Ecosystem

Introduction

The Great Salt Lake ecosystem is of worldwide importance for migratory bird populations, brine shrimp and mineral extraction industries. GSL is one of the premier wetlands areas of the United States and is a major recreational and aesthetic resource for Utah. (SRC, 1999c)

The GSL ecosystem is comprised of many subsystems (SRC, 1999b and c) and each is strongly influenced by changing lake levels and lake chemistry. Shallow water, wetland areas and deep water portions of the lake are spatially and temporally dynamic in response to changing environmental conditions. Variations in precipitation and fresh water inflows together create a dynamic mosaic of habitat types along the shores of the lake. Variations in salinity affect species community composition and structure which also varies across all of the lake's ecosystems. There is a distinct difference in salinity between the north and south arms of GSL and this directly influences species distribution and abundance. There is also a strong east-to-west ecosystem gradient in regard to GSL habitat and productivity (SRC, 1999b). Natural and human-induced inputs and outputs occur via inflow, atmosphere and other mechanisms (SRC, 1999c). There are many other components and interactions which determine ecosystem function and productivity. GSL resources are inter-connected and human use influences ecosystem response. GSL components and interactions are closely associated, thus making the management of GSL ecosystems complex and challenging.

Great Salt Lake Subsystems

GSL and its watershed represent a complex web of interacting physical, socioeconomic and ecological systems and subsystems (SRC, 1999c). Current understanding of the complexity of GSL ecosystems and lake dynamics limits the ability to accurately describe and forecast the dynamics of the various system components (SRC, 1999c) such as hydrology, landscape, chemistry, biology, water and air. A subsystem analysis emphasizes the linkages between these components and human interactions from a large-scale perspective. Subsystems and their interactions are usually represented by using a Venn Diagram (Exhibit 11). The subsystems approach can be a management tool for resource planners and managers to identify issues, limitations and areas of uncertainty.

These linkages are best depicted by studying cause-and-effect chains (Exhibit 12 is a simplified example of GSL systems biological linkages). Understanding cause-and-effect chains and their interconnected linkages helps resource managers identify potential methods of altering conditions or managing a system.

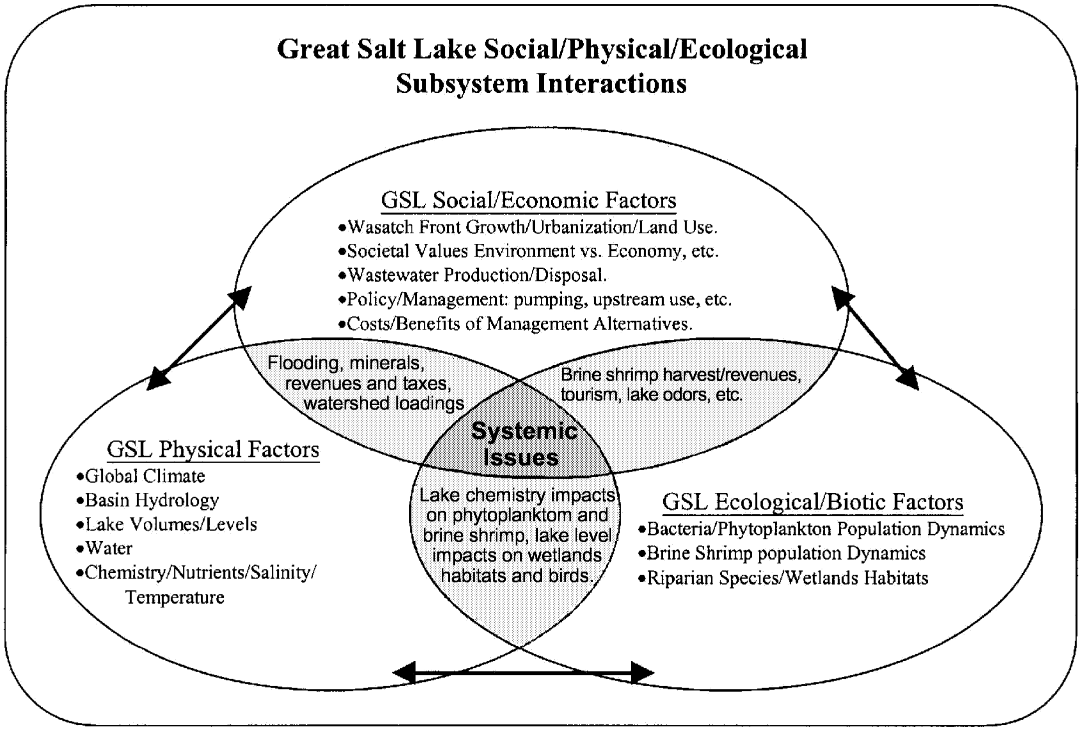

Exhibit 11: Great Salt Lake Subsystem Interactions and Management Problems (SRC, unpub.).

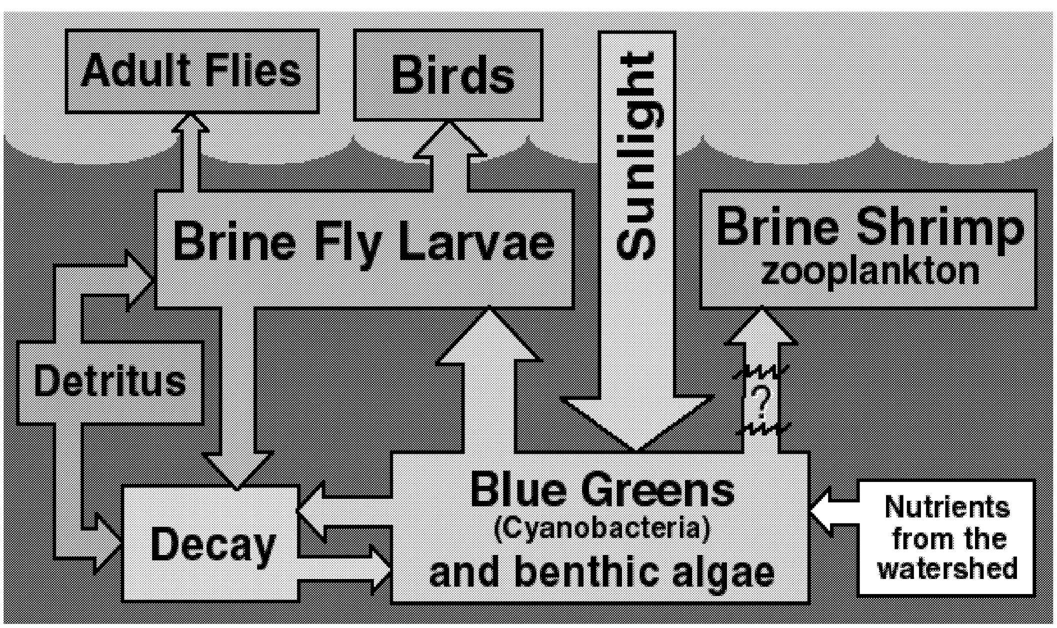

Exhibit 12: View of GSL Ecosystem (USGS, 1999)

Physical Subsystems

Physical subsystems are the physical environment or setting and include basin geology, global and local climate, hydrology, lake level fluctuation, hydrodynamics and lake chemistry. The geologic setting and geography of the landscape creates this watershed and terminal basin. These influence the behavior of other physical components. Lake geomorphology which includes the erosion, transport and distribution of sediments and their patterns in the ecosystem are not well understood (SRC, 1999b).

Hydrologic processes cause fluctuations of lake volume, lake level and salinity. All are strongly influenced by each other and respond to regional and global climatic factors ("Water-Hydrology" section). Climatic forces drive watershed response and lake level fluctuations at multi-year, decadal and longer time scales. The ability to predict these changes is very limited. Resource managers deal with uncertainty in the long-term behavior of lake hydrology and at best can predict lake levels in the short term (one-to-three years) along with some associated management implications and ramifications (SRC, 1999b).

Biological/Ecological Subsystems

These subsystems focus on biological and ecological interactions. Lake level fluctuations, salinity and water quality affect the dynamics of the lake's ecosystems. This has implications for wetland habitats and the population dynamics of brine shrimp, brine flies and birds. There are further implications for tourism and commercial brine shrimp harvesting. Nutrient availability, air and water quality have ecological consequences. Lake managers have yet to fully understand these interactions and the affect of lake chemistry on biota (some research is currently underway). The physical arrangement sets the stage for biological subsystems' ability to function. Temperature, light, salinity, nutrients and many other factors have an effect on shallow and open-water ecosystems which create dynamic biological systems and subsystems with their seasonal and annual variability (SRC, 1999c). There is limited information available to understand these interactions. Time scales of ecological subsystems behaviors range from diurnal to multi-year.

Socioeconomic Subsystems

Socioeconomic subsystems relate to human interactions that influence ecosystem response. This subsystem includes population, economic and other human-related interactions with a system. Salt extraction, mineral production, brine shrimp harvesting and oil and gas reserves are also important lake economic resources. Tourism and recreation are additional important lake uses.

Rapid urbanization and agricultural expansion is occurring in portions of the GSL uplands and the watershed. This area contributes the vast majority of fresh water inflows to the lake. These human-induced impacts change the amount and temporal distribution of runoff into the lake, as well as the quality of runoff water. These changes affect lake level, water chemistry and ultimately other subsystem components. Management strategies may also influence lake level and chemistry, air and water quality.

Upstream and watershed activities such as discharges, development and water allocation all interact with other lake ecosystems and all three conceptual subsystems. The political and economic arenas drive management actions within this subsystem. Activities within socioeconomic subsystems occur and affect the lake at seasonal to multi-year time scales.

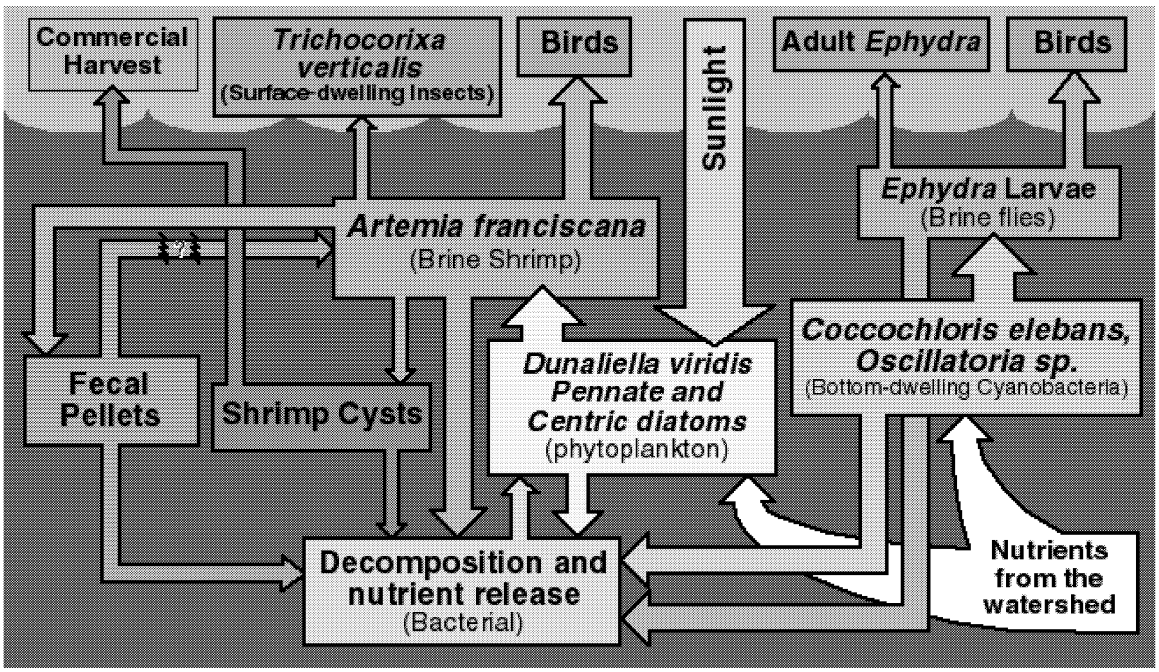

Exhibit 13. Components of GSL System (USGS, 1999)

Subsystems Management and Planning

Many management issues occur at the interface among these three subsystems (Exhibit 11). Each subsystem varies spatially, temporally and structurally and impacts each of the others. Management actions intended to influence environmental conditions in one subsystem may impact another. For example, high lake levels in the 1980s and flooding (physical system changes) impacted infrastructure and other major economic resources (socioeconomic system) around the lake. Physical subsystem changes, such as lake level fluctuations and salinity variability influence lake aquatic organisms (phytoplankton and brine shrimp populations). This also has implications on the quantity of wetland and riparian habitat available to migratory birds and other wildlife, thus demonstrating that GSL subsystems have many linkages and are dynamic and interactive (SRC, 1999c).

Lake managers currently recognize that:

> GSL dynamic subsystems operate at different spatial and temporal scales and interact with one another to produce complex nonlinear behaviors that are difficult to predict (1999c).
>
> Sufficient scientific understanding for management purposes is needed and includes the dynamics, complexity and uncertainty inherent in the behavior of lake subsystems (SRC, 1999c). Additional study and research is needed to better understand lake dynamics ("Monitoring and Research" section of the Great Salt Lake Comprehensive Management Plan and Decision Document).
>
> Lake level fluctuation and variability in lake salinity are important aspects of ecosystems function and are important management considerations.

Ecosystem/Biological Linkages

Invertebrates and fish in some areas are important links between the primary producers (algae and macrophytes) and the bird populations that make these ecosystems valuable and unique resources. Available information on these components (Huener and Kadlec, 1992, Osmundson, 1990, Flannery, 1988 and others), is marginal. Information for invertebrates in similar ecosystems exists (Murkin and Batt, 1987; SRC, 1999e).

In shallow and less saline regions of the lake, brine shrimp are not as abundant and different invertebrate communities are more prevalent. In marshes, brine flies are not abundant but midges are usually abundant and are the main food supply for avocets (Osmundson,1990) (SRC, 1999c).

This dynamic of interconnected GSL ecosystems creates a reliable resource (major concentration area) for many species and huge populations of birds. During high water years, birds relocate to other areas and resources. High bird population numbers today suggest that this has been an extremely productive ecosystem for a very long period of time. Food resources have been reliable for huge populations and many species of birds have developed migratory behavior that capitalizes on these resources. Variability within natural limits is good for ecosystem productivity (SRC, 1999c).

Sustainability and Ecosystem Health

Sustainability is "a system's ability to maintain its structure (organization) and function (vigor) over time in face of external stress (resilience)"(Costanza, 1992). A system responds to outside stresses and nature of the stress may even be more significant (Smol, 1995) (SRC, 1999c).

A well buffered system is able to maintain its structure and function (SRC, 1999c). Biodiversity is another important consideration for planners and managers.

A "healthy" ecosystem is one that existed before significant anthropogenic impact (Smol, 1992), but ecosystem health is difficult to define. As environmental conditions change, the system adjusts to these changes. Therefore an "unhealthy" condition is beyond the natural range of fluctuation due to conditions resulting from some human-induced modification of the system (SRC, 1999c).

Ecosystem Impacts

There are several types of environmental impacts that managers consider in planning and managing for important natural resources. Managers consider short- and long-term, immediate and site-specific impacts. There are also adverse, unavoidable, irreversible and irretrievable impacts.

Direct impacts are the result of circumstances or activities that occur at the same time and place and hence alter a system. Indirect impacts are further removed but are still reasonably foreseeable and influence a system. Cumulative impacts occur when there are multiple effects on the same values. Gradual impacts occur on resources when combined with past, present and future actions (BLM, 1998). There are many direct, indirect and cumulative impacts to GSL and its environs. The following list cites a few examples of human-related direct and indirect GSL impacts:

- Dikes and causeways
- Brine shrimp harvesting
- Exotic species introduction
- Mineral extraction
- Oil and gas production
- Lake level modification
- Recreational activities
- Grazing
- Discharges/Accidental spills
- Upstream water allocation
- Water and air quality
- Population growth
- Wetland-nutrient loading
- Loss of GSL wetlands
- Agriculture activities
- Road salts
- Mosquito abatement
- Trash and pollution

Some GSL impacts have a positive effect on lake resources, such as the creation of state and federal wildlife management areas and duck club habitat enhancements. These alterations enhance habitat resources and provide forage and cover for wildlife. Others may cause degradation over time. Ecosystem threats include population growth, water and air pollution, commercial and industrial development such as diking and mineral extraction pond conversion.

The sovereign land multiple-use and sustainable yield management framework requires that lake managers consider these and other impacts to lake resources.

Resource planners and managers consider impacts in lease permits, management activities and in protecting resource sustainability. Better monitoring and research adds to the information base and helps managers make good management decisions.

Cumulative impacts are often difficult to identify but will play an increasingly important role in lake management. As the knowledge base increases through monitoring and research, the consequences and mitigation measures to avoid cumulative impacts on lake resources will be better understood.

Great Salt Lake Impacts - Examples

Some areas of the lake are more susceptible to impacts due to their shallowness and proximity to large population centers. Farmington and Bear River Bays have very limited data to investigate the implications of possible or future impacts to these areas. Shallow water and wetland areas of the lake, especially on the north end and east side of the lake, are different both ecologically and in regard to the multitude of threats to these areas. These ecosystems are interfaces or buffers between the main body of the lake and surface and ground water inflows (SRC, 1999c).

Environmental conditions adjust to changes in water depth, salinity, volume and chemistry of inflows. Natural and human-induced changes in water levels and salinity have major impacts on the spatial and temporal distribution of the shallow lake and lake margin ecosystems. Variability is essential to GSL ecosystems function and productivity. Ecosystem changes are likely the result of changes in individual species biology (Foote, 1992 and Engelhardt, unpub.). Often, ecosystem changes are more or less predictable depending upon available species-specific information. Some species-specific information exists (Kadlec and Wentz, 1994, Foote, 1991 and Kantrud et al., 1989). Species tolerance to changing conditions within GSL ecosystems should be better understood (SRC, 1999c).

Lake hydrodynamics have been impacted. Water does not circulate freely throughout the system due to dikes or causeways resulting in several sub-ecosystems with different hydrologic and water chemistry characteristics. This limits the variability of lake levels, salinity and water circulation. Farmington and Bear River Bays' salinity conditions have some positive consequences for wildlife productivity.

The multiplicity of GSL ecosystems, lake dynamic interactions and lake level fluctuation makes it difficult for resource managers to detect undesirable changes and determine their causes. Gaps in the information base limit knowledge and understanding of the GSL ecosystem and its many sub-ecosystems. A well-designed monitoring and research program can help improve lake management, evaluate lake impacts and help protect sustainability while still allowing for a wide variety of multiple uses (SRC, 1999b and c).

Planning Team Ecosystem Health and Salinity Conclusions

The planning team has considered concerns regarding declining numbers of brine shrimp in the south arm (Gilbert Bay). Changes in salinity can change the abundance of brine shrimp (Stephens, 1998b). Brine shrimp are important consumers of algae and are also an important food source for GSL birds. Brine shrimp are also commercially harvested which complicates an ecosystem analysis. Brine shrimp population studies indicate that lower salinity levels in the south arm are impacting algal community compositions, specifically *Dunaliella virdis*. These green algae are a major food source for brine shrimp and are being replaced by larger pennate diatoms, which are difficult to digest (Stephens, 1998b). Reduced salinity appears to contribute to a higher winter loss of brine shrimp cysts, making it difficult for the population to restart when conditions are favorable in the spring. Research studies in 1998-99 identified this problem. However, other environmental variables may also impact brine shrimp population numbers, and according to the SRC, brine shrimp are not the best indicator of ecosystem health or of the overall condition of the lake (SRC, 1999c).

DNR resource managers are concerned that the south arm of the lake may be trending beyond its natural range of variability due to human-induced impacts to the lake. This concern raises a sustainability issue regarding ecosystem function. The northern railroad causeway has restricted flow between the north and south arms of the lake ("Water-Chemistry" and "Water-Hydrology" sections).

As resource managers, how should we then evaluate "ecosystem health?" The planning team has considered using brine shrimp as an indicator of ecosystem functioning. The SRC suggest that algae would be a good indicator since they are widespread and trackable in GSL sediments over time, plus are responsive to human-induced and environmental change. Some historical measurements of lake level and salinity are available and, along with future paleolimnological studies (SRC, 1999c), can be useful to assess the health of GSL ecosystems. An additional method would be to investigate a community or group of species response to ecosystem change, but historical data of this type are very limited. No single species is a reliable indicator of GSL ecosystem condition. The SRC suggests that we should also study other factors whose interactions and variability are less known, such as nitrogen, water transparency, temperature, brine shrimp harvesting, algae, diatoms, other primary producers, invertebrates and their interactions (SRC, 1999c).

Diatoms are often used as bio-indicators of environmental change (Dixit et al., 1992) and are well preserved in lake sediments. They can be used to indicate past environmental conditions (Moser et al., 1996). Other past limnological variables can be inferred from the sediment record. This makes diatoms a powerful and robust tool for ecosystem management. However, this information is either limited or not available at this time (SRC, 1999c).

The physical, socioeconomic and biological/ecological subsystems and their resulting interactions describe one approach to investigate the implications of salinity and human impacts on GSL ecosystems. The economic and political reality in the context of GSL "ecosystems" planning is that the railroad causeway is a human-induced change that is altering the function of GSL ecosystems. Brine shrimp populations are declining in both the south arm (low salinity and south arm industry concerns) and the north arm (high salinity). The northern railroad causeway has restricted natural lake hydrodynamics (lake circulation, level and salinity or the movement of fluid with in the lake) to a point at which environmental conditions have been noticeably altered (Appendix G and Appendix H).

A "focus species" is a species that for several reasons is a compass of changing conditions, economic and other human-induced change. The planning team believes that the GSL brine shrimp population is an indicator of the overall condition of the lake and reflects the socioeconomic factors related to recently observed salinity trends. Economic, political and environmental factors will be considered in view of ecosystem sustainability and health.

Great Salt Lake Ecosystem Management

The main ecosystem driving forces, lake level and salinity, are an integral part of the lake's ecosystems. DNR intends to allow for as much natural lake level fluctuation as reasonably possible to enhance ecosystem processes. It is also important to recognize when human-induced impacts are altering or restricting lake hydrodynamics and the ability of the lake to exist as a natural body of saline water.

Existing jurisdictional boundaries limit the ability of DNR and its divisions to consider GSL ecosystems beyond the meander line and champion or monitor GSL ecosystems. It is the intent of DNR to change this situation by improving coordination among the different divisions that have management authority on the lake. It is the role of this planning effort to initiate in-house collaborative coordination to resolve long-standing issues, integrate GSL management policies and to help determine gaps in information that require research or monitoring for this valuable local, state and world-wide resource.

The GSL plan will provide a framework and help guide this activity. However, initiating more comprehensive planning efforts for the lake and its watershed will require legislation and financial backing. Multi-agency collaborative efforts are essential to accomplish and support plan research and ecosystem monitoring objectives and to continue ongoing efforts.

This planning process in itself has improved coordination among the divisions of DNR. GSL management requires a coordinated front to address lake management issues. However, many issues transcend the state and private land boundaries and post-plan watershed coordination will also help protect long-term sustainability.

Sustainability and Development

"In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, attack and prevent causes of environmental degradation where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation" (Bergen Ministerial Declaration on Sustainable Development in the ECE Region, 1990). There is often industry and political opposition to the precautionary approach since it interferes with traditional ways of conducting business and the scientific process utilized to provide decision-making rationales (Buckingham-Hatfield and Evans, 1996). Traditional ways to conduct business may lead to over exploitation while waiting for better scientific data to be compiled. The planning team believes that the proposed salinity management preferred alternative is an example of a precautionary approach.

Jurisdictional boundaries of GSL systems for planning are limited by different land-based resource agencies which limits the effectiveness of government to plan for sustainable development. Other constraints include scientific/technical, economic factors, political and ideology and the lack of industry volunteerism. Managing for sustainability often requires a regulatory framework to protect public trust resources and to identify appropriate tradeoffs in balancing multiple-use and sustainability objectives. Sustainability is defined by societal and political values rather than a scientific based concept. The long-term viability of the resource is determined by the outcome of social values. However impacts on GSL systems cut across economic, social and political boundaries.

Sustainability is achieved by “knowing the state of the environment.” This is the resource inventory and provides the baseline to evaluate monitoring and identify trends that are useful for formulating effective management policies. Managing for sustainability assumes that resource managers understand management actions and their consequences (impacts) on dynamic systems. Precise cause-and-effect observations are often vague and problematic since scientific information may have several different interpretations. Therefore research and monitoring objectives must be carefully designed.

Sustainable planning for GSL ecosystem should include “targets” or objectives for determining the effectiveness of multiple-use and sustainable management objectives in balancing development and maintaining environmental integrity. Management targets are based on scientific understanding of GSL ecosystems limits and tolerances to human-induced change. Management targets may be established at different scales and levels. (Buckingham-Hatfield and Evans, 1996). A few ideas to evaluate management objectives are:

1. Identify sustainability indicators or targets for resource management and decision-making.

2. Identify tradeoffs and determine if acceptable tradeoffs will maintain the integrity of GSL resources to ensure that each generation should at least inherit a similar natural environment.

3. Identify environmental quality or performance measures that are reportable and measurable over time.

4. Determine a conceptual approach for monitoring and assessing the state of the environment.

5. Identify information needed to assess the “state of the environment.”

6. Identify vigorous monitoring strategies.

7. Design analysis and reporting strategies.

Sustainable use of GSL ecosystems means limiting the use of renewable natural resources at a pace where they can renew themselves through natural processes (Fischer and Black, 1995). Ecosystem management objectives should include and consider:

1. Allowance for reasonable multiple-uses to the extent they are consistent with the Public Trust Doctrine

2. Wise resource allocation to ensure long-term sustainability

3. Establishment of checks and balances to ensure an acceptable level of environmental protection

4. Minimizing negative impacts on GSL ecosystems

5. Engaging industry in ensuring sustainable resources by preventing and managing for crises in their operations and to help in monitoring impacts

These measures will allow for economic growth that is mindful of the limited natural resource base (Fischer and Black, 1995). It will be challenging to balance public needs and ensure long-term resource protection with projected population growth scenarios. Sustainable management ensures that GSL natural resources will be available for future uses.