CHAPTER 6

Human Dimensions and Applications

6.1 Introduction

Human Dimensions refer to the conditioning factors and driving forces that influence human activities and their environmental consequences. These forces include the following: population and other demographic changes, technological change, economic structures and market forces, political-social institutions and their interaction and societal values. Its research focus is thus the scientific investigation of the physical, biological, sociological, psychological, cultural and economic aspects of resource utilization and management on several scales.

By "applications" we mean the transformation and communication of relevant research results to meet specific needs of decision-makers in the public and private sectors, and the capacity building needed to facilitate this process, i.e., education and training. The critical need lies in the process of guiding the communication and transformation of forecasts into usable information in a given context to support decision-making at private, local, regional and national levels.

These two complementary research themes present an exciting challenge to move from the notion of "impacts" of climate and weather to practical "mitigation" of social vulnerability (**Fig. 6.1**).

Recent scientific developments, such as in ensemble medium range forecasting and ENSO prediction, and the availability of long-term data-sets, such as COADS, provide opportune conditions for interaction and cooperation of scientists and decision-makers in the application of climate information to social, economic and environmental issues. These advances offer support to adaptive approaches in the application of knowledge about the future and its uncertainties. While other research in this volume focuses on research methods, data acquisition and management, this section addresses the acceptability and context for the use of such information in climate-sensitive settings.

The key emphasis in integrated human dimensions-applications research is thus on how social transformations, such as demographic changes, influence social and environmental vulnerability to climate and weather risks, the perception and values applied by society to such risks, and to realize the benefits afforded by developments in climate research, products and services. The research and applications goals in this component are

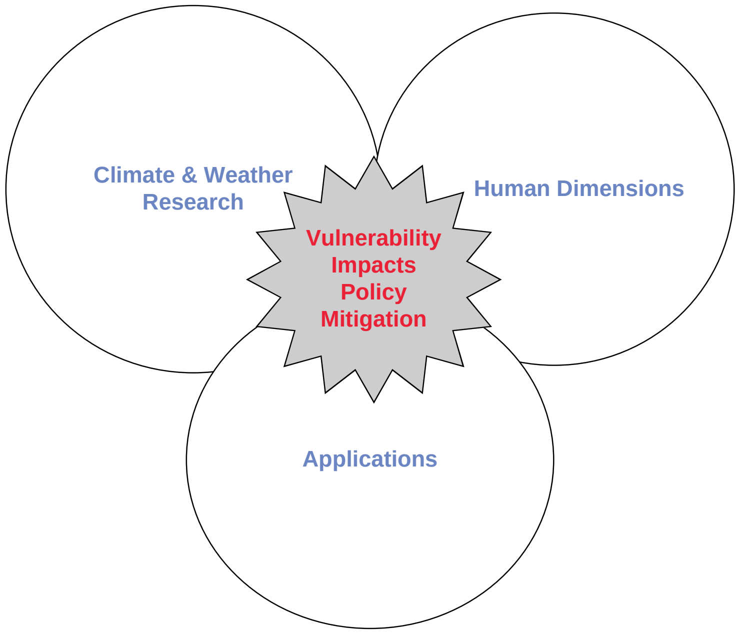

Fig. 6.1. Schematic illustrating the interaction of science, applications, and society.

at the climate-society interface and may be summarized as follows:

(1) Assess impacts, vulnerability, and adaptation to climate on the seasonal and decadal to centennial scales, including urbanization, design, land-use, environmental trends.

(2) Develop pilot projects and prototypes for demonstration of use of climate information and to increase collaboration between scientists and decision-makers. This includes identification of user needs and alternatives in the reduction of economic and social vulnerability on an ongoing basis.

(3) Support decision-making with respect to system outputs e.g. water, agriculture, fisheries, energy, private sector investments.

(4) Improve policy analysis and policy instruments, including problem definitions, agenda setting, capacity building, research and institutional frameworks and structure, to mitigate climate risk and uncertainty i.e. hazards, variability and change such as heat waves, hurricanes, and drought.

6.2 Efforts completed under the human dimensions research and applications focus.

6.2.1 Climate, salmon and hydropower in the Columbia River Basin: Use of seasonal forecasts in balancing salmon restoration efforts and hydropower requirements

It has become increasingly clear that climate-driven fluctuations in the freshwater and marine environments occupied by Pacific Salmon are an important influence on population variability. It is also clear that there are significant prospects of climate predictability on seasonal to decadal timescales which may prove advantageous in managing water resources in the Columbia River Basin. A study on the role and usability of climate forecasts and information was carried out with the cooperation of nineteen institutions and agencies involved in salmon restoration efforts and hydropower production through power production, irrigation, navigation, flood control, recreation, municipal and industrial water supplies, and fish and wildlife habitat management. The study 1) described the climate and management environments of the Columbia River basin; 2) assessed the present degree of use and benefits of available climate information; 3) identified new roles and applications made possible by recent advances in climate forecasting; and 4) elicited from the point of view of present and potential users in specific contexts of salmon management--what information might be needed, for what uses, and when, where and how it should be provided.

Understanding the limitations to information use formed a major component of this study (**Table 6.1**). The complexity of the management environment, the lack of well-defined linkages among potential users and forecasters, including clear decision paths, and the lack of supplementary background information relating to the forecasts, pose substantial barriers to their use (**Fig. 6.2**). Recommendations to address these problems are offered. The use of climate information and forecasts to reduce the uncertainty inherent in managing large systems for diverse needs bears significant promise for this region.

6.2.2 Hurricane risk, vulnerability and disaster mitigation

Until quite recently, tropical storms and hurricanes posed a primary threat to human safety, and property losses, while high, compared to other natural hazards, was perhaps, not as visible an aftermath, as is presently the case. With the advent of greatly improved monitoring and prediction systems, it is generally possible to provide enough lead warning time to enable the coastal populations in the path of a hurricane to take the necessary precautions to avoid death and injury. On the other hand, the growth of coastal population and economic development along coasts, means that, today, the degree of exposure to devastation from the effects of hurricanes is high.

The recognition of enhanced levels of property-loss exposure to hurricanes in the region is one reason why new public-private partnerships are being developed to address the issue of hurricane-related risks. The book shown in **Fig. 6.3** is an outgrowth of a workshop titled *Atlantic Hurricane Variability on Decadal Timescale: Nature, Causes and Socio-Economic Impacts* held at the National Hurricane Center in February, 1995. The goal was to focus attention to changes in hurricane frequency operating on timescales of a few decades, which result in very different storm tracks and landfalling patterns occurring from one epoch to another. In particular, the period of the 1930s to 1950s saw a high level of hurricane activity in the western Atlantic, with many hurricanes

TABLE 6.1. Barriers to the use of climate information and seasonal forecasts

a) Forecasts not "accurate" enough, i.e., need at least 75% event accuracy.
b) Fluctuation of successive forecasts ("waffling")
c) The nature of what a forecast is, and what is being forecast (e.g., types of El Niño and La Niña impacts, non-ENSO events, what are "normal" conditions?)
d) Non weather/climate factors are deemed to be more important (e.g., uncertainty in other arenas, such as freshwater and ocean ecology)
e) Low importance is given to climate forecast information because its role is unclear, or impacts are not perceived as important enough to community resources
f) Other constraints deny a flexible response to the information (e.g., meeting flood control or Endangered Species Act requirements)
g) Procedures for acquiring knowledge and making and implementing decisions, which incorporate climate information, have not been clearly defined
h) Events forecast may be too far in the future for a discrete action to be engaged
i) Availability and use of locally specific information may be more relevant to a particular decision
j) "Value" may not have been demonstrated by a credible reliable organization or competitor
k) Desired information not provided (e.g., number of warm days, regional detail)
l) There may be competing forecasts, or other conflicting information
m) Lack of "tracking" information; does the forecast appear to be verifying
n) History of previous forecasts not available. Validation statistics of previous forecasts not available

striking the United States. Subsequent decades experienced reduction from this level of tropical storm activity, although major storms continued to severely impact the U.S., even during this "low-activity" period e.g. Hurricane Andrew in 1993. The trends leading to increased social and economic vulnerability to hurricane variability were the focus of this effort. A comprehensive definition of vulnerability is proposed, combining elements of physical risk (e.g. event frequency, severity, location), exposure (e.g. demographic changes in coastal regions) and, the social capacity to recover or adapt (i.e. resilience). This approach highlights the factors that turn hurricane-hazard into a disaster. Cases were drawn from the recent history of hurricane-society interaction in the United States, Central America and the Caribbean. Mitigation efforts to address these issues generally lag behind the advances made in hurricane forecasting A framework for assessing vulnerability in light of these physical and social trends and conditioning factors is provided. Hurricane Andrew, which devastated portions of South Florida provided a "wake-up" call to many state and local governments, and particularly to the property insurance industry. A summary of key points is given in **Table 6.2**.

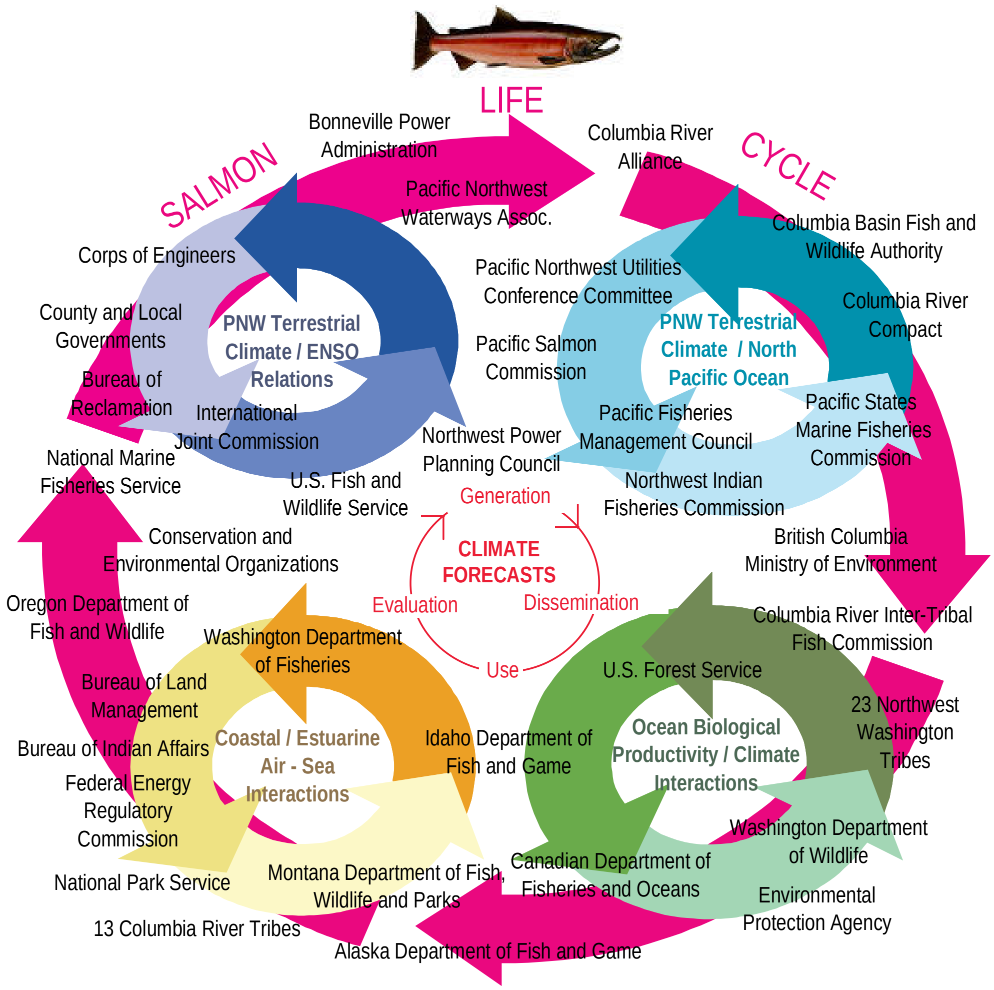

Fig. 6.2 Climate and institutional interactions in salmon management in the Columbia River Basin.

Recent knowledge about hurricane variability indicates that changes in landfall frequency are to be expected, and that the hurricane risk on the U.S. Atlantic seaboard is increasing. Further studies of decadal -scale variability of the conditions favoring hurricane activity can be expected to reduce uncertainty about the physical risk. However, at this time forecasting decadal-scale variability is in its infancy. Uncertainty is unavoidable. Thus, the cycle of preparedness, response and recovery must be framed within strategies for longer-term mitigation. A strong need exists for incorporating mechanisms for evaluating programs throughout their planning and implementation stages and in the larger contexts of disaster management. Scientific information and knowledge for understanding and reducing vulnerability exists, however, the mobilization of political will to undertake needed actions remain a central concern.

In addition to the book, a review of hurricane-risk in relation to coastal man-

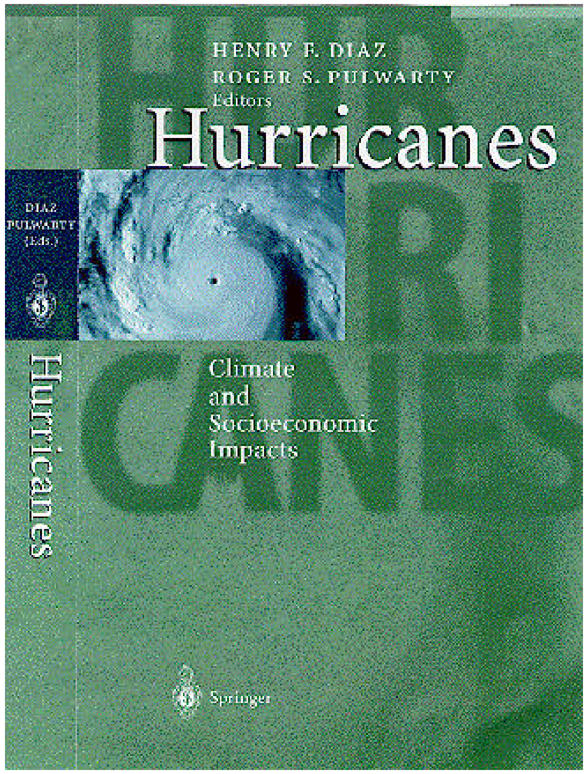

Fig. 6.3. Front cover of book entitled *Hurricanes: Climate and Socio-economic Impacts.*

agement policies on the U.S. Atlantic seaboard is also being completed. The growing concern by the insurance industry and increased attention by federal emergency response agencies promises to enhance partnerships between the public and private sectors in disaster mitigation.

6.2.3 Decadal-scale climate variations in the Western U.S.: Lessons from recent events and implications for water resources and management

The challenges posed by water resources in the United States are multifaceted and interacting. The three major research issues are, (1) physical and hydrological, such as flood forecasting, reservoir management i.e. supply management and augmentation, (2) biological, such as non-point sources of pollution, in-stream quality-salinity temperature, groundwater contamination, population viability, urban-wildlands interface, and (3) policy and institutional, such as responding to extreme events, demand management, historical water allocation constraints, Endangered Species and Clean Water Act requirements. From a resource management standpoint information is needed on present and future availability of water, present and future demand and on consequences on the environment. The overall goal from the scien-

Table 6.2. Summary of conclusions from *Hurricanes: Climate and Socioeconomic Impacts*

The historical record can provide useful lessons about the impacts of particularly severe events. During the month of October 1870 three hurricanes claimed the lives of over 24,000 people. Four storms in this century have each resulted in fatalities exceeding 8,000 people
Understanding decadal trends in hurricane activity may be critically dependent on understanding the broader issues of decadal variations of the major ocean circulation
Most of the largest losses of life during the past 50 years in the Caribbean have resulted from freshwater-induced floods, mud slides and landslides. In the U.S. loss of life due to storm surges has steadily decreased primarily due to improvements in the hurricane warning system.
Modeling studies indicate that the upper bounds on hurricane intensity will increase under global warming scenarios but little is known about how the average intensity would change. However, large-scale atmospheric circulation changes resulting in weakening of the Hadley circulation and warming of the upper troposphere may result in a significant reduction in the number of hurricanes
Ecosystem dynamics, including structural composition and distribution, are linked to the occurrence of low frequency hurricane events. Natural history may be inextricably tied to decadal-scale variations in hurricane impact
Recent large losses from landfalling hurricanes in the U.S. are due primarily to exponential growth in coastal populations and the valuation of coastal property
The relationship between hurricane intensity and damage is nonlinear. Damages in a particular location can be doubled by relatively small changes in intensity
Vulnerability to hurricanes may be defined in terms of risk, exposure and capacity to recover
Changes in vulnerability can occur without changes in hurricane frequency
“Voluntary choice” does not provide a sole explanatory model for why people are located in risk-prone areas
There is a need to document the long-term social, economic and political trends that increase vulnerability
Crises can provide an opportunity to introduce innovations in mitigation. The success of programs is inextricably tied to the people, place, values, institutions and environments concerned
Insurability must be coupled to mitigation strategies particularly where private insurance goals and social objectives may be similar
There is a strong need to increase not only vertical but horizontal communication, education, and coordination across sectors, agencies and local groups

tific viewpoint is to improve predictions on the time and space scales that are most relevant to the management of water resource at urban-rural interfaces, and to those appropriate to understanding hydrologic variability of surface and ground water basins.

The key components of water management are supply management and augmentation, demand management and allocation, and the resulting environmental concerns. The conditioning factors on present and future water resources management in the West can be summarized as follows: increasing population and consumption, deteriorating water quality, environmental water allocation, uncertain reserved water rights, ground-water overdraft, outmoded institutions, aging urban water infrastructures, and the changing nature of federal state and local interactions. Instream uses include hydropower generation, recreation, fish and wildlife habitat, navigation and waste disposal. Withdrawal uses include irrigation, industrial processing, thermoelectric power generation and municipal uses.

Vulnerability of Western water

Preliminary estimates of vulnerability to weather extremes and climate conditions in the major river basins of the West indicate that thresholds have been reached in the areas of storage and consumptive depletion vs. renewable supply, increasing dependence on hydroelectric power, high streamflow variability, and increasing groundwater overdrafts exacerbated during periods of reduced surface flow. The U.S. Bureau of Reclamation has indicated that during a dry period such as occurred from 1931-40 the water needs of the lower Colorado River Basin would not be met.

The nine western water regions identified by the USGS (excluding Alaska and Hawaii) accounted for 90% of the total (surface and ground) water withdrawn for irrigation in the U.S. Four out of the five costliest weather-related disasters between 1980-1997, excluding hurricane impacts, occurred within the basins of western states. Each exceeded $1 billion in damages and costs, with the recent 1996 drought in Texas reaching $5 billion. Even in the water-rich Pacific Northwest region, trade-offs between hydropower, irrigation and salmon requirements have brought allocation systems to their limits, threatening the very sense of community and reducing the likelihood of water transfers to drier regions.

The dimensions of water (quantity, quality, timing, location) influence its value in a particular use. Variability in these dimensions continually define and redefine the West. The alterations of western hydrology reflect a complex story of human settlement, large-scale water diversions, the development and evolution of water policy and law, and expanding frameworks of water resources management. In addition, the focus on supply and the resulting design of water management agencies in the West evolved under the presumption of water as an open resource. Recent emphases on demand management and environmental concerns have altered the traditional roles of federal, state and local agencies.

Demographic, institutional, and climatic variations and changes can disrupt existing relationships and current wisdom about society-environment interactions.

Case studies

Three well-documented cases, from the Western U.S. are used to draw lessons about institutional learning and decisions in the interaction of decadal-scale climate variations and social changes. The cases were:

• The Colorado River Basin: 1900-present.
  Change in streamflow around 1920 can be regarded in retrospect as a climate change.

• California Drought 1987-1992.
  Drought provided a natural "experiment" on the flexibility of large water systems to respond to persistent precipitation deficit i.e. greater than one year.

• Pacific salmon decline in the Columbia River Basin.
  Scientific management, incremental decision-making, and the "surprise" of the 1976-77 step change in the north Pacific.

The economic impacts and management adjustments affecting water allocation over time are described in detail. Responses to these variations are put in the context of already available knowledge of how organizations learn about climate and water resources and the barriers to applying knowledge in a policy context. Strategies in use at present include: water banks, interbasin transfers, advanced decision support/expert systems, streamflow and demand forecasting, drought management programs, indicators and some efficiency improvements. The study clearly shows that decision-making about long-term environmental problems, especially those involving significant changes in behavior, is for the most part reactive rather than anticipatory. It cannot be addressed without an understanding of the political dynamics of the institutions whose behavior is at stake.

The water systems discussed in this study all have the characteristics of "closing systems" where (a) management of interdependence becomes a public function, and (b) the development of mechanisms to get all users to acknowledge interdependence and to engage them in negotiations and binding agreements becomes necessary. It should be noted, however, that implementation of such mechanisms does not appear to be viable under anything less than a full-blown crisis situation brought on by large-scale, persistent drought, legal constraints or quantification of tribal rights.

Lessons drawn for the practical management of variations and climate change indicate that expectations about the future tend to be better understood by those within organizations if there is a clear parallel with the past. Absent such a socially framed grasp of whose behavior needs to be changed and how they may be led to do so, resource management tends to be fragile and lacking in needed adaptive flexibility and modern analytical tools. Expectations about the future make sense, organizationally, only when there is a compelling parallel with the past. Weak signals in the present are unlikely to spur the deep revision of assumptions implied by double loop learning (i.e., learning to learn) when there are heavy costs in doing so and the risks of inaction are unclear.

While water banking and inter-basin transfers have been used to mitigate the effects of short-term drought, the maintenance of supply during periods of severe long-term droughts of 10 to 100 years (the timescales of project implementation and ecosystem management efforts), that are known to have occurred in the West over the past 1000 years is as yet untested. The spatial extent and persistence of drought may produce shortages not only in the locale considered, but also in neighboring regions that otherwise are supposed to make surplus water available for inter-basin transfers. Increases in flood and drought variability would require a re-examination of emergency design assumptions, operating rules, system optimization, and contingency measures for existing and planned water management systems. Designing programs aimed to increase social learning in the management of climate variations, for example, adaptive management, provides a bridge between knowledge and action.

Climate, environment and development in the West: A research framework

The case studies identified above point to a reframing of research goals in order to identify, (1) critical water-related problems; (2) social and economic trends altering demands and influencing the degree of vulnerability of system outputs (agriculture, recreation, power, water quality) to extremes of climate variations and to sequences of events; (3) lessons from past events and measures to increase the flexibility of water allocation among users in response to interannual variability and longer-term trends; (4) the types of information that scientists can and should produce to substantiate change; and (5) entry points for the application of scientific information to mitigation measures employed by water managers and decision-makers.

To incorporate the natural, cultural, and economic factors that must be a fundamental element of sustainable development requires balanced and careful reviews of current knowledge under a comprehensive framework. Key policy questions to be addressed under this framework are as follows:

- what does sustainable development of water resources mean for the Western U.S., what is to be sustained and for whom?

- what trends affect the realization of these goals, and where did these issues originate?

- what factors are responsible for the trends? what are the primary driving or influencing forces?

- what is the probable course of future events and developments (i.e., processes and projections of change)?

- how can this information be used to change such courses of action and to realize or achieve more of the desired goals, and for whom?

A primary focus of this effort is to increase the role of the scientific community in providing insight into policy decisions and implementation. Policymakers are more likely to seek scientific advice if scientists are explicitly addressing controversies in the scientific literature, attempting to clarify their implications and producing coherent assessments.

6.3 Other activities

A key component in all of the studies, described above, has been to provide practical management options using risk based information i.e. climate and weather forecasts, and to highlight areas of uncertainty created by incomplete information and surprise. Thus adaptive approaches to managing seasonal to centennial variations are necessary. Other work highlights the role that science and scientists can play in the adaptive management of natural resources, and reviews the issues involved and lessons learned in producing usable climate information to meet regional needs for sustainable development. In addition contributions have been made to the American Meteorological Society and the U.S. Weather Research Program Societal Impacts groups.

The creation of a database on water allocation and projected needs as related to seasonal to decadal snowpack variability and change in the Colorado and Columbia River Basins has been initiated under a National Science Foundation-funded grant. This information will be provided directly and in usable form to river basin managers and councils. In other areas, a research framework was designed to assess the human dimensions of climate and environmental variability on fisheries and the temperate coastal zones of the Americas. These presentations were invited by potential user groups desiring to enhance their awareness and use of climate information for decision-making in the context of long-term variations.

A graduate/undergraduate course funded by CIRES and titled *"Climate and the Future of the Western United States"* was developed and offered under the University of Colorado Arts and Sciences Critical Thinking Core Curriculum during Spring, 1996. As part of the University of Colorado's Global Change and Environmental Quality Program, a system-wide symposium was organized, in April 1996, under the title "The Role of University Research in Public and Private Environmental Decisions". The symposium highlighted opportunities for interaction between academia, federal and other state institutions and private interests.

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