area grazed [13]. Soil compaction, which increases runoff and decreases the amount of water available to plants, may also affect riparian vegetation [12]. In grazing studies in the Idaho mountains in the western United States, some riparian habitat alteration occurred when vegetation was used at a rate equal to or greater than 65 percent of that available; habitat alteration was insignificant when the utilization rate was 25 percent or less.

Excessive grazing also reduces the ability of riparian vegetation to protect streambanks and trap sediments [14]. When livestock graze on streambanks, trampling and hoof slide may cause banks to collapse and soil to enter the stream. As a result, stream channels may become wider and shallower. In a study of 17 environmental conditions in a riparian environment that was subject to heavy grazing pressures from sheep, it was found that streams were over four times wider in heavily grazed areas, that stream depth was five times greater in lightly grazed areas, and that the percentage of instream vegetative cover was higher on lightly grazed areas [15]. Livestock grazing can also reduce overhanging bank vegetation, which may lead to stream water temperature increases of as much as 12° F [13]. The widening and shallowing of stream channels or a reduction in summer low flows, both potential impacts from livestock grazing, may also cause increases in water temperatures [14]. These changes can in turn affect aquatic ecosystems.

4. Water Quality Impacts

Livestock grazing affects local surface water quality by increasing the concentrations of nutrients and bacteria. The severity of the impacts is a function of waste concentration, the proximity of waste to the receiving water, and the opportunity for runoff [14]. Nitrogen and phosphorus in animal wastes can stimulate algal and aquatic plant growth, which may in turn reduce the levels of dissolved oxygen.

Livestock grazing may also cause increases in bacterial concentrations in rangeland streams. Bacteria enter streams through direct deposition of waste material or transport by overland flow. Bacterial concentrations may fluctuate widely depending upon the time of day, recent storm or runoff events, and the presence of wildlife which represent additional sources of enteric bacteria. Indicator bacteria, such as fecal coliform and fecal streptococcus, can survive for months in an aquatic environment, even after livestock are removed. Benthic sediments, which typically increase the survival time of bacteria, contain significantly higher concentrations of enteric bacteria than overlying waters in rangeland streams [16]. Disturbing the stream bottom, either by increasing stream flow or by livestock or wildlife moving through the water, may resuspend these bacteria and cause them to move downstream.

5. Wildlife Impacts

Both domestic livestock and wildlife need food, water, cover, and space to survive [17]. Cover is particularly important to wildlife since they use it to avoid detection by predators, to escape predators once they have been detected, and to protect themselves against extreme temperatures and high winds. Cover may also increase food availability by creating a micro-environment that encourages growth of preferred plant species or by making it impossible for competing herbivores to reach the food supply.

Livestock grazing may adversely affect wildlife populations in areas where requisite resources are limited. For example, desert tortoises north and west of the Colorado River in the western United States have been listed as a threatened species, primarily because they must compete with livestock for forage [18]. To illustrate the competition, a single cow and her calf consume 12,000 pounds of forage per year while a desert tortoise consumes only 23 pounds annually [19]. Livestock may also trample individual tortoises and cause habitat disturbances, such as the introduction of exotic plants, that change habitat quality [18]. As another example, the Maximilian sunflower provides food and cover for game birds, including the northern bobwhite, mourning dove, wild turkey, and greater prairie chicken [20]. It is also an important forage plant for livestock, deer, and pronghorn. However, the sunflower has a low tolerance to grazing pressure, and overgrazing can eliminate it completely, resulting in the loss of an important source of food and cover for wildlife.

The impact of livestock grazing on birds varies depending on when the species feeds or nests and when grazing occurs [13]. Livestock can reduce or remove cover through grazing and browsing, thus making birds subject to greater predation; and livestock may trample nests. For example, upland sandpipers, a medium-sized shorebird, when subjected to five different grazing levels in southcentral North Dakota, experienced detrimental effects on reproduction and nesting density [21]. These effects were attributed to the physical presence of cattle or to changes in the structure of vegetation resulting from grazing. As a second example, the level of cattle grazing can also influence waterfowl habitat quality. Specifically, in a four-year study in North Dakota, the number of breeding pairs of waterfowl, number of nests, and nest successes were generally reduced by 23, 39, and 50 percent, respectively, when compared to ungrazed control areas [13].

Compaction of soil makes habitat unsuitable for some invertebrates, and this reduces the food supply for small animals such as shrews and frogs [22]. For example, the number of overwintering invertebrates in leaf litter in an area without heavy grazing for ten years was 2.5 times higher than in forested areas with continuous heavy grazing [13].

Finally, overgrazing is one of the principal factors contributing to the decline of native trout in the western United States [12]. Livestock affect fisheries by causing accelerated erosion and sedimentation of spawning beds; and in areas that produce invertebrates that serve as food for fish, by widening and shallowing stream channels, by increasing stream temperature, and by reducing hiding cover and food provided by vegetation [13]. Five independent studies found an average 184 percent increase in fish production when livestock use was light or eliminated by fencing [12]. Further, streamside exclosure resulted in a two- to five-fold increase in fish biomass over short periods of time [13].

MEASUREMENT TECHNIQUES FOR POTENTIAL IMPACTS

Several measurement techniques can be used to quantify, or at least qualitatively estimate, the impacts of livestock grazing on rangelands. The techniques presented herein were selected because they generally do not require large expenditures for field or laboratory equipment, they can be fairly rapidly used, and they are relatively easy to learn. Table I contains a composite listing of the included techniques, with several identified as generating an environmental index.

TABLE I Examples of measurement techniques for grazing impacts

Issue or Impact category	*Measurement techniques*
Overgrazing (stocking rate)	*Holechek procedure based on total useable forage, forage demand by animals, distance from water, and land slope
	Troxel and White procedure based on allocating 25% of the ungrazed crop to livestock
	Application of U.S. Soil Conservation Service guidelines
Vegetative Impacts	Vegetation weight based on clipping, visual observation, or indicators
	Plant vigor based on plant height, number of flower stalks, and amounts of seed
	Vegetative cover based on the line intercept method
	Canopy cover based on a species comparison chart and dominance rating (index)
	*Integrated monitoring method involving annual data collection on canopy cover, livestock utilization patterns, indicator plant species, and soil status
Soil Impacts	Visual observations of surface soil characteristics
	Field observation-derived numerical ratings related to erosion, runoff, and sediment yield (index)

TABLE I (Continued)

Issue or Impact category	*Measurement techniques*
	Quantitative estimation of sediment yield based on streamflow suspended sediment measurements
	Quantitative estimation of soil loss through use of the Universal Soil Loss Equation (index) *Quantitative estimation of sediment yields based on the "Pacific Southwest Inter-agency Committee procedure" (index) Quantitative estimation of infiltration rates, with such rates serving as indicators of changes in soil properties
Riparian Zone Impacts	Visual observations of riparian vegetation Visual observations of streambank stability and cover, undercut banks, and overhanging vegetation Classification of streambank stability based on several measurable variables (index) Determination of stream channel morphology based on channel depth and width Measurement of percentage of fine sediment in stream Determination of stream pool index by measuring five variables; the resultant index is related to fish abundance (index) *USFS method for rating streambank stability in terms of an upper bank, lower bank, channel bottom, and total score (index)
Water Quality Impacts	Concentration of nitrogen and phosphorus in stream *Concentration of fecal coliform and/or fecal streptococcus in stream
Wildlife Impacts	Bobwhite Quail Habitat Appraisal System based on grazing area food, nesting cover, brood habitat, protective cover, and interspersion for this selected evaluation species (index) *Deer Habitat Appraisal System based on grazing area food, water, protective cover, and interspersion for the white-tailed deer used as a selected evaluation species (index) * COWFISH Habitat model for trout fisheries; the model is based on percent streambank with overhanging vegetation, percent embeddedness, percent streambank undercut, percent streambank in an altered condition, stream width/depth ratio, channel gradient and presence/absence of granitic parent material (index)

* Possible technique of choice for the issue or impact category.

1. Overgrazing (Stocking Rate)

Determination of an appropriate stocking rate is important for projecting potential negative environmental impacts and their documentation in EISs, environmental assessments (EAs), and grazing permit decisions. In the "Holechek procedure", the stocking rate, which can be used as an indicator of overgrazing, is calculated based on the total usable forage and the forage demand by animals, and then adjusted for the distance from water and for the slope [23]. The total usable forage is a function of the ungrazed standing crop at the end of the growing season, pasture size, and percent use. Based on published literature, a forage demand of 2 percent body weight per day for livestock on a year-long basis is typically used. As distance from water or the slope increases, the grazing capacity should be reduced since, in general, cattle do not use areas more than 3.2 kilometers from water or with slopes greater than 10 percent.

The "Troxel and White procedure", which is more conservative than the Holechek procedure, allocates 25 percent of the ungrazed crop to livestock, 50 percent for site protection, and 25 percent for natural disappearances due to insects, wildlife, and weathering. The U.S. Soil Conservation Service (SCS) has also published stocking rate guidelines; however, they are subjective and based mainly on experience. Both the Holechek and Troxel and White procedures have yielded stocking rate estimates closer to actual measured rates on experimental rangelands than did the SCS guidelines [23].

In general, the Holechek procedure provides an intermediate stocking rate if reliable data are available on the ungrazed standing crop. The rate decision to be specified in a permit action should also be based on professional judgment concerning how the animals use the pasture, recent weather, and competitive grazing pressures by wildlife. In controversial rangeland areas, the Holechek procedure and the Troxel and White procedure can be combined to provide an averaged estimate of a projected acceptable stocking rate.

2. Vegetative Impacts

Measurable attributes of vegetation include weight, plant vigor, and cover [24]. Weight, which may be the best single measure of plant growth, can be determined by clipping, visual observation, or indirect methods, such as estimating weight based on annual or seasonal precipitation. Plant vigor, which may include a plant's appearance, vitality, and rate of growth, is closely associated with grazing intensity.

The most commonly used and easily measured criteria to determine plant vigor are plant height, number of flower stalks, and amounts of seed produced. Like weight, vegetative cover (the area occupied by vegetation) can be evaluated by several techniques, with one being the line intercept method.

Determination of canopy cover can provide useful information on grassland, shrubby, woodland, and forest sites [25]. A comparison chart is used to estimate the percentage of ground covered by each plant species and the percentage of ground covered by all plant species on a representative plot. Each species is also assigned a dominance rating. The estimates for individual species can be validated by comparing their sum to the estimate for total cover. The comparison charts can also be used to estimate the percentage of plants in each major age class for a single species.

An integrated method for monitoring the long-term impacts of livestock grazing has also been developed [26]. In this method, canopy cover data collected annually and at five-year intervals are integrated to provide information about the condition of the rangeland. Annual data about livestock utilization patterns are also collected after every grazing season. Periodically, data are also collected from permanently established plots that represent each major ecological site in the grazing area. Typically, the plant species on the permanent plot that are particularly indicative of trends should be identified, and canopy cover should be estimated. Further, trends in soil status are measured by estimating the percentage of bare ground, the percentage of ground covered with gravel and stones, the percentage of ground covered with litter and mulch, and the percentage of ground covered by mosses and lichens. Estimates of the amount of forage available and plant vigor can provide supplemental information.

3. Soil Impacts

Visual observations of surface soil characteristics can be used to evaluate soil stability in grazing areas [27]. For example, visual indicators of erosion include the presence of rills and gullies, the elevation of plants or rocks above the soil surface, and the deposition of eroded material around plants or in fans or dunes. BLM has developed numerical ratings, based on field observation, which can be used to evaluate soil movement, surface rock and/or litter, pedestalling, flow patterns, and rills and gullies [8]. The ratings increase from one to five as each included soil characteristic improves from poor to excellent. However, professional judgment is also necessary to determine the significance of visual observations and the probable magnitude of erosion, runoff, and sediment yield.

Quantitative methods have been used to estimate sediment yield from rangeland grazing areas. The amount of eroded material can be directly determined by measuring suspended sediment in local streamflow [10]. Other quantitative methods are based on models that require minimal field measurements. For example, BLM used the Universal Soil Loss Equation (USLE) in some of its grazing action EISs to quantify existing soil loss and to predict soil loss due to changes in vegetative cover [28]. According to the USLE, soil loss is a function of factors related to rainfall energy, soil erodibility, slope-length, vegetative cover, and erosion control practice [5]. The USLE can also be used for comparing the soil loss associated with alternative grazing strategies [28]. However, local field validation of the USLE may be needed. Conversely, generic soil erodibility and slope-length factors from the USLE have been used to calculate erosion susceptibility in numerous areas, including semiarid rangelands in eastern Kenya [29].

It has been found that sediment yields predicted by the "Pacific Southwest Inter-Agency Committee procedure" were within 15 percent of measured yields from sagebrush rangelands in southwest Idaho [30]. Based on the equation used in this procedure, sediment yield depends upon factors related to surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport.

Finally, the infiltration rate is a useful indicator of changes or differences in soil properties, especially in situations where changes are expected but are difficult to evaluate using other physical measurements. For example, in a long-term grazing study in Oklahoma, it was found infiltration rates were significantly higher for low grazing intensities when compared to medium and high grazing intensities [31]. Infiltration rates can be calculated from measurements of precipitation and surface runoff, from plot studies of natural rainfall, or from tests of artificial applications of water [10]. Artificial applications include:

(1) ponded, falling-head infiltration tests; (2) ponded, constant-head infiltration tests; and (3) simulated rainfall infiltration tests.

4. Riparian Zone Impacts

Riparian zone impact measurements should be made during the summer base streamflow period in order to reflect the more extreme stream and riparian conditions resulting from the yearly cycle of runoff, vegetative growth, and nonpoint source impacts.

Visual observations can be used to identify trends in riparian vegetation. For example, such vegetation subject to grazing often shifts from natural grasses and native willow shrubs to Kentucky bluegrass, grasses, and forbs [12]. Visual observations can also be used to estimate streambank stability, streambank cover, undercut banks, and the amount of overhanging vegetation [14]. Streambank stability can also be approximated by measuring the lengths of banks on both sides of a representative section of the stream and placing them into one of four classes based on the degree of stability and cover. For example, streambanks are judged to be unstable if there is any evidence of breakdown, slumping banks, fractures, or vertical, uncovered banks. Banks are considered to be uncovered if perennial vegetative ground cover is 50 percent or less, if roots cover 50 percent or less of the bank, if 50 percent or less of the surface is protected by rocks of cobble size or larger, or if 50 percent or less of the surface is protected by logs that are at least 4 inches in diameter.

Stream channel morphology can be determined *via* measurement of water/channel depth and water/channel width, and the calculation of width/depth ratio. This ratio is proportional to streamflow and increases with channel degradation. The percentage of fine sediment can be estimated using plot grids or particle counting techniques. The physical measurements can be used to quantify the impacts of grazing actions.

Fish abundance is related to the diversity of habitats and the number and quality of stream pool environments. Pool quality can be indicated by measurements of depth, substrate, overhead cover, submerged cover, and bank cover; with the results aggregated into a pool quality index. In this index, each factor is given a single digit score ranging from 0 to 2, and the scores are summed to yield an overall quality rating. For example, if pool depth is less than 0.5 feet, the score equals 0. If pool depth is greater than 1.5 feet, the score equals 2. Possible scores for the overall quality rating range from 0 to 10, with low values indicating low quality. The subjectiveness of the pool quality rating can be reduced by measuring length of undercut bank, length and width of overhanging vegetation, and other cover components of the pool. Spatial variations in this index allow comparisons of the index in heavily grazed sites with the index in unimpacted or lesser grazed sites.

In 1975, the USFS developed a method to rate the stability of streambanks and channel bottoms. The method is currently used by 60 percent of all national forest managers in grazing impact studies; BLM also uses the method to assess grazing impacts and the potential for stream recovery. For example, data from rangeland streams in Nevada were used to analyze the variation of 15 streambank stability rating variables with stream type and with the level of grazing animal-induced bank damage [32]. Data on hydraulic gradient, sinuosity, width/depth ratio, bed material size, valley confinement, and landform feature erodibility were used to classify the rangeland streams into nine types. The level of animal-induced damage to streambanks, which was determined by observing signs of grazing and trailing, varied from no or light damage to excessive damage. Each streambank stability rating variable was ranked excellent, good, fair, or poor and had an associated importance weight. Appropriate stability variables were summed into a composite index to yield upper bank, lower bank, channel bottom, and total scores.

In the USFS method, the sum of the four upper bank indicator variable scores (landform slope, mass wasting, debris jam potential, and vegetative bank protection) was not influenced by grazing animal-induced bank damage. The sum of the lower bank variables (channel capacity, bank rock content, obstructions and flow deflectors, cutting, and deposition) varied, with the stream type itself controlling the lower bank stability. The channel bottom indicators (rock angularity, brightness, consolidation or particle packing, bottom size distribution and percent stable materials, scouring and deposition, and clinging aquatic vegetation) varied with grazing animal-induced damage for only one stream type. Therefore, it was concluded that stream type was more likely to determine streambank stability than the level of grazing animal-induced bank damage, and that livestock affected certain streams much more than others. In addition, although several of the individual stream stability rating variables provided useful information about the impacts of livestock grazing, this information became masked when the variables were combined into a total score [32].

5. Water Quality Impacts

Stream water quality sampling and analysis can be used to determine the concentration of nutrients or bacteria [14]. Nutrients can be determined by testing for total phosphorous, dissolved orthophosphate, and total oxidized nitrogen, which encompasses most of the nitrogen available in surface waters. Bacterial indicators, which can be used to detect the entry of livestock or wildlife waste into surface water, include fecal coliform, fecal streptococcus, and their ratio.

6. Wildlife Impacts

A model has been developed for use in selecting cattle grazing (stocking) rates and vegetation management practices that maximize profit subject to limitations on the degradation of wildlife habitat quality and on the availability of resources, including land, labor, and capital [33]. Habitat quality for two wildlife evaluation species were chosen for evaluation, with the resultant quality expressed *via* a numerical index. The "Bobwhite Quail Habitat Appraisal System" requires the assignment of a numerical rating from zero to one to selected grazing area criteria (food, nesting cover, brood habitat, protective cover, and interspersion). The ratings for each criterion are then averaged to create an overall habitat rating. As the numerical value of the resultant index increases, the quality of the habitat for bobwhite quail also increases. The "Deer Habitat Appraisal System" uses four criteria (food, water, protective cover, and interspersion) as the basis for an overall habitat rating for the white-tailed deer. In general, the results of these index models can be used to establish appropriate cattle stocking rates. From a wildlife conservation perspective, lower stocking rates should be selected in areas exhibiting higher quality indices for the two species. Further, changes in these habitat indices can be used as measures of impacts in monitored grazing areas.

The USFS has also developed the "COWFISH habitat model", which identifies the optimum and existing numbers of several trout species, as a basis for predicting the effects of livestock grazing on trout fisheries [34]. In this model, the percent of the streambank with overhanging vegetation, percent embeddedness, percent streambank undercut, percent streambank in an altered condition, and the width/depth ratio are determined by field observation. Channel gradient and the presence or absence of granitic parent material are determined using available databases. Using data from 43 stream sites in Beaverhead National Forest, Montana, the COWFISH model was found to provide reasonable estimates for the optimum and existing numbers of catchable trout for several trout species at 19 sites [34]. It was concluded that the COWFISH model could be used to assess trends in stream habitat condition resulting from livestock grazing.

IMPACT INDICES FOR THE EIA PROCESS

As summarized in Table II, three indices each for soil, riparian zone, and wildlife impacts are already available. Indices for vegetative and water quality impacts can be easily developed. Further, stocking rates

TABLE II Summary of measurement techniques and indices related to grazing impacts

Issue or impact category	*Summary of measurement techniques*	
	Total number listed in Table I	*Indices listed in Table* I
Overgrazing (stocking rate)	3	0[a]
Vegetative Impacts	5	0[b]
Soil Impacts	6	3
Riparian Zone Impacts	7	3
Water Quality Impacts	2	0[c]
Wildlife Impacts	3	3

[a] the stocking rates developed *via* the Holechek procedure and the Troxel and White procedure could be expressed as fractions of such rates under ideal environmental conditions.
[b] data collected for the integrated monitoring method could be assembled into an index format.
[c] the measured concentrations for nitrogen, phosphorus, fecal coliform, and fecal streptococcus could be expressed as a ratio to applicable water quality standards for each parameter, or to field data from many locations representing a range of stocking rates.

as determined *via* the Holechek procedure and the Troxel and White procedure could be expressed on a fractional basis. Finally, still other indices which have been used in the EIA process, such as the Water Quality Index, could be used directly or in a modified format, in grazing action impact studies [5].

Consideration could be given to the individual use of the indices listed in Table I and summarized in Table II. A composite grazing impact index could be developed by choosing one representative index from each of the five impact categories listed in Table II. If the indices and related impacts are considered to have equal importance weights, unitized values for each index could be averaged.

Single impact indices, or a composite index if one is developed, can be used for several purposes within the EIA process. For example, indices can be used to summarize baseline conditions for vegetation, soil, riparian zones, water quality, and wildlife in areas proposed for grazing permits. These index results can provide a framework for predicting impacts associated with various animal stocking rates, including overgrazing scenarios. In fact, the baseline conditions can be used to ascertain the general acceptability of grazing in specific areas, to facilitate determination of appropriate stocking rates, and to serve as a basis for planning targeted monitoring programs. In addition, monitoring results expressed *via* several indices can be used to instigate changes in grazing practices. Comparisons of index results during grazing with baseline index data represent one approach for quantitatively expressing experienced impacts. If grazing practices are changed or other mitigation measures implemented, the resultant index values can be used to determine the effectiveness of the management decisions.

CONCLUSIONS

Livestock grazing on federal lands often damages soils, vegetation, riparian zones, and water quality, thus resulting in the degradation or loss of wildlife habitat. In extreme cases, the detrimental effects of overgrazing may be irreversible. Several cost-effective measurement techniques and environmental indices have been emphasized herein as a means of providing sufficient data to facilitate EIS-derived permitting decisions and to monitor rangeland trends. The use of extant impact indices, which would limit data collection to the factors that are most indicative of the negative environmental impacts of grazing at a particular site, is recommended in order to simplify rangeland monitoring, impact predictions, permitting and evaluation of decisions related to grazing practices. Further, an overall composite index could be developed and used for such purposes.

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