

Gap Analysis and National Parks: Adding the Socioeconomic Dimension

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Editor's Note: The Oct. 16, 1993 issue of Science News (pp 248-251) features an article by Elizabeth Pennisi, "Filling in the Gaps: Computer Mapping Finds Unprotected Species." The cover is a computer model of the state of Idaho, captioned "Mapping Biodiversity." It makes an informative companion piece to the article below.

The conservation of biodiversity is an issue of growing concern to park managers, for the global system of protected areas is an important means of conserving biodiversity *in situ*. Four percent of the world's land area is protected in over 5,000 individual areas covering nearly 530 million ha (WR1 1990). In the US, national parks include a diversity of gene pools, populations, species, communities and ecosystems. The National Park Service (NPS) manages a *de facto* biodiversity reserve system, albeit incomplete.

Yet, national parks and the biodiversity they contain face threats from a variety of human actions (Machlis and Tichnell 1985; NRC 1992). Increased attention to the biodiversity values of parks is necessary in the face of human activity (such as economic development) and ecological challenges. Successful strategies will require 1) ecosystem-scale management that extends beyond park boundaries and involves other agencies and landowners, 2) better understanding of hu-

man actions that impact biodiversity, and 3) analytical techniques and practical tools for making land management decisions. One such technique is *gap analysis*.

Gap Analysis: A Brief Description

In order to identify underprotected yet critical areas of biodiversity, gap analysis uses geographic information systems (GIS) to map biodiversity and the location of protected areas. Elements of biodiversity including vegetation types and vertebrate species distributions are entered into the GIS; species richness maps are derived from these data. The resulting maps are overlaid with protection status such as national parks, wilderness areas, state parks and so forth. Locations with important biodiversity values and low protection status (the specific criteria can be adjusted) represent "gaps" in biodiversity conservation (see Scott et al. 1993 for a detailed description).

Gap analysis in its general form has been used in various situations, including USFS wilderness areas, tribal lands, Australian national parks, the Hawaiian Islands, California, Costa Rica, Ecuador and certain African protected areas (McKendry and Machlis 1992). A gap analysis program is now underway in 32 states in the US. It is anticipated that all states will be completed by 2009, and

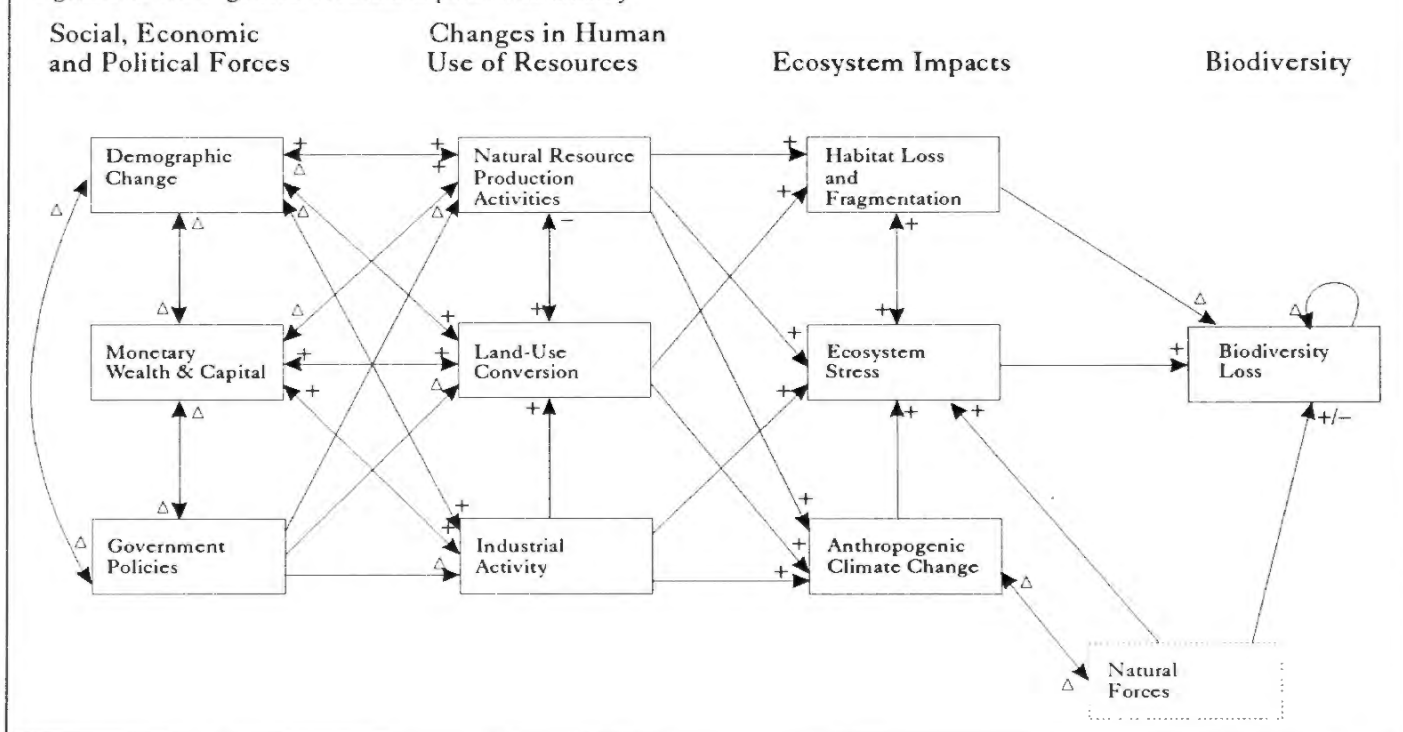
plans are being made to integrate state gap analyses into a national assessment (Scott et al. 1991). Gap analysis is likely to be an important component of the National Biological Survey.

Adding the Socioeconomic Dimension

Since human actions may increase the vulnerability of gap locations to future biodiversity loss, the University of Idaho's Cooperative Park Studies Unit (UI CPSU) Sociology Project has begun research extending gap analysis to include socioeconomic factors. A model was developed that identifies the major paths by which human actions impact biodiversity (see Fig. 1; for a detailed description see Machlis and Forester, forthcoming). Social, economic and political factors are considered the driving force behind changes in how people use resources. Changing resource use leads to impacts on ecosystems, some of which may result in biodiversity loss.

Extending the gap analysis technique to include socioeconomic factors is relatively simple. Socioeconomic zones of influence are delineated around each biodiversity gap location. Based upon the model, indicators of human action are collected and entered into the GIS database (see Table 1 for examples). Related indicators are combined into

Figure 1. A Working Model of Human Impacts on Biodiversity.



indices, again based upon the model. Finally, an index of vulnerability is created, and each gap location is given a relative index score. The results are displayed in map form; the maps may be useful to managers, landowners, resource agencies, advocacy groups and interested citizens (for a description, see McKendry and Machlis 1993).

The Idaho Pilot Project

The potential of adding a socioeconomic dimension to gap analysis was tested through a recently completed pilot project in Idaho. The research was funded by the NPS and the State of Idaho; the UI CPSU Sociology Project, the Idaho Cooperative Fish and Wildlife Research Unit, and the Clark University Graduate School of Geography were cooperators on the project.

Native vertebrate species richness (excluding fish) was used as the basis for the biological analysis. Data for the state were aggregated by 635 km² hexagons developed for the EPA's Environmental Monitoring and Assessment Program. Gap locations were determined using a specific algorithm, or mathematical procedure. The hexagon with the highest number of species was identified, followed by the hexagon that added the highest number of species not already in the first hexagon. This procedure continued until all native vertebrate species were included in the set of hexagons. The result was the minimum number of hexagons containing all native vertebrate species in the state. Five hexagons were selected for further analysis. Together, the selected hexagons contained approximately 95% of all native vertebrates in Idaho.

Each of the five hexagons was identified as a "gap location," i.e., potentially important to biodiversity in Idaho. A map of these gap locations was overlaid with a map of protected area status in Idaho; areas were defined as having "complete" or "partial" protection based on The Nature Conservancy classification system (see Map 1, page 8). None of the hexagons are totally protected, though small portions of protected areas are present in several of the gap locations. (In the on-going gap analysis program, other biological criteria and more sophisticated algorithms are being developed to identify areas of important biodiversity. The techniques are evolving rapidly, as scientists gain more experience in gap analysis.)

Socioeconomic indicators similar to those listed in Table 1 were collected for the counties surrounding each gap location. Data were entered into the GIS database; dBase IV, pcArc/Info, and IDRISI were used as software for the analysis. Four indices were constructed and mapped: socioeconomic change, government policies, land development and ownership complexity. Map 2,

page 9 (both maps are black and white conversions of their color originals) shows the results for socioeconomic change; the lower the index score, the lower the predicted level of future population and income growth. The four indices were then combined into an overall index of vulnerability. Based on the analysis, the gap locations were ranked as to their relative vulnerability to future biodiversity loss.

The results are presented in map form, with explanatory text. GIS and graphic design software used to produce the final maps included pcArc/Info, IDRISI, CorelDraw! and Micrografx Picture Publisher. A prototype atlas, *Idaho: An Atlas of Biodiversity* (Machlis et al. 1993) was prepared.

Next Effort: Puget Sound Gap Analysis

The UI CPSU Sociology Project has begun an effort to apply what was learned in the Idaho pilot project to the Puget Sound region of Washington. The research is supported by both the NPS (Pacific Northwest Region) and the EPA (Division of Strategic Planning and Management). The USFWS Washington Cooperative Fish and Wildlife Research Unit is a cooperator.

The Puget Sound study offers the opportunity to improve the integration of socioeconomic factors into the gap analysis technique. It allows for working at a different scale (ecoregion rather than state), and Puget Sound is a large, rapidly growing metropolitan area adjacent to several national parks. Additional socioeconomic indicators will be employed. Different presentation possibilities, including an interactive atlas on CD-ROM, are being explored. An advisory committee is being established, and will help assure the results are useful to managers and decision-makers.

Applications to National Park Management

While the technique needs further development, extending gap analysis to include socioeconomic factors could prove beneficial to national park managers and others interested in biodiversity conservation. Several potential uses are illustrated below:

- Gap analysis can help identify locations vulnerable to biodiversity loss. For example,

locations where human population growth is leading to rapid land-use conversion and habitat fragmentation can be identified. Importantly, the results could identify areas (1) high in biodiversity values, (2) vulnerable to biodiversity loss, and (3) not in national parks, yet which may impact the parks. South Florida and Puget Sound are examples of regions where such an effort may have merit.

- Once gap locations and their vulnerabilities have been identified, long-term monitoring can answer such questions as: Are critical socioeconomic trends continuing? Have actions been taken to reverse those trends contributing to biodiversity loss? What indirect impacts might be resulting from human activity in or near the gap locations? Monitoring critical socioeconomic trends and landscape changes can (1) provide an "early warning system," (2) help clarify management challenges, and (3) suggest potential actions. Such monitoring for the Greater Yellowstone Ecosystem, or along the US-Mexico border may be useful.

- Threats adjacent to parks could be treated as significant factors influencing biodiversity within parks. Increased biodiversity loss outside of national parks may signal increased concern for protection within parks. Park boundaries are permeable, and effective biodiversity conservation demands examining and understanding processes in the wider landscape of which protected areas are part. For example, the technique could prove critical to buffer zone and corridor planning; the North Cascades National Park Complex and certain historic battlefields (which may also preserve significant biodiversity values) might be appropriate sites.

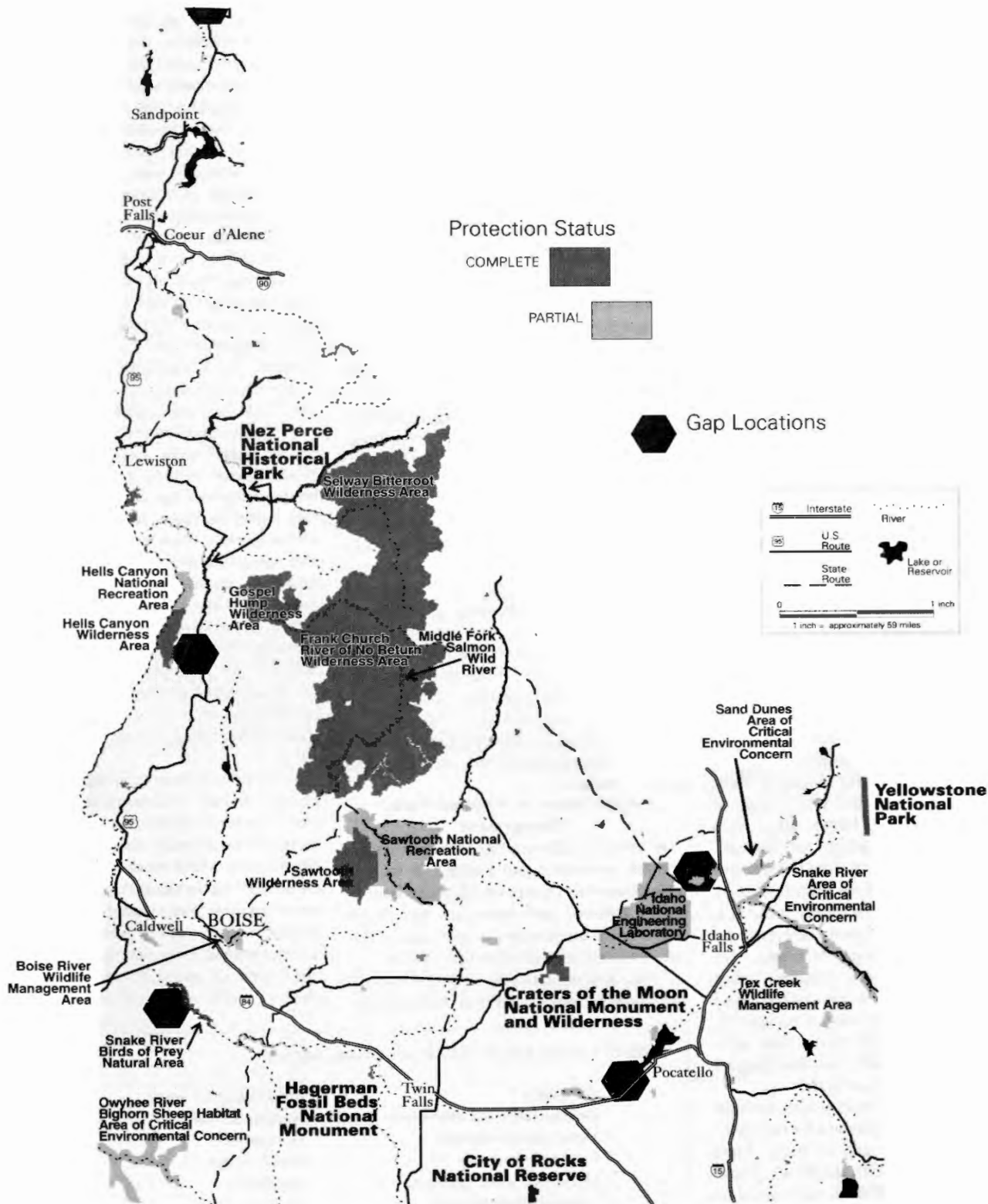
- Gap analysis that includes socioeconomic factors can help to determine which unprotected areas of high biodiversity are at greatest risk of biodiversity loss. This can assist in determining which areas to consider for additional protection status or revised management regimes. For example, given one gap location with low risk of biodiversity loss and another with high risk, decision-makers may opt to provide protection to the area most likely to suffer biodiversity loss. In addition,

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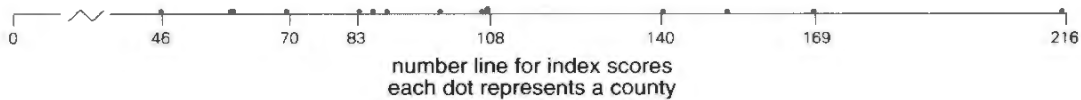
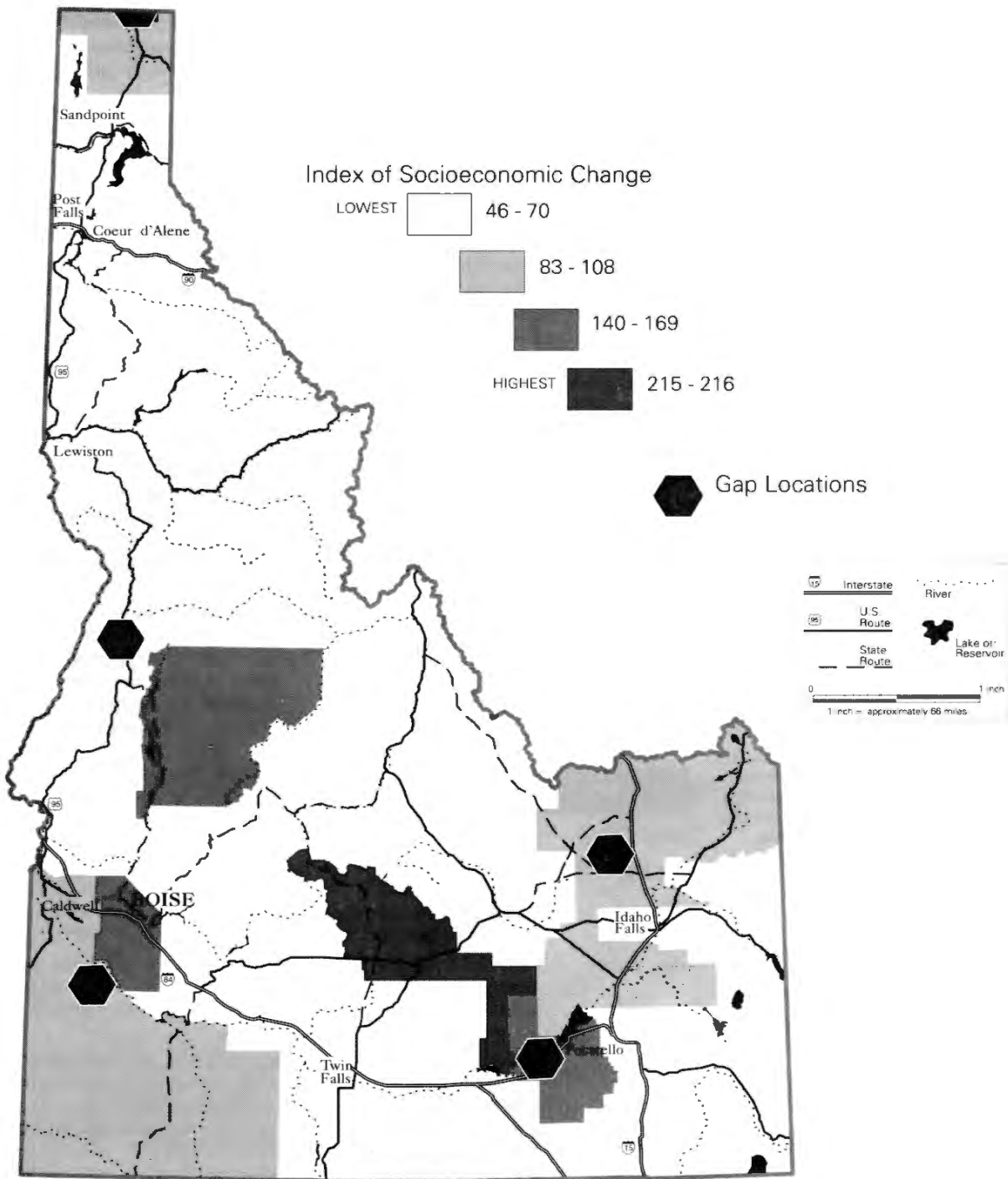
Table 1. Example Indicators for Extended Gap Analysis.

Air quality	Municipal solid waste
Defense lands and installations	Number of vehicles
Demographic forecasts	Occupation
Economic forecasts	Political units
Hazardous waste exposure	Population
Housing characteristics	Population and economic projections
Labor force projections	Population density
Land use regulations	Real estate transactions
Location of manufacturing	Residential construction

Map 1. Protected Areas and Gap Locations



Map 2. Socioeconomic Change and Gap Locations



gap analysis can help identify areas where careful development may minimally harm biodiversity values. Such information may be useful to non-governmental organizations with land acquisition programs, federal and state agencies, and private developers.

Conclusion

Gap analysis is evolving rapidly, and numerous state databases are being constructed. The technique likely will become an important conservation planning tool. Gap analysis can provide a systematic source of information for scientific analysis, professional management, and public dialogue. All are necessary for successful ecosystem management and the conservation of biodiversity. Extending gap analysis to include socioeconomic factors will further increase its usefulness and application. While much work remains before the technique is fully operational, park managers may soon benefit from its use.

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