The Biosphere: Problems and Solutions, edited by T.N. Veziroğlu
Elsevier Science Publishers B.V., Amsterdam, 1984 — Printed in The Netherlands

POTENTIAL INDICATORS FOR MONITORING BIOSPHERE RESERVES

Gary E. Machlis and R. Gerald Wright
Cooperative Park Studies Unit
National Park Service
College of Forestry, Wildlife and Range Sciences
University of Idaho
Moscow, Idaho 83843, U.S.A.

ABSTRACT

Biosphere reserves are internationally recognized landscapes that have been set aside to protect various ecological characteristics. The monitoring of ecological change within such reserves is a central component of biosphere reserve management, and traditional methods have proven difficult and costly. This paper explores an alternative technique using social indicators to monitor biophysical change. The technique may provide a practical "early warning system" for reserve managers. The paper reviews biological and sociological monitoring techniques and provides a theoretical framework for experimenting with social indicators. Several indicators of Olympic National Park Biosphere Reserve are developed to illustrate the potential of social indicators for monitoring biosphere reserves.

1. INTRODUCTION

A central component of biosphere reserve management is the ability to monitor biophysical change within a reserve, both as an impetus for management actions and as critical baseline data for ecological research (Franklin 1977). Programs to monitor specific ecological parameters have been established over the years in many national parks, national forests, and experimental ranges, which have since been designated biosphere reserves.

Yet several difficulties exist. Even in instances where there is interest and a desire to develop long-term monitoring programs, it is clearly impossible to measure or monitor all biological variables. The most ambitious monitoring program can only deal with a fraction of the important biological parameters (Johnson and Bratten 1978). Because of the biological and physical complexity of most ecosystems, most monitoring to date has been disciplinarily-oriented, site-specific, and narrow in scope (Huckabee 1973). Likewise, it is often difficult to decide in advance which biological parameters may prove to be important years in the future. The result is that, even when monitoring programs are in force, there is no guarantee that the proper parameters will be measured or that the information will be available quickly enough to alert managers to a potential environmental problem.

This paper seeks to show how an alternative technique might be developed to indirectly indicate potential ecological changes in biosphere reserves. The approach incorporates the use of social indicators. We attempt to show how monitoring changes in certain social indicators may alert management to the potential of subsequent ecological change within a reserve. We do not maintain that this approach is a substitute for site-specific biological monitoring, but rather it is an "early warning system" which can be used to identify key problems requiring more detailed analysis.

First, we briefly discuss the causes of ecological change within biosphere reserves, and then review current biophysical monitoring efforts. Next, social monitoring is reviewed, and the process of constructing social indicators described. We then provide a theoretical framework for hypothesizing that social indicators may be related to changes in biophysical parameters within a reserve. Finally, we explore how this method might be applied, using data from Olympic National Park Biosphere Reserve and its surrounding region.

2. CAUSES OF ECOLOGICAL CHANGE WITHIN BIOSPHERE RESERVES

Ecosystems within biosphere reserves are far more dynamic than generally acknowledged (Smith 1966). This is particularly true for reserves designated in national parks, and for which management places few restraints on the actions of natural processes. Such environmental changes or fluctuations, both in structure and composition, occur in response to succession, natural disturbances such as fire, flood, and erosion, and in response to various animal species. The importance of natural processes in many ecosystems is now becoming recognized (Godfrey 1978; Bonnicksen and Stone 1982), and is being incorporated into resource management planning for parks and equivalent reserves (Westhoff 1971; Dolan et al. 1978).

The natural ecosystems within biosphere reserves are also changed or modified by human influences. None of the biosphere reserves in the continental U.S., even in the national parks, can be considered to represent pristine environments. Several have been altered in the past by logging, grazing, mineral exploration, water diversion projects, homesteading, and agricultural use. However, the resiliency of the natural environments, and the protection afforded by present management policies, has allowed many of the reserves to recover from past abuses (Gregg and Goigel 1981). For example, old homesteads and agricultural plots of the Great Smokeys National Park Biosphere Reserve have been reclaimed by the rich mesophytic forest of the region in a period of only 50 years. The once nearly extirpated grizzly bear and big-horn sheep populations of Glacier National Park Biosphere Reserve have again become viable entities in a similar period of time (Keating 1983).

Despite these apparent successes, the natural systems of biosphere reserves are becoming more and more susceptible to change or modification by human influences. A 1980 survey of U.S. national parks (NPS 1980) found that managers perceived none of the parks as immune from threats that are causing irreversible damage; parks designated as biosphere reserves had a significantly higher number of reported threats. In addition, 75 percent of the reported threats were inadequately documented.

The problems threatening biosphere reserves are, however, not limited to the U.S. A study documenting resource management problems facing protected areas throughout the world was recently completed by Tichnell and Machlis (1984). This study sampled 98 sites in 50 countries, chosen to facilitate comparisons of problems among areas in countries at different stages of economic development, located in different biomes, and that were affiliated with different management programs. Thirty-seven biosphere reserves and World Heritage sites were included in the survey; their most common threats were lack of personnel, illegal removal of animal life, removal of vegetation, trampling, erosion and loss of habitat. In contrast to the U.S. parks study, Tichnell and Machlis found no significant difference between biosphere reserves and national parks in the number of reported threats. Like the U.S. study, lack of documentation was high; 41 percent of the reported threats were inadequately documented.

The findings of these and similar studies point out the urgency of developing a practical and reliable means to monitor and predict the impact of human activities on natural systems. To date, all efforts have focused on biophysical monitoring.

3. A REVIEW OF BIOLOGICAL MONITORING

There are two common types of techniques for monitoring biophysical parameters. One type employs direct measurement through the use of electronic instrumentation to measure chemical or physical parameters primarily associated with air and water quality. The deployment of such equipment has been increasing rapidly, particularly with advances in microcircuitry. However, the high cost, lack of trained personnel, and the frequent need to service equipment has restricted its placement in most remote natural areas where power and access is limited. The subtle, long-term effects of many types of pollutants and the fact that they are often transferred through the food chain rather than in an air or water medium, also contribute to the ineffectiveness of instrumented monitoring.

The second technique employs the use of various living organisms, either plant or animal, as indicator species to indirectly monitor environmental quality. The usefulness of such organisms in this capacity is based primarily on the sensitivity of the selected species for specific pollutants (Heck 1966). Useful indicator organisms are those which are sessile or move very little. They must not be able to avoid the pollutant by their motility (Stein and Denison 1967). Plants fit this criteria well and have long been used to provide an index of air quality (Juhren *et al*. 1957; Pyatt 1970; Treshow 1968).

The use of vegetation, however, has limitations. To separate visible symptoms of air pollution damage from all other factors that could produce similar traits requires a competent observer. The observer must also be in the field to read the symptoms at the proper time, and the sensitive vegetation must occur with a reasonable distribution over the area (Brandt 1973). In other cases, the vegetation may not be visibly injured or killed, and the effects of pollutants may only be expressed in terms of generalized chlorosis, early senescence, or poor growth. These problems are difficult to identify in the field (Brandt 1973).

The identification and use of suitable animal species to serve as indicators of environmental quality has been the subject of increasing interest and study (Jenkins 1971, 1972). Aquatic organisms, particularly those which are filter feeders, appear to be particularly suitable as sentinels for indicating levels of pollutants in the water environment (Goldberg *et al*. 1978; Dissalvo *et al*. 1975; Stegeman and Teal 1973). The use of animal organisms, however, suffers from the same problems as plants; the availability of organisms, the need for competent observers, and in addition the laboratory facilities, money, and time needed for extensive histopathological analyses (Goldberg *et al*. 1978).

The use of biological indicators in monitoring biosphere reserves has received attention, but evidence suggests such monitoring is neither systematic nor widespread (Gregg and Goigel 1981). Early monitoring programs consisted primarily of routine observations of various biological resources. These early observations were essential in developing a knowledge of the then little understood resources of the protected areas, and were a valuable means to document changes in biological systems. These observations often represent the only baseline data available to contemporary scientists seeking to reconstruct historic landscapes in parks (Bonnicksen 1982; Vankat 1977), and they form the basis for on-going monitoring programs in many biosphere reserves.

Unfortunately, the highly descriptive, qualitative, and variable nature of the early descriptions, and the lack of proper uniformity among observers, diminishes the usefulness of much of the early data. Funding problems, personnel turnover, and changes in priorities caused most studies to be limited to short-term efforts (Houston 1971).

Current monitoring efforts are similarly limited. White and Bratten (1981) surveyed 33 U.S. biosphere reserves regarding their overall monitoring efforts. Twenty-five had some kind of permanent plot vegetation monitoring, and six had population monitoring. Mack _et al_. (1983) conducted an in-depth survey of 14 U.S. biosphere reserves regarding baseline resource inventories, long-term monitoring, and long-term ecological research. They developed an index (on a 100 pt. scale) of the comprehensiveness of scientific activities. Table 1 shows that the index scores are relatively low, with macro-climate monitoring receiving the highest rank and aquatic systems (biological factors) the lowest. Finally, data on 27 World Heritage Sites and Biosphere Reserves from over 20 countries found that 41 percent of all threats to the natural resources reported by managers were suspected but not documented (Tichnell and Machlis 1984).

Table 1. Index of Long-Term Environmental Monitoring, 14 U.S. Biosphere Reserves.

Index	Index Rating
Macroclimate	38
Aquatic systems, chemical factors	31
Disturbances, anthropogenic (causes)	25
Disturbances, exotic species (causes)	23
Disturbances, anthropogenic (vegetation recovery)	22
Disturbances, natural (causes)	22
Aquatic systems, physical factors	15
Disturbances, natural (vegetation recovery)	14
Disturbances, exotic species (vegetation recovery)	11
Aquatic systems, biological factors	7

- adapted from Mark _et al_. (1983)

Hence, biological monitoring is a central component of any effort to understand change with biosphere reserves. Limitations include high cost, difficulties in data collection, lack of trained personnel, the need for laboratory research, and sporadic application. Can other approaches be useful? We now turn to a brief review of "social" monitoring, or the use of social indicators.

4. A REVIEW OF SOCIAL MONITORING

In the social sciences, monitoring of human activity has been primarily accomplished with the use of social indicators. A social indicator is a social statistic used to indicate a trend in some variable of interest to decision makers. Divorce rates, for example, can be used to indicate changes in the stability of community social systems. Social indicators share these characteristics:

1) They are components in a theoretical framework or model of a social system that helps illuminate important variables (Burch 1984).

2) They can be collected at a sequence of points in time and accumulated into a time series (Land 1970).

3) They are either directly or indirectly related to policy and provide guidance for social intervention (Sheldon and Land 1972).

The importance of social indicators was recognized as early as 1929, when President Hoover set up the President's Research Committee on Social Trends. The committee's report attempted to describe life in the United States by means of a varied set of social statistics. This was repeated 30 years later by President Eisenhower's Commission on National Goals (1960) and the National Planning Study (Lecht 1966). Both studies recommended that a system of social accounts be established to supply information about the nation's "social health" and its needs, in order to provide a firm basis for policy decisions.

These major efforts have intermittently continued, with three key U.S. Government reports in 1973, 1976 and 1982. The Organization for Economic Cooperation and Development (OECD) and the Statistical Office of the United Nations have been active in the development of social indicators on an international basis.

Methodological development of social indicators has followed. Several studies have focused on the purpose of social indicators (Bauer 1966; Sheldon and Moore 1968; Etzioni 1970); others deal with problems of measurement and definition (Land 1970; Gastil 1970; Anderson 1973). While social indicators have often been linked to measuring "quality of life" (Liu 1975), a variety of rationales have been developed to support their use. All seem to emerge from a common concern for the consequences of public policy decisions (Burch *et al*. 1984).

5. CONSTRUCTING SOCIAL INDICATORS

The construction of social indicators involves several general steps. First, a theoretical framework must be developed that provides a rationale for the choice of variables, and the variables must be operationally defined. The indicator for each variable must be chosen, and the measurement units selected with care; social data is often aggregated by formal administrative units (such as counties and states) that may not be meaningful in the context of monitoring local or regional trends. It is often necessary to choose from among several statistical series; Table 2 suggests several important characteristics.

Table 2. Important Characteristics of Social Indicators.

Validity: the extent to which an indicator measures the phenomenon or concept it is intended to measure.

Reliability: the proportion of an indicator's variance that is not error variance.

Stability: the lack of unwanted variability in an indicator over time, especially responses to extraneous and irrelevant influences.

Responsiveness: the speed and magnitude of an indicator's response changes in related aspects of society.

Availability of Data: the accessibility of existing data sources, adaptability of existing vehicles for data collection, or capacity of new data collection procedures to measure the needed data.

Disaggregatability: the capacity of a social indicator to be assessed and reported separately as a function of other variables (for example, characteristics of subpopulations, types of communities, regions of the country).

Intertemporal Comparability: the extent to which successive measures can have the same interpretation.

Intergroup Comparability: the extent to which measures for different populations can have the same interpretation.

Timing Relative to the Occurrence of a Problem: whether an indicator leads, is coincident with, or lags behind a problem.

Timeliness: the availability of indicator data when needed and the lack of obsolescence of these data for their intended use.

- adapted from Rossi and Gilmartin (1980).

After social indicator data are collected, it is possible to combine two or more indicators into composite indices. For example, to monitor trends in crime, indicators of various criminal activity may be aggregated for an overall indicator, and hence provide a better measure of the general crime variable than individual crime statistics. Rossi and Gilmartin (1980) suggest that there are several techniques for combining indicators, including correlation analysis, regression analysis, factor analysis, expert judgement, and ad hoc selection.

In addition, the components of a social indicator index may need to be weighted. In a general crime index, it may be useful to weight crimes by their "seriousness", level of violence, or some other characteristic. These include both statistical and conceptual approaches. The validation of such composite indexes involves the testing for extraneous variation (such as changes in data collection techniques) and improvement in the theoretical framework that rationalized the choice of variable, indicator and measurement unit. Structural equation models, dynamic time series models, and specific transition models (called demographic accounts) can aid in the refinement of monitoring efforts (Land and Felson 1976; Land 1978; Pampel *et al*. 1977).

This general process for constructing social indicators is primarily designed for use in monitoring trends directly related to the chosen indicator; reported crimes is a closely linked indicator of criminal activity. The use of social indicators as proxies for biophysical indicators, and their utility as indicators of biological change is a relatively untried approach. The National Wildlife Federation has constructed "Environmental Quality Indexes" since 1969, which mix biological and social indicators. Similar efforts have been made by Lave and Seskin (1970) and Liu (1975). Baskerville (1976) combined socio-economic and environmental indicators of forest ecosystem change in his analysis of various spruce budworm management alternatives. Yet these efforts do not explore the rationale or potential of using social indicators to monitoring ecological change. As mentioned earlier, the first step is the development of a theoretical framework.

6. A RATIONALE FOR USING SOCIAL INDICATORS TO MONITOR ECOLOGICAL CHANGE

One of the major characteristics of *Homo sapiens* is the species' ability to alter its habitat. Swidden agriculture modifies soil fertility; logging near streams and rivers changes water turbidity; manufacturing consumes coal and petrol, produces air contaminants and alters the acidity of rain. The documentation of these impacts has increased in recent years; empirical case studies include warfare in Vietnam (Westing *et al*. 1981), forestry and agricultural development in the upper Amazon (Gentry *et al*. 1981), sewage discharges in South Africa (Orren *et al*. 1981), and tourism in the Carribean (Beckhuis 1981).

This capacity for significantly altering ecosystems primarily occurs because of *Homo sapiens*' ability to coordinate activities, to organize into complex units; it is this organizational skill that allows human technology to increase its power (Burch *et al*. 1984; Mumford 1967). That is, our ability to organize into societies provides the mechanism for lumber mills to produce saw logs, factories to manufacture cars, farms to produce food. These activities in turn produce changes in the natural environment.

Such alterations of natural ecosystems produce changes in many environmental parameters--air quality, plant and animal abundance, water quality and so on. These parameters can be directly measured by biophysical indicators, e.g., suspended particulates per cubic meter, number of individuals per hectare, leaf area per meter and so forth. *Yet the activities of society which cause these changes can themselves be measured by social indicators*--i.e. the number of logging mills, the amount of saw logs produced, the acres in food production.

Figure 1 illustrates this idea. Social indicators of human activity are hypothesized to be related to the environmental parameters altered by those human activities. If automobile gasoline consumption causes a rise in airborne hydrocarbons, then trends in the number of gallons consumed by the transportation sector may be an appropriate indicator of air quality changes.

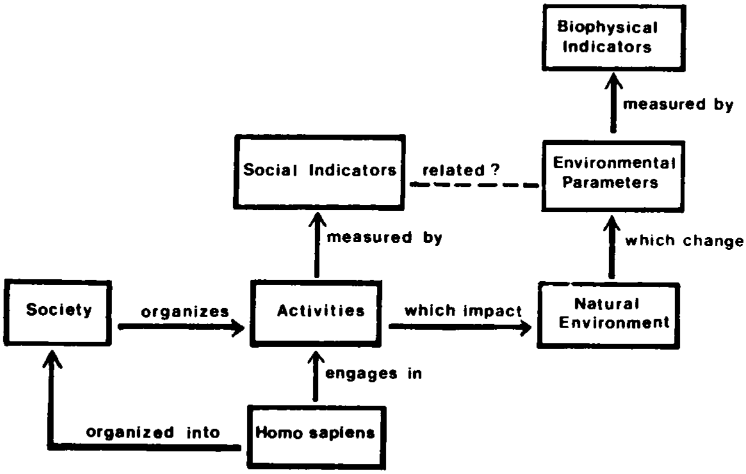

Fig. 1. A Rationale for Using Social Indicators to Monitor Ecological Change

Obviously, intervention effects and extraneous variables may make such relationships spurious. New anti-pollution devices may reduce the automobile's contribution to reduced air quality, and petrol consumption may no longer be a useful indicator. Yet the possibility exists that carefully constructed social indicators could track environmental change within biosphere reserves.

Methodological pitfalls exist. Careful causal arguments and consistent, strong correlations between the proposed social indicator and biophysical indicators are necessary to development of useful measures. Yet resistance to such an approach may not lie in the methodological requirements. Other than the economic values of price, there is a tendency among resource decision makers to consider social measurement a "soft" rather than "hard" scientific technique. Yet as Burch writes:

> Part of this attitude may be due to the common assumption that measuring human behavior is nearly impossible. This is absurd. The procedure for inventorying a human habitat, setting, or locale is similar to ecological analysis of the environments of other large animals. One counts a variety of things—size and structure of population, fecundity, fertility, territory, hierarchy, social change, organization of the breeding and socializing unit, to mention a few. The real point is that most nonhuman ecosystem studies have relatively primitive theoretical questions, which only require simple, elementary measures, and it is precisely these elementary, simple measures of the human community that are most readily available and generally superior to accuracy to similar measures made in field studies of other animals (1984:7-8).

Epidemiologists provide an instructive example. As Burch notes, the statistical associations they find between disease episodes and alterations in air and water quality are based upon aggregated data. Their studies use social indicators of health changes and biophysical indicators of environmental change to predict, for instance, that the installation of a particular industry with a known process and a known emission system is likely to produce an increase of so many grams per square meter of particular pollutants, which will result in certain changes in morbidity and mortality rates for specific segments of particular populations.

Like the public health official, the biosphere reserve manager may be able to use social indicators to predict short-term perturbations and long-term trends in a reserve's ecological characteristics. Indicators of those activities most directly linked to ecosystem change (logging, grazing, visitor use and so forth) might serve as a kind of "early warning system" for the biosphere reserve resource manager--signalling that ecosystem change is likely occurring and suggesting the direction and magnitude of the change. To illustrate, we explore potential indicators for Olympic National Park Biosphere Reserve.

7. SOCIAL INDICATORS FOR OLYMPIC NATIONAL PARK BIOSPHERE RESERVE

7.1 Description of Olympic Biosphere Reserve and Surrounding Area

Olympic National Park Biosphere Reserve, located on the Olympic Peninsula in northwestern Washington State, covers an area of 896,597 acres (362,848 hectares). Ninety-six percent of this area has been officially nominated as wilderness. The majority of the park covers a region of rugged forested and glaciated mountains. Approximately 3254 acres (1317 hectares) of the park are still in private hands, although these inholdings are being purchased as funds become available.

Olympic National Park lies within the boundaries of four counties on the Olympic Peninsula; the four-county area is treated in this analysis as the Olympic "region." The economy of the Olympic region is heavily dependent upon the area's natural resources. The forest products industry is dominant, with no county having less than 45 percent of its total land area classified as commercial forest land. Coastal areas, forested lands, and Olympic National Park all contribute to the prominence of the recreation and tourism industry. The fisheries sector of the economy is becoming increasingly important.

7.2 Sample Social Indicators

Three key variables were chosen for this sample monitoring effort--the <u>utilization of natural resources</u>, <u>industrial development</u>, and <u>tourism</u>. The use of a natural resource such as forests can impact the surrounding natural ecosystem. Depending on how it is done, an increase in logging can degrade the quality of watershed, lead to extensive soil erosion and eliminate wildlife habitat (Miller 1979). Industrial development is associated with higher energy consumption (Bennett 1976), greater production of wastes (Garvey 1972), and more intensive use of natural resources (Simmons 1974). In the 1980 State of the Parks Study, 26 percent of all reported threats were related to industrial development (NPS 1980). Finally, a variety of studies suggest that tourism has an impact on the environment (Machlis 1979). Tourist developments adjacent to a biosphere reserve may increase pollution (USDC 1976); trampling, erosion, wildlife harrassment and increased occurrence of man-caused wildfires can also be consequences of heightened levels of tourist activity inside a biosphere reserve.

Figures 2 through 4 illustrate 34-year trends in several key indicators. Figure 2 shows that the Olympic region timber harvest climbed rapidly in the mid-sixties, yet has recently dropped to levels similar to the 1950s. Figure 3 shows that from 1948 to 1970, the number of manufacturing and construction employer units (the number of employers operating in the industry for a given year) remained steady. Manufacturing and construction employers rose rapidly in the 1970s, and has recently declined. Figure 4 shows an erratic but continuous rise in the number of visitors to the biosphere reserve, with a leveling off in the last decade.

If the percentage change of each indicator is added to form an unweighted index of human activity in the region, a decline in the rate of change is evident, beginning in the middle of the 1960s. Figure 5 illustrates this "rate of change" index, using four-year averages. The data suggest that from approximately 1965 to 1977 the Olympic region experienced a significant increase in resource utilization, industrialization and tourism, and that since 1977 socio-economic activity in the region has stabilized.

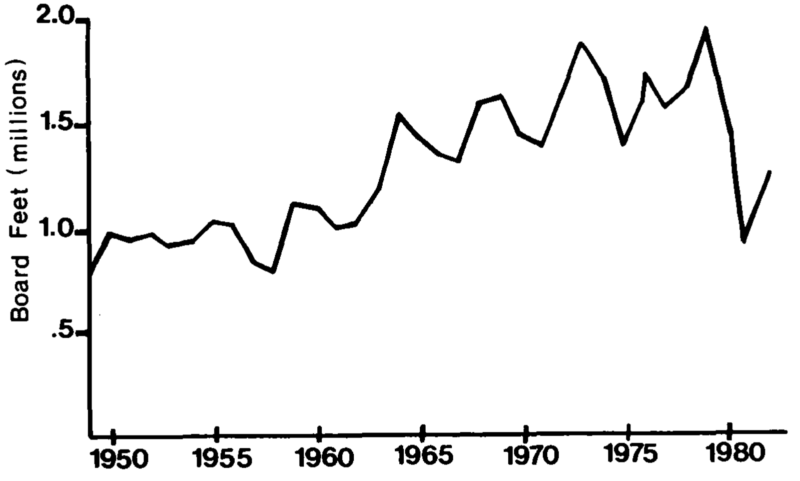

Fig. 2. Olympic Region Timber Harvest by MBF 1948-1982.

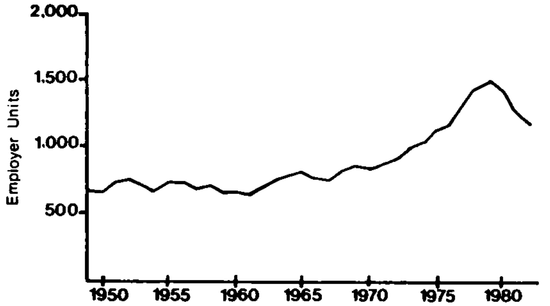

Fig. 3. Annual Average Number of Employer Units in the Olympic Region in Manufacturing and Construction, 1948-1982.

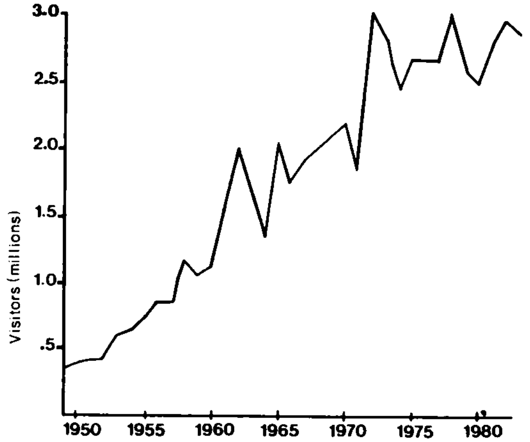

Fig. 4. Park Visitation, Olympic National Park, 1948-1982.

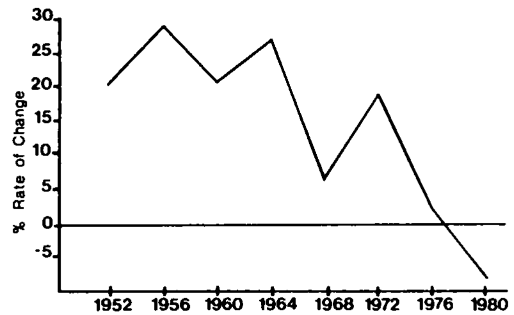

Fig. 5. Percent Rate of Change in Combined Indicators, 1948-1982.

To test the correlation of these social indicators and biophysical changes within the reserve, time-series data on air quality, water quality, wildlife populations, and so forth are needed. Ironically (and true to Burch's earlier statement), no such detailed and continuous data set is available for biophysical variables. Statistical tests of correlation, including lagged time-series analysis, is the next step in the development of these and similar social indicators.

8. CONCLUSION

There are a variety of ways that social indicators such as those just described could be used in biosphere reserve management. First, they serve as an inexpensive set of baseline data. Periodic updating should keep them reasonably current, and long-term trends could be assessed. Tourism indicators could serve as benchmarks for assessing future visitation within reserves; the rate of change index could indicate regional socio-economic development.

Second, the indicators may provide an "early warning" of impacts upon the biosphere reserve. A sudden increase in construction employer units could signal a spurt in industrial development and a decrease in air quality as manufacturing facilities are completed. Once alerted, park resource specialists and scientists could intensify their biophysical monitoring efforts to gather more accurate data. Hence, the social indicators could suggest site-specific biophysical monitoring.

Third, social indicators could be used to compare several reserves. For example, data on timber harvest adjacent to Olympic National Park and Great Smokeys Biosphere Reserves could be compared over 40 years, and the relative potential for impacts could be assessed.

Clearly, this is a very modest beginning. The link between social indicators and environmental change needs to be rigorously examined, and the practical utility of such indicators must be borne out by their useful application to biosphere reserve management. Yet we think this paper raises the possibility that social indicators may prove useful in monitoring biosphere reserves. We hope others are intrigued or irritated enough to explore these ideas and help refine them further.

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