REPORT

# The Value of Kol River Salmon Refuge's Ecosystem Services


Research conducted by University of Vermont's Department of Community Development & Applied Economics and Gund Institute for Ecological Economics

**Authored by: Charles Kerchner, Roelof Boumans, and William Boykin-Morris**



**Date Report: November 23, 2008**

*Prepared for and funded by:*

Wild Salmon Center

## List of Tables



## List of Figures

## EXECUTIVE SUMMARY

### Introduction

Policymakers in Russia Far East have arrived at an important juncture when it comes to designing land management alternatives for Kamchatka Peninsula. One development path relies primarily on nonrenewable resources (e.g. minerals, oil and gas) and built capital. This path will provide short-term economic benefits, but may also sacrifice the long-term economic benefits of a productive, self-maintaining ecosystem. Several studies have shown that following this path will not lead to optimal economic or social returns. Sinyakov (2005) and Shirkov et al. (2001) confirmed that investing in the maintenance of biological resources in Kamchatka will yield a more sustainable economic return, in the long-term, than investing in nonrenewable resources.

The other path leads to investment in the natural capital that remains on Kamchatka and provides long-term benefits from renewable resources and ecosystem services, which are critical to human well-being (Daily, 1997). While this path includes harvesting aquatic bioresources, such as salmon and other fish species, as currently done, it could also includes investing in ecosystem services. This approach is known as Payments for Ecosystem Services (PES) which has become a popular approach to resource management over the past decade (Landell-Mills et al., 2002).

Investing in ecosystem services is critical to the sustainable development of the region because the fishing industry, on its own, may struggle to provide a satisfactory living standard for the 379,000 residents of Kamchatka. While the fishing industry is the highest valued sector in Kamchatka, it provides only US $111 per capita revenue a month (Sinyakov, 2005). Given this modest income, the development of other sources for income is inevitable. In many cases, this includes the development of nonrenewable industries, but it could also include the development of ecosystem service markets. Developing these incentives for salmon ecosystem conservation will help “tip the scale” toward conservation and alleviate pressure on complex, fragile ecosystems in Kamchatka.

This study is the first attempt to approximate the total flow of ecosystem services in a selected watershed in Kamchatka. We have developed a comprehensive valuation framework that has produced a baseline range of values for 13 land cover classes and 24 ecosystem services. The goal of this study is to answer the question: What is gained in terms of economic value to society by preserving Kol River Salmon Refuge’s pristine ecosystem?

### Methods

We estimated the value of ecosystem services in the Kol River Salmon Refuge using 4 steps. Step 1 quantified the ecosystem services using Geographic Information System (GIS) technology and Step 2 estimated marginal economic values ($/ha/year) for each of the 13 land cover classes and 24 ecosystem services. For Step 1 and 2, we developed an excel-based model called the Kol Refuge Rapid Assessment Valuation (KOL RAV) to produce minimum and maximum values for each ecosystem service and land cover. Using the baseline values derived from the KOL RAV, we then developed a dynamic, spatially explicit model called Kol Refuge Ecosystem Service Evaluation Model (KRESEM) to run land cover change scenarios. The development of KRESEM was completed in Steps 3 and 4.

**Summary of Findings: 10 Points**

1. The total value of ecosystem services in the Kol Refuge range **from $784 million to $2.38 billion per year.** The average value per hectare (ha) per year ranges from $3,539 to $10,793. To put this in relative terms, the total economic value of fish exports from Kamchatka was US $326 million in 2002.

2. Most of the ecosystem service values are not captured in the market economy. The findings from this study are similar to others – the value of nonmarket goods and services is greater than the value of market goods and services.

3. For nonmarket services, some market mechanisms exist that could capture the value of several ecosystem services in Kamchatka. For example, the size of the global carbon market has increased dramatically in recent years. The market (compliance and voluntary) more than doubled from US $31 billion in 2006 to US $64 billion in 2007. If forest in the Kol Refuge qualified for avoided emissions via conservation of existing carbon stocks through Reduced Emissions from Deforestation and Degradation (REDD) the value could exceed US $50 million per year in the voluntary market. If REDD qualified under the Clean Development Mechanism (CDM) the carbon market value in Kamchatka would be much higher.

4. Because many ecosystem services are inherently non-excludable, such as storm protection, nutrient regulation, and pollination it would be difficult, if not impossible, to develop markets for them. However, these ecosystem services have significant economic value (e.g. nutrient regulation had the highest ecosystem service value in this study from US $60- $885 million) and their protection is critical to human well-being. Therefore, government has an important role in developing land management policies in Kamchatka that ensure the provision of pure public goods.

.

5. The total benefit of protecting the Kol Salmon Refuge over 100 years is US $78 to $238 billion using a zero percent discount rate, US $25 to $76 billion using a 3 percent discount rate, and US $11 to $34 billion using a 7 percent discount rate.

6. When examining land use value per ha per year, the highest minimum value is wetlands ($13,289) followed by water surface ($12,837) and shrublands ($3,733). For maximum values per hectare per year, wetland is the highest ($47,489), water

surface is the second highest ($31,504) and coastal area is the third highest ($30,968).

7. For ecosystem services, nutrient regulation is the highest value (US $886,514,860), water supply is the second highest (US $360,266,987), and gas regulation is the third highest (US $206,925,224).

8. We estimated the economic value of salmon caught in the Kol Refuge to be between US $981 thousand and US $3.7 million per year. This value range is the contribution to Russia's national wealth.

9. KRESEM, a spatially explicit model developed in this study, simulated several land use change scenarios. One of the greatest economic losses resulted from conversion of land cover to human development. In one scenario, riparian buffers (salmon habitat), wetlands, and coastal areas were converted to human development (via pipelines, roads, mines, and oil and gas development) at a rate of 5 percent for 50 years. Approximately 8 percent of Kol Refuge's total ecosystem value was lost from this scenario.

10. Findings from KRESEM indicate there is very little potential for economic gain from any land conversion scenario. This suggests that the pristine ecosystem in the Kol Refuge is currently at its maximum economic value.

11. While there is little potential for economic gain from land conversion, there is potential for significant economic loss. This means that unless mechanisms are developed to preserve the Kol Refuge ecosystem, society will most likely lose large economic value in the long-term.

**Recommendations and Conclusions**

- The scenarios run in KRESEM highlight the importance of ecosystem service markets. The revenue per capita in Kamchatka was US $249 per month (US $111 from fishing industry) in 2003. Given this modest income there is a need to develop a greater revenue stream for individuals. However, as KREMSEN demonstrates, shifting land cover to human development (e.g. roads, pipelines, and oil and gas development)significantly reduces the total ecosystem service value. The Kol Refuge is a great example of how the majority of ecosystem values fall outside the market realm and thus are not internalized in land management decisions. To internalize the externalities of providing the host of ecosystem services outlined in this study, mechanisms must be developed to start paying for them. Developing incentives for ecosystem service protection in the Kol Refuge should be a priority for any management strategy.

- While market incentives may help protect some ecosystem services in the Kol Refuge, markets cannot be developed for many of the nonmarket services (e.g.

storm protection, nutrient regulation, and pollination). Thus, the role of government in developing sound land management policies is also critical to the long-term economic viability of the region.

- Scientists, practitioners and policymakers who work in the Kol Refuge should use KRESEM as a tool to examine how monetary values change over the landscape in response to land management decisions. This will integrate ecosystem service values in policy and management decisions, which is currently lacking in the majority of conservation projects.

- Considering beneficiaries (society) only pays for a fraction of the US $784 million - $2.38 billion dollars worth of services provided by the Kol Refuge per year, society should begin compensating stakeholders for their provision. The development of an eco-trust used to invest in natural capital in the Kol Refuge should be considered.

- One way to protect ecosystem services is to develop programs that pay an incentive for their protection or enhanced provision. There are examples of these types of conservation programs throughout the world. For example, in the U.S. the United States Department of Agriculture's Conservation Reserve Program (CRP) preserves over 34 million acres of land a year by providing an annual rental payment to landowners to establish vegetative cover and other soil conservation practices. These payments help reduce sedimentation in streams, improve water quality, establish wildlife habitat, and enhance forest and wetland resources. Similar conservation programs that provide an incentive for salmon conservation could be examined in Kamchatka. In this study, we estimated the amount an incentive payment would have to be to induce the desired changes for salmon conservation (US $296 to US $1,125 per metric ton of salmon).

- Considering the marginal value of carbon sequestration for temperate forest in Russia is expected to increase from US $870 per ha per year in 2007 to US $9,890 per ha per year in 2050 (as predicted by COPI's upper bound estimates), the potential for carbon markets should be assessed.

- Because of the potential for nonrenewable industries (e.g. oil, gas, minerals etc…) in Kamchatka, Forest Trend's Business and Biodiversity Offsets Program (BBOP) should be considered as an avenue for biodiversity offsets. This study can provide important information of the economic value of these offsets.

- Poaching is one of the greatest anthropogenic influences on salmon ecosystems and threatens the security and biological diversity of the Kol Refuge. A total of 60-75 mt of roer are poached per year and 2,000 – 2,500 mt of salmon are killed per year in the Kol and Kehta Rivers. Funding for additional park rangers and identifying other methods of enforcement should be a priority.

## 1. INTRODUCTION

Policymakers in Russia Far East have arrived at an important juncture when it comes to designing land management alternatives for Kamchatka Peninsula. One development path relies primarily on nonrenewable resources (e.g. minerals, oil and gas) and built capital. This path will provide short-term economic benefits, but may also sacrifice the long-term economic benefits of a productive, self-maintaining ecosystem. Several studies have shown that following this path will not lead to optimal economic or social returns. Sinyakov (2005) and Shirkov et al. (2001) confirmed that investing in the maintenance of biological resources in Kamchatka will yield a more sustainable economic return, in the long-term, than investing in nonrenewable resources.

The other path leads to investment in the natural capital that remains on Kamchatka and provides long-term benefits from renewable resources and ecosystem services, which are critical to human well-being (Daily, 1997). While this path includes harvesting aquatic bioresources, such as salmon and other fish species, as currently done, it could also includes investing in ecosystem services.  This approach is known as Payments for Ecosystem Services (PES) which has become a popular approach to resource management over the past decade (Landell-Mills et al., 2002).

Investing in ecosystem services is critical to the sustainable development of the region because the fishing industry, on its own, may struggle to provide a satisfactory living standard for the 379,000 residents of Kamchatka.  While the fishing industry is the highest valued sector in Kamchatka, it provides only US $111 per capita revenue a month (Sinyakov, 2005). Given this modest income, the development of other sources for income is inevitable. In many cases, this includes the development of nonrenewable industries, but it could also include the development of ecosystem service markets. Developing these incentives for salmon ecosystem conservation will help “tip the scale” toward conservation and alleviate pressure on complex, fragile ecosystems in Kamchatka.

This study is the first attempt to approximate the total flow of ecosystem services in a selected watershed in Kamchatka. We have developed a comprehensive valuation framework that has produced a baseline range of values for 13 land cover classes and 24 ecosystem services.  The goal of this study is to answer the question: What is gained in terms of economic value to society by preserving Kol River Salmon Refuge’s pristine ecosystem?

## 1.1 Research Objectives

The objectives of the Kol River Salmon Refuge valuation study are to:

a. Understand the link between ecosystem services and human welfare;
b. Make a first attempt at an approximation of the total value of market and non-market ecosystem services that flow from the Kol River Salmon Refuge;
c. Make the range of ecosystem service values more apparent so policymakers can make informed land management decisions; and
d. Provide Wild Salmon Center with the initial information for creating an eco-trust fund or incentive-based mechanisms for salmon conservation.

## 1.2 Background: Kamchatka and Kol River Salmon Refuge

Kamchatka Peninsula in Russia Far East is home to one of the last salmon strongholds on earth. An estimated sixth to a quarter of wild Pacific salmon originate from the peninsula, making a significant contribution to local livelihoods and national economy. The fishing industry in Kamchatka accounts for 44.5 percent of per capita revenue, which exceeds any other industry or agricultural sector in the region (Sinyakov, 2005). Kamchatka also provides important ecological functions at the global level. The world's salmon market is dominated by hatcheries – the world supply of salmon from hatcheries increased from 2 percent in 1980 to 65 percent in 2004 (Knapp et al., 2007). Kamchatka is very unique in that less than 2 percent of salmon catches come from hatcheries. It also provides 60 percent of the natural spawning grounds in the Far East (Sinyakov, 2005).

Despite the environmental, economic and social importance of Kamchatka's ecosystem, its ecological integrity is being threatened by development. The conflict between ecosystem integrity and development is particularly relevant in the 544,000 acre Kol River Salmon Refuge[1] located in west-central Kamchatka which lies in the Sobolevski District (Figure 1).

While the Kol Refuge is a small percentage of total land area on the 1,000 mile long Kamchatka Peninsula, it is one of the most productive basins for salmon spawning grounds and other ecological functions. All six species of native Pacific salmon reproduce naturally in the Kol and Kehta basins which include the pink salmon (Oncorhynchus gorbuscha); chum salmon (O. keta); coho salmon (O. kisuth); sockeye salmon (O. nerka); chinook salmon (O. tschawytscha); and cherry salmon (O. masou). Other species such as rainbow trout (Parasalmo mykiss); Siberian Char (Salvelinus leucomanis); other species of char (Salvelinus alpinus and S. malma) in addition to one member of Thymallidae (Thymallus acticus mertensi) (Kall) also spawn in the basins (U.N. Interim report, 2005).

[1] For readability, we refer to Kol River Salmon Refuge as Kol Refuge in this report

The Kol Refuge also has high biodiversity indicators for a relatively small area.  There are 291 bird species on Kamchatka of which 127 species were observed within the spawning ground boundaries of the Kol and Kehta river basins. Salmon in the Kol Refuge provide other ecological functions as they are an important source of food for river otters, American minks, wolverines, foxes, eagles and brown bears (U.N. Interim report, 2005).

**Figure 1: Map of Location of Kol River Salmon Refuge within Russia Far East**


Scientists, citizens and policymakers are concerned about the impact that development will have on this fragile, complex ecosystem.

Anthropogenic threats (from U.N. Interim report, 2005):

- Telegraph lines traverse the territory of the spawning grounds and lower part of the rivers along the seashore of the peninsula;
- Sobolevo to Petropavlovsk-Kamcharski gas pipeline and parallel road traverse the territory of the spawning grounds at the lower and middle currents;
- Part of the seacoast is heavily polluted by human debris; a width of over 100 meters for the entire length between the Kol and Kehta rivers exists;
- Upon completion of the gas pipeline the service road will be passable by passenger vehicles;
- While no populated centers in the Kol Refuge exist, some temporary  and permanent settlements are present;
- Poaching is one of the greatest anthropogenic influences on salmon ecosystems and threatens the security and biological diversity of the Kol Refuge. Interviews with local rangers, scientists, and helicopter pilots suggests a total quantity of 60-75 metric tons of caviar are poached per year and 2,000 – 2,500 metric tons (mt)

of salmon are killed per year in the Kol and Kehta Rivers (Wild Salmon Center, personal communication);

- Other threats to the region include mining for oil and minerals both onshore and on the continental shelf

## 2. ECOSYSTEM GOODS, ECOSYSTEM SERVICES, AND MARKET FAILURE

Ecosystems provide multiple goods and services that benefit individuals at various spatial scales. Some are market goods that provide benefits at the local level, such as salmon and food products, while others are non-market services, such as water regulation, storm protection and biodiversity that provide public good benefits at the local, regional and global level. Although these services have shown to have a significant economic value and are critical to human well-being (Pearce, 2001; de Groot, 1992, 1994; Daily, 1997; Costanza, 1997), they continue to be degraded at astonishing rates. The Millennium Ecosystem Assessment (MEA) (2005) found that ecosystem services have declined more rapidly over the past 50 years than any other period in human history.

If we, as humans, depend on these goods and services for existence, why are they being degraded? If the maximum economic value of wetlands in the Kol Refuge is US $47,489 per hectare (ha) per year, as found in this study, why would land be converted for profits that are much smaller?

One reason is that most of the Total Economic Value (TEV) of ecosystem services comes from the provision of non-excludable goods and services, meaning that no one can be prevented from using that particular good or service. For example, no one can prevent a coastal resident from benefiting from storm protection provided by an intact wetland. Since a coastal resident will benefit whether or not they pay for it, there is little incentive to pay and therefore little incentive for the market to provide the resource. Hardin (1968), Clark (1990) and many others have explained how non-excludable and rival goods are subject to over-consumption. Rival goods means that consumption by one person precludes that by another (Daly and Farley, 2004). Hardin (1968) popularized the problem as the 'tragedy of the commons'.

**Table 1: Types of Goods and Ecosystem Services in Kol Refuge**

| | Excludable | Non-excludable |
|---|---|---|
| **Rival** | **Market goods**<br>-Pacific salmon<br>-Timber<br>-Minerals<br>-Food<br>-Hunted bear | **Open - access resources**<br>-$CO_2$ waste absorption capacity<br>-Water supply (when users do not pay)<br>-Poaching salmon and salmon roe |
| **Non-rival** | **Toll goods**<br>-Recreation (congestible)<br>-Scientific Information (if patented or government protected) | **Pure public goods**<br>-Biodiversity<br>-Nutrient cycling provided by salmon<br>-Storm protection<br>-Erosion control<br>-Scenic beauty |

### 2.1 Why is This Important?

Understanding the inherent characteristics of ecosystem goods and services is important to understand how we use them, how we benefit from them, and the methods that should be used to value them. It is widely acknowledge that ecosystem services have an economic value to humans. The question is then: How much are they worth? Before we answer that question, however, we must first answer an even more important question: What is the purpose of this valuation study?

Ecosystem service valuation can be an extremely valuable tool for scientists, policymakers and practitioners to help make informed natural resource management decisions. However, it is critical that the correct valuation approach is used to correctly answer the questions asked. To choose the right valuation approach we must ask: What is the policy question we are trying to answer? There are four main valuation approaches described by Pagiola et al. 2004 (Table 2).

**Table 2: Approaches Used in Valuation**

| Approach | Why Do We Do It? | How Do We Do It? |
|---|---|---|
| 1. Determining the total value of the current flow of benefits from an ecosystem | To understand the contribution that ecosystems make to society | Measure quantity of service and multiply by the value of each service |
| 2. Determining the net benefits of an intervention that alters ecosystem conditions | To assess whether the intervention is economically worthwhile | Measure change of each service as result of intervention and multiply marginal value of service |
| 3. Examining how the costs and benefits of an ecosystem are distributed | To identify winners and losers, for equity and practical reasons | Identify stakeholder groups and determine which services they use and value of service to those groups |
| 4. Identifying potential financing sources for conservation | To help make conservation financially sustainable | Identify group that receive large benefit flows, from which funds could be extracted using incentive mechanisms |

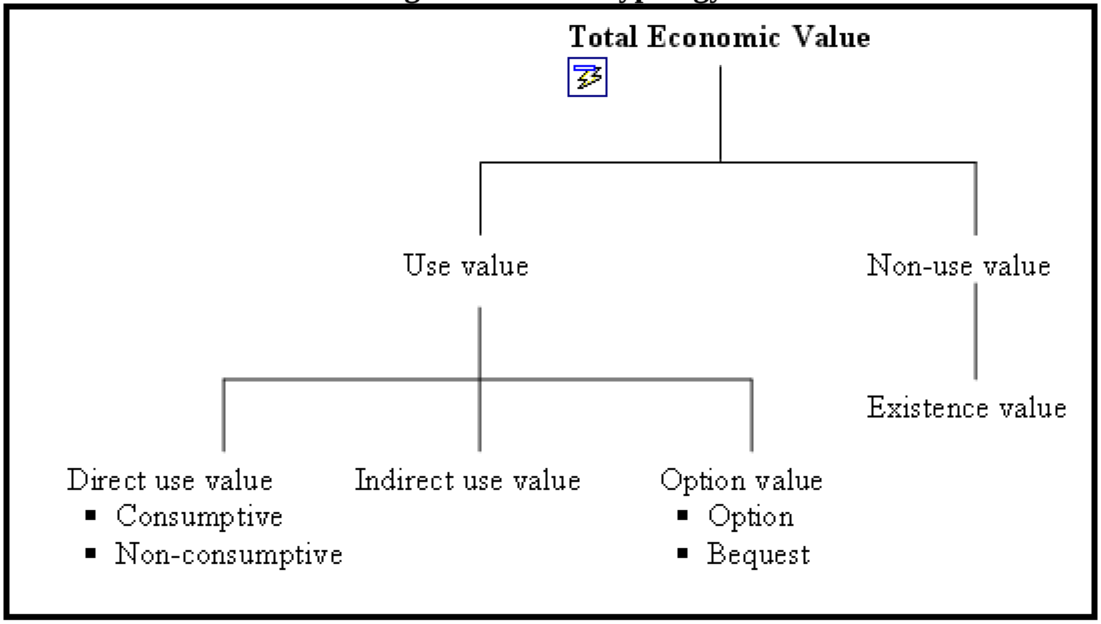
Source: Pagiola et al. 2004

This study estimates the total global flow of ecosystem benefits from the Kol Refuge (approach 1 above). Valuing the full suite of ecosystem services is important for several reasons. Ecosystems are complex, self-maintaining systems that depend on a mosaic of interrelated biological and chemical processes. If only one isolated ecosystem service is valued, and others are ignored, valuation studies can lead to presumptuous conclusions and misinformed policy recommendations. Ecosystems are like cars that rely on multiple components, such as a motor, timing belt and starter to run efficiently. If one of those components is taken away, the whole system breaks down. Likewise, to preserve the diversity of salmon species in the Kol Refuge it is critical to ensure the natural state of spawning streams is kept intact. Estimating the economic value of the total flow of services is one of the first steps necessary to understand the contribution of these services to human well-being and to identify mechanisms for preserving them.

## 2.2 Valuation Typology

There are four general categories of ecosystem values: (a) direct use values, which refers to goods and services that can be used directly by humans (e.g. salmon, timber and other market goods); (b) indirect use values that usually include benefits from regulating services like storm protection from wetlands; (c) option values which refers to preserving the option to use future ecosystem goods and services; and (d) non-use values that refer to the enjoyment of something that you may never use, but get satisfaction simply knowing that it exists (Figure 2).

**Figure 2: Value Typology**




Source: Pagiola et al. 2004

Economists use certain economic techniques depending on the type of ecosystem service being quantified and valued. Table 3 shows the different valuation techniques most widely accepted for use and non-use values.

**Table 3: Valuation Methods and Techniques**

| *Methodology* | *Approach* | Application | Data requirements | Limitations |
|---|---|---|---|---|
| | | ***Revealed preference methods*** | | |
| **Direct Values** | | | | |
| Production function (known as change in productivity) | Trace impact of change in ecosystem services on produced goods | Any impact that affects goods | Marginal change in service; impact on production; (e.g. for salmon the elasticity of demand - if quantity changed how much would price change) | Data on quantity and price is needed for multiple years |
| Other Market Price methods | Use market price set in marketplace | Habitat functions, scientific information, and others | Amount of money donated for conservation | Requires data and sometimes difficult to subtract costs to determine marginal benefit |
| **Indirect Values** | | | | |
| Cost of illness, human capital | Trace impact of change in ecosystem services on morbidity and mortality | Any impact that affects health (e.g. air or water pollution) | Change in service; impact on health (dose-response functions); cost of illness or value of life | Function linking environmental conditions to health often lacking; value of life not estimated easily |
| Replacement cost | Use cost of replacing the lost or good or service | Any loss of goods or services that can be "replaced" by human-made systems | Extent of loss of goods or services, cost of replacing them | Tends to over-estimate actual value; should be used with caution |

| | | | | |
|---|---|---|---|---|
| Travel cost (TCM) | Derive demand curve from data on actual travel costs | Recreation | Survey to collect monetary and time costs of travel to destination, distance traveled | Limited to recreational and other indirect benefits; hard to use when trips are to multiple destinations |
| Hedonic pricing | Extract effect of environmental factors on price of goods that include those factors | Air quality, scenic beauty, cultural benefits | Prices and characteristics of goods | Requires vast quantities of data; very sensitive specification |
| ***Stated preference methods*** | | | | |
| Contingent valuation (CV) | Ask respondents directly their willingness to pay for a specific service | Any service | Survey that represents scenario and elicits WTP for specified service | Many potential sources of bias in responses; guidelines exist for reliable application |
| Group valuation | Based on the assumption public decision making should result from open public debate | Any service | Focus group or open forum where public discussion can take place | Potential bias in response from a group setting |
| ***Other methods*** | | | | |
| Benefits transfer | Use results obtained in one location for another location | Any for which suitable comparison studies are available | Valuation exercises at another other site should be adjusted accordingly | Can be difficult to use values for a site that were derived from a different context |

Source: Source: adapted from Pagiola et al. (2004) among others

Before we discuss the specific valuation methods used for this study we define the typology and framework used. Understanding typology is important to identify and quantify the services that exist in the Kol Refuge.

There are several studies that have tried to identify and classify ecosystem functions, goods and services. For the purpose of this study we will follow the framework established by de Groot et al. (2002), which has the same general typology as the Millennium Ecosystem Assessment (2005). Using this typology allows us to identify, quantify and value ecosystem services in the Kol.

Ecosystem functions are grouped into four main categories:

1. Regulating functions
2. Habitat functions
3. Provisioning (production) functions
4. Cultural (information) functions

These functions can be broken down into 24 functions, goods and services underlying these functions (Table 4).

**Table 4: List of Ecosystem Services and Functions in Kol River Salmon Refuge**

| Functions | | Ecosystem Processes and Components | Examples |
|---|---|---|---|
| ***Regulating functions - Maintenance of essential ecological processes and life support systems*** | | | |
| 1 | Gas regulation | Role of ecosystems in bio-geochemical cycles | Maintenance of good air quality |
| 2 | Climate regulation | Influence of land cover and biol. Mediated processes on climate | Maintenance favorable climate for human and salmon existence |
| 3 | Disturbance prevention | Influence of ecosystem structure on dampening environmental disturbances | Storm protection from wetlands |
| 4 | Water regulation | Role of land in regulating runoff & river discharge | Drainage, natural irrigation, and regulation of flows necessary for spawning |
| 5 | Water supply | Filtering, retention and storage of fresh water | Provision of water for consumptive use (e.g. drinking water) |
| 6 | Soil retention | Role of vegetation root matrix and soil biota in soil retention | Maintenance of water clarity |
| 7 | Soil formation | Weathering of rock, accumulation organic matter | Maintenance of productivity on different land cover types |
| 8 | Nutrient regulation | Role of biota in storage and re-cycling of nutrients | Nutrient cycling salmon provide for Kamchatka brown bears, birds and other species |
| 9 | Waste treatment | Role of vegetation & biota in removal or breakdown of nutrients and compounds | Pollution control |
| 10 | Pollination | Role of biota in movement of trophic-dynamics | Pollination of wild plant species |
| 11 | Biological Control | Population control through trophic-dynamic relations | Control of pests and diseases |
| ***Habitat functions - Providing habitat (suitable living space) for wild plant and animal species*** | | | |
| 12 | Refugium functions | Suitable living space for wild plants and animals | Suitable habitat for Kamchatka Brown bears |
| 13 | Nursery function | Suitable reproduction habitat | Suitable spawning area for Pacific Salmon |
| ***Provisioning functions - Provision of natural resources*** | | | |
| 14 | Food | Conversion of solar energy into edible plants and animals | Pacific salmon as a food source |
| 15 | Raw materials | Conversion of solar energy into biomass for human construction and | Timber provided by forests |

| | | | |
|---|---|---|---|
| | | other uses | |
| 16 | Genetic resources | Genetic material and evolution in wild plants and animals | Drugs and pharmaceuticals |
| 17 | Medicinal resources | Variety in (bio)chemical substances in natural biota | Plants used for medicinal purposes |
| 18 | Ornamental resources | Variety of biota in natural ecosystems with ornamental use | Resources used for fashion or jewelry (e.g. feathers or orchids) |
| ***Cultural functions - providing opportunities for cognitive development*** | | | |
| 19 | Aesthetic information | Attractive landscape features | Enjoyment of scenic views in Kamchatka |
| 20 | Recreation | Variety of landscapes with recreational uses | Tourism as a result of salmon fishing |
| 21 | Cultural and artistic information | Variety in natural features with cultural and artistic value | Use of salmon in books, painting, national symbols, advertising etc… |
| 22 | Spiritual and historic information | Variety in natural features with spiritual and historic value | Use of nature for religious purposes |
| 23 | Science and education | Variety in nature with scientific and educational value | Use of Kamchatka biostations for scientific research |
| 24 | Navigational | Variety in nature with navigational value | Use of natural objects for navigating |

## 3. METHODS

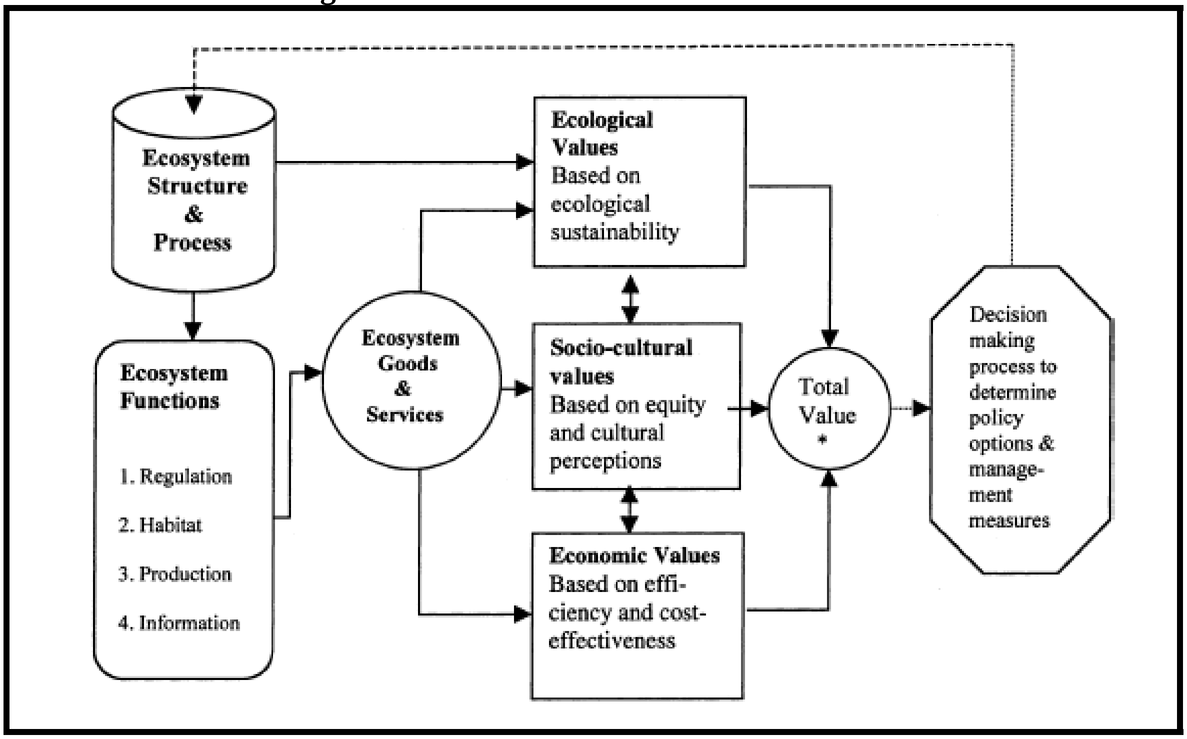
We estimated the value of ecosystem services in the Kol Refuge using 4 steps. Step 1 quantified the ecosystem services using Geographic Information System (GIS) technology and Step 2 estimated marginal economic values ($/ha/year) for each of the 13 land cover class and 24 ecosystem services. For Step 1 and 2, we developed an excel-based model called the Kol Refuge Rapid Assessment Valuation (KOL RAV) to produce minimum and maximum values for each ecosystem service and land cover. Using the baseline values derived from the KOL RAV, we then developed a dynamic, spatially explicit model called Kol Refuge Ecosystem Service Evaluation Model (KRESEM) to run land cover change scenarios. The creation of KRESEM was completed in Steps 3 and 4, which is explained in more detail below.

### 3.1 Step 1: Ecosystem Service Quantification in KOL RAV Model

In Step 1, GIS technology was used to quantify the ecosystem services produced by Land Use Land Cover (LULC). Using LULC to assess the value of ecosystem functions, being produced from a watershed, is an accepted valuation method (Darwin et al., 1996) and has been used in several valuation studies at the Gund Institute (Costanza et al., 1997; Boumans et al., 2002; Batker et al., 2005) and for other international organizations.

Land Cover is the physical boundaries of the ecosystem defined as ecosystem structure (Figure 3). Ecosystem structure consists of interactions between abiotic (chemical and physical) and biotic (living organisms) components that generate ecosystem functions (de Groot et al., 2002). As mentioned earlier, ecosystem functions are broken down into four main categories: regulating, habitat, provisioning (production), and cultural (information) (de Groot et al., 2000; MEA, 2005). These ecosystem functions provide ecosystem goods and services which have value to humans (Costanza et al., 1997; MEA, 2005).

**Figure 3: Valuation Framework**




Source: de Groot et al., 2002

### 3.1.1 Metadata: GIS Data Used for Land Use Land Cover

The Kol Refuge ecosystem value layer (Figure 8, p. 31) is a composite derived from three spatially-explicit sources: coarse-resolution land cover, high-resolution stream path data and digital elevation data. Base data was derived from the MODIS Global Land Cover Dataset (MOD12Q1), representing International Geosphere-Biosphere Program (IGBP) land cover classes (Table 5) in year 2000 at a spatial resolution of 1 square kilometer per pixel. Land cover data for the study region was extracted using the Kol River watershed boundary layer and then converted to vector format for integration with other data sources. Specifically, the MODIS[2] land cover dataset did not represent surface water and riparian classes with sufficient accuracy, so high-resolution stream data provided by the Wild Salmon Center was buffered to a width of sixty meters and merged with the MODIS product. The 17 land cover types were then aggregated into 13 classes shown in Table 5.

**Table 5: Land Use Land Cover Class from MODIS to Re-Classification**

| Class # | Class Name | New Class # | Reclassified Name |
|---|---|---|---|
| 0 | Coastal | 11 | Coastal |
| 1 | Evergreen Needleleaf Forest | 2 | Conifer |
| 2 | Evergreen Broadleaf Forest | | |
| 3 | Deciduous Needleleaf Forest | 3 | Deciduous |
| 4 | Deciduous Broadleaf Forest | | |
| 5 | Mixed Forest | 1 | Temperate Mixed Forest |
| 6 | Closed Shrubland | 6 | Shrubland |
| 7 | Open Shrubland | | |
| 8 | Woody Savannas | 4 | Savannas |
| 9 | Savannas | | |
| 10 | Grasslands | 5 | Grasslands |
| 11 | Permanent Wetlands | 10 | Wetlands |
| 12 | Croplands | 7 | Agriculture and Pasture |
| 13 | Urban and Built-Up | 8 | Urban |
| 14 | Cropland/Natural Vegetation Mosaic | 7 | Agriculture and Pasture |
| 15 | Snow and Ice | 12 | Rock/Ice |
| 16 | Barren or Sparsely Vegetated | N/A | N/A |
| 17 | Surface Water | 9 | Water surface |
| | | 13 | Open Ocean |

Note: Open Ocean was not a MODIS land cover class, but was added as a land cover class in the model so it could be used in future scenarios if desired.

Elevation zones (Table 6) were generated by classification of digital elevation data from the Shuttle Radar Topography Mission (SRTM) at a vertical and horizontal resolution of ninety meters. These zones were then intersected with the land cover data described above. Minimum and maximum dollar values per square kilometer were assigned to each class and elevation group and displayed accordingly.

[2] Despite the presence of input data at moderate to high spatial resolution, this dataset is based on the coarse-resolution MODIS land cover product. As such, the Kol river basin map cannot be considered accurate at any resolution finer than one square kilometer.

**Table 6: Elevation Ranges**

| Elevation Zone | Elevation Range (meters) |
|---|---|
| 1 | 0-200 |
| 2 | 200-500 |
| 3 | 500-900 |
| 4 | 900-1200 |
| 5 | 1200-1820 |

### 3.2 Step 2: Ecosystem Service Valuation in KOL RAV Model

In Step 2, an economic value for the 13 re-classified land covers (Table 5), weighted by health estimates, was estimated as marginal value per ha per year for each of the 24 ecosystem services (Table 4). For the purpose of this study, each land use was given the same "high" health estimate across all elevations. Ecosystem health is an important factor in determining the economic value of land cover. For example, forest areas that have been clear-cut will not provide the same ecosystem services as forested lands. Therefore, the health estimates should be adjusted to reduce the ecosystem service value for that area. Researchers, scientists and policymakers working in the Kol Refuge should adjust health estimates in the model based on their knowledge of the area. See Appendix C to see how values change by elevation zones when health estimates are adjusted in the KOL RAV model.

For water surface land cover three of the twenty-four ecosystem service values (food, recreation, and scientific information) were derived from the study site. However, due to time constraints and resource limitations it was not possible to conduct site specific estimates for each ecosystem service. Therefore, a benefits transfer method was used for the majority of ecosystem services, which is a widely accepted, cost-effective valuation method (Costanza et al, 1997; Desvouges et al., 1998; Batker et al., 2005 and COPI et al., 2008).

#### 3.2.1 Benefits Transfer

Benefits transfer method is used for the majority of ecosystem services in the Kol Refuge. The basic idea behind benefits transfer is to use valuation estimates already completed in a separate area for another area. For example, a study by Ruijgrock et al. 2006 estimated the value of climate change regulation for shrubland to be equivalent to US $503 ha/year (in $2007 dollars). While this study was conducted for shrubland in Europe, it is possible to use it as a proxy for the value of climate change regulation for shrubland in Russia.

The most important question to ask when using benefits transfer is: How do the conditions of the original study site compare to the conditions in the Kol Refuge? There are several factors that should be considered. For one, it is important to examine the type of valuation method used in the original study.   Many valuation methods are not easily transferable from on context to another. Let's take for example, a recent study by Costanza et al. (2008) that found a loss of 1 ha of wetland corresponded to an average increase of $ 33,000 in storm damage on U.S. coastal property.   It would be difficult to justify using this estimate for wetland value in the Kol Refuge for several reasons.  First, there are few settlements in the Kol Refuge so a hurricane or storm would not cause the same monetary damage to built infrastructure compared to coastal Florida.  Second, wetland value was determined in large part by the probability of a coastal region being hit by a storm. Kamchatka is less likely to be hit by a hurricane than coastal U.S. Because of these conditions, it was not included in the valuation database for this study.  However, it was not possible to examine the conditions for each original valuation study in the database.  Therefore, these values should be viewed as a starting point, a crude initial estimate of the magnitude of these values for which further analysis can be completed (e.g. using a meta-analysis benefits transfer or site specific valuation studies).

Values from an existing database of known ecosystem service values for land cover classes at the Gund Institute and from the Cost of Policy Inaction (COPI) valuation study (commissioned by the Convention on Biological Diversity) were used.  All the reference papers and valuation studies used in this report were drawn from peer reviewed journal articles. All values were converted in US $ 2007 dollars.  See Appendix A for examples of references from the valuation database used in this study.

### 3.2.2 Benefits Transfer – Meta-analysis

One challenge with benefits transfer is accounting for wide variability between countries GDP and forest biome.  To adjust monetary values already estimated for one given study area to the Kol Refuge we used estimates, for some ecosystem services, that were derived from a meta-analysis developed by Markandya et al. (2008) in the COPI report.  In the COPI valuation, a value transfer protocol is used for provisioning and regulating functions for forest biome (Table 7).  Different value transfer methods are used for the two services.

**Table 7: Ecosystem Services Used in Meta-Analysis**

| Function Type | Land Cover Type | Ecosystem Services |
|---|---|---|
| Provisioning | Forest | Food, Fiber, and Fuel |
| Regulating | Forest | Climate regulation (e.g. carbon storage) |

Source: Markandya et al. (2008)

**Benefits Transfer - Meta-analysis for Provisioning Services**

The value transfer framework for provisioning services described by Markandya et al. (2008) consisted of two main phases:[3]

1. Calculation of total annual values: the FAO export values for different industrial sectors were adjusted for domestic production quantity and converted into estimates of net income, in order to estimate the total provisioning value for forest biome.
2. Calculation of marginal values: total values are combined with information from different forest biome to estimate the annual marginal values per hectare for each forest biome.

In the first valuation phase, provisioning service for wood forest products was classified into two main categories; wood forest products (WFPs), and non-wood forest products (NWFPs) (Table 8).

**Table 8: The Provisioning Services Provided by Forest Ecosystem**

| Wood forest products (WFPs) | Non-Wood Forest Products (NWFPs) | |
|---|---|---|
| | Plant Products | Animal Products |
| • Industrial Roundwood<br>• Wood Pulp<br>• Recovered Paper<br>• Sawnwood<br>• Wood-based Panels<br>• Paper and Paper Board<br>• Wood Fuel | • Food<br>• Fodder<br>• Raw material for medicine and aromatic products<br>• Raw material for utensils, crafts & construction<br>• Ornamental plants<br>• Exudates<br>• Other plant products | • Living animals<br>• Hides, skins and trophies<br>• Wild honey and beeswax<br>• Bush meat<br>• Other edible animal products |

Source: Markandya et al. 2008

For each product, the relevant market values were taken from FAO database (FAOSTAT) for Russia (Table 9). These values were then adjusted for the estimated total provisioning values. From these values the net income is obtained based on the financial returns from the wood forest production. The net return from forestry in the three-year period 2003-2006 was estimated to be equal to 8.2% per year.

[3] For a complete explanation of meta-analysis methods and algorithms see Markandya et al. 2008, in *The Economics of Ecosystems & Biodiversity*, Annex II.

**Table 9: Total Production Values by Forest Product from Russia (US $1,000 (2005)) (calculated from FAOSTAT)**

| Forest Products | Value |
|---|---|
| Industrial Roundwood | $8,226,139 |
| Wood Pulp | $2,740,455 |
| Recovered Paper | $237,272 |
| Sawnwood | $2,878,806 |
| Wood Based Panels | $2,561,221 |
| Paper & Paperboard | $3,507,696 |
| Wood Fuel | $738,702 |
| **TOTAL WFPs** | $20,890,291 |
| **NWFPs** | $4,820 |
| **TOTAL WFPs + NWFPs** | $20,895,111 |

Source: Markandya et al. 2008

Table 10 shows the marginal values of provisioning services, estimated for Russia by Markandya et al. 2008, adjusted for profits and converted to US $2007. These marginal values (ha/year) were assigned to forest biome in the Kol Refuge (Table 9).

**Table 10: Marginal Value of Provisioning Services in Russia by Forest Biome, adjusted for profits (US $2007/ha/yr)**

| Forest Biome | US $/ha/year |
|---|---|
| Boreal | $139 |
| Temperate mixed | $106 |
| Cool coniferous | $19 |
| Temperate deciduous | $7 |

Source: Markandya et al. 2008

**Benefits Transfer - Meta-analysis for Regulating Services: Carbon Sequestration**

The economic value of carbon sequestration for forest biomes was estimated by Markandya et al. 2008 as marginal value (ha/year). To complete this valuation study two pieces of quantitative information were needed: the mt carbon (mtC) sequestered by each forest type in Russia and economic information as to the value for each mtC sequestered. The value per mtC is taken from EU project CASES (Cost of Assessment of Sustainable Energy System), providing the baseline year of reference and future period scenario.

There are two basic steps for carbon sequestration used:

1. Identification of the capacity of carbon sequestration by forest biome in Russia
2. Monetary estimation based on the region and forest biome

For the estimate of carbon stock there were two factors that were considered; forest type, and the area of forest. Simply multiplying the tons of carbon per ha (weighted by world COPI region coefficient, in this case Russia) by value per ha of carbon stock gives you the value/ha/year for the COPI region[4, 5]. Table 11 shows the capacity of carbon sequestration by forest biome in Russia.

**Table 11: Capacity of Carbon Sequestration in the World Forests (mtC/ha/year)**

| Forest Biome | mtC/ha/year |
|---|---|
| Boreal | 37.70 |
| Temperate mixed | 37.98 |
| Cool coniferous | 37.37 |
| Temperate deciduous | 37.98 |

Source: Markandya et al. 2008

Table 12 shows the lower bound and upper bound estimate for carbon sequestration by forest biome. The lower estimate is based on the Marginal Damage Cost (MDC) approach. The high estimate is based on the Marginal Avoidance Cost (MAC) approach[6].

**Table 12: Marginal Value of Carbon Sequestration in Russia and Forest Biome (US $2007/ha/year)**

| Forest Biome | Lower Bound Estimate ($/ha/year) | Upper Bound Estimate ($/ha/year) |
|---|---|---|
| Boreal | $348 | $856 |
| Temperate mixed | $354 | $870 |
| Cool coniferous | $348 | $856 |
| Temperate deciduous | $354 | $870 |

Source: Markandya et al. 2008

[4] Calculation is: $V_{wr,b} = (tC / ha_{wr,b})*\$ / ha$

Where:

$V_{wr,b}$ = value/ha/year by COPI region *wr-th* and forest biome *b-th*

$tC / ha_{wr,b}$ = tons of carbon stocked per ha by world COPI region *wr* and forest biome *b*

$ / ha = value per ha of carbon stocked

Wr = world COPI region

[5] For complete explanation of meta-analysis methods see Markandya et al. 2008, in *The Economics of Ecosystems & Biodiversity*, Annex II.

[6] See CASES deliverables for the valuation methodology: http://www.feem-project.net/cases/downloads_deliverables.php

As mentioned earlier, Ruijgrock et al. 2006 estimated the value of climate change regulation for shrubland in Europe to be equivalent to US $503 ha/year. This value falls within the monetary value range of carbon sequestration estimated using a meta-analysis benefits transfer approach. This highlights two important points. The first is the importance of using a minimum and maximum value procedure to account for variability and uncertainty when conducting valuation studies. For each ecosystem service and biome we estimated a minimum and maximum value range, when feasible.

The second point is that values estimated in one area can be used as a proxy for another without further analysis completed. There are limitations to using benefits transfer: many ecosystem services are not easily transferable from one context to another (as explained earlier in this section) and estimates are only as good as the original study. However, it provides a starting point for which in-depth site specific valuation can be conducted.

### 3.2.3 Site Specific Valuation Estimates for Water Surface Land Cover: Salmon, Caviar, Recreation and Scientific information

We were able to conduct site specific valuation estimates for three ecosystem services provided by water surface land cover: food (salmon and caviar), recreation and scientific information (Table 13). Different valuation methods were used to estimate monetary values for these services. For salmon, caviar and scientific information, we estimated a minimum and maximum value range using the market price method and for recreation we used the travel cost method.

**Table 13: Site Specific Valuation Estimates: Food, Recreation, and Scientific Information**

| Function | Land Cover Type | Ecosystem Service | Method Used |
|---|---|---|---|
| Provisioning | Water surface | Food (salmon and caviar) | Market price method |
| Cultural | Water surface | Recreation | Travel cost method |
| Cultural | Water surface | Scientific information | Market price method |

***Salmon – Market Price Method***

To estimate the range of salmon market value in the Kol Refuge we performed two basic valuation estimates using the market price method. The market price method estimates the economic value of ecosystem products or services that are bought and sold in markets. This method was also used by Sinyakov et al. (2005) to assess the value of salmon to Russia's National Accounting System (NAS). It is recognized by the United Nations and International Monetary Fund (IMF) has a valid method to assess resource contribution to national wealth estimates. The use value of salmon in the Kol Refuge can be expressed as **V = (P-C)Q**

Where:
**V** is the economic value of salmon caught in the Kol Refuge
**P** is the market price of salmon
**C** is the expenditures on catch (or cost)
**Q** is the quantity of salmon caught and sold

Data on fish caught in the Kol Refuge were obtained from the U.N. Interim report (2005). The U.N. report used information from KamchatNIRO fund that records data on salmon catches for the Kol Refuge. From the period 2001-2003 there was an annual average coastal catch of 3,304.2 mt of Pacific salmon in the Kol Refuge. Pink salmon comprised close to 86 percent of the total catches, followed by Chum (13 percent), and Char (1 percent). Sockeye, Coho, and Chinook catches each comprised of less than 1 percent of total catches (Table 14).

**Table 14: Pacific Salmon Caught in Kol and Kehta Rivers: Three Year Averages Annualized**

| Species | Catch (mt) | Percent of Total Catch |
|---|---|---|
| Pink | 2,830.9 | 85.68% |
| Chum | 420.3 | 12.72% |
| Sockeye | 5.3 | 0.16% |
| Coho | 11.8 | 0.36% |
| Chinook | 0.9 | 0.03% |
| Char | 35.0 | 1.06% |
| Cherry | ** | |
| **Total** | **3,304.2** | **100%** |

Quantity Source: U.N. Interim Report, 2005

For the first valuation estimate, we used average ex-vessel prices (2000-2003) for salmon caught in Alaska (Alaska Department of Fish and Game, 2006). Because we were not able to obtain Russian ex-vessel prices, Alaskan ex-vessel prices were used as an approximate value for prices in Russia. Ex-vessel prices are the price received by fishermen for fish sold “at the dock”. We were unable to obtain cost estimates for catching salmon in the Kol Refuge. While we were not able to subtract the variable cost of catching fish from revenue gained, we still consider this an underestimate of Kol Refuge’s salmon market value to NAS. The **lower bound estimate of market value for salmon in the Kol Refuge was US $981 thousand per year** (Table 15).

**Table 15: Pacific Salmon Caught in Kol and Kehta River, in Tons; Three Year Average and Total Estimated Market Value Using Alaska Exvessel Prices**

| Species | Catch (mt) | Exvessel Value US $/mt | Value by Specie |
|---|---|---|---|
| Pink | 2,830.9 | $259 | $733,203 |
| Chum | 420.3 | $534 | $224,440 |
| Sockeye | 5.3 | $1,427 | $7,506 |
| Coho | 11.8 | $1,041 | $12,284 |
| Chinook | 0.9 | $3,508 | $3,262 |
| Char | 35.0 | ** | |
| Cherry | ** | ** | |
| **Total** | **3,304.2** | | **$980,696** |

Quantity Source: U.N. Interim Report, 2005
Price Source: 2001-2003 Average Exvessel Price: Alaska Department of Fish and Game (2006)

For the upper bound estimate of salmon value in the Kol Refuge we used wholesale salmon prices in Russia and Japan estimated by Sinyakov et al. 2005. The market wholesale prices are considered the first stage of technological processing. Therefore prices should not be considered an overestimate. The **upper bound market value for salmon from the Kol Refuge, using wholesale prices, was estimated at US $3.7 million** per year (Table 16). The output column in Table 16 assumes 75 percent of the original catch will be sold at wholesale markets. Therefore, the quantity product column is 75 percent of the total catch quantity.

**Table 16: Value of Kol Salmon Coastal Catch; Three Year Averages (2001-2003) and Wholesale Prices of Russian and Japan Markets**

| Species | Catch (mt) | Output | Quantity product (mt) | Wholesale price US $/mt | Market | Value by specie |
|---|---|---|---|---|---|---|
| Pink | 2,830.9 | 0.75 | 2,123.2 | $1,430 | Russia | $3,036,140 |
| Chum | 420.3 | 0.75 | 315.2 | $1,874 | Russia | $590,732 |
| Sockeye | 5.3 | 0.75 | 3.9 | $5,263 | Japan | $20,763 |
| Coho | 11.8 | 0.75 | 8.9 | $2,315 | Japan | $20,488 |
| Chinook | 0.9 | 0.75 | 0.7 | $3,508 | Russia | $2,447 |
| Char | 35.0 | 0.75 | 26.3 | $1,835 | Russia | $48,169 |
| Cherry | ** | | | $1,874 | Russia | |
| **Total mt** | **3,304.2** | | | **Total Value** | | **$3,718,738** |

Quantity Source: U.N. Interim Report, 2005
Market price estimate: Sinyakov et al. 2005

Using these two methods, we estimate the value range of **salmon contribution to NAS to be between US $981 thousand to US $3.7 million per year.**

***Caviar – Market Price Method***

While poaching may not be accounted for in Russia's NAS, it still has an important economic value. Through interviews with scientists, helicopter pilots and other key stakeholders conducted by Wild Salmon Center personnel we estimated the **total value of poached caviar to be between US $453 – US $566 thousand per year**[7](Table 17).

**Table 17: Quantity, Wholesale Price, and Economic Value for Caviar**

| Quantity (tons) | Average Price Japan (2000-2004)-US$/kg | Average Price Japan (2000-2004)-US$/lb | Average Price Japan (2000-2004)-US$/ton | Total |
|---|---|---|---|---|
| 60 | $7.55 | $3.43 | $7,552 | **$453,123** |
| 75 | $7.55 | $3.43 | $7,552 | **$566,404** |

*Quantity Source: Wild Salmon Center, personal communication, 2008*
*Price Source: Sinyakov et al. 2005*

***Recreation – Travel Cost Method***

The travel cost method was used to estimate the value of recreation for water surface in the Kol Refuge. The travel cost method can estimate economic use values associated with ecosystems or sites that are used for recreation. The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. The cost incurred by visitors can be used as a proxy for their willingness to pay for a visit to the site. These costs can include the transportation costs to the site, entrance fees, and amount of time spent traveling to the site. Contingent valuation or contingent choice methods could also be used in this case. However, those methods would require surveys and would be timely and costly to implement.

For water surface recreation value, we used the costs for a tour operator and transportation to sport fishermen that visit the Kol Refuge. There are an estimated 70 sport fishermen that visit the Kol Refuge per year (WSC, personal communication). Tours usually cost $6,000 per person and transportation can range from US $2,000 from Moscow to $8,000 from USA or Europe. As shown in Table 18 the recreation value for water surface in the Kol Refuge is between $500 thousand and $1 million per year.

[7] It is important to note that we used wholesale price estimates of Caviar in the Japan market. Because poaching is illegal, documentation that records the costs was not available. Therefore this could potentially be an overestimate of use value for caviar.

**Table 18: Recreation Value for Water Surface and Rivers in Kol Refuge**

| Sport Fishermen | Tour Costs US$ (per person) | Airfare US$ | Total Value US$ |
|---|---|---|---|
| 60 | $6,000.00 | $2,000.00 | $480,000 |
| 70 | $6,000.00 | $8,000.00 | $980,000 |

Source: Wild Salmon Center, personal communication

***Scientific Information – Market Value***

Scientific information is identified as a cultural function in the typology used in this study. We estimated the value of water surface to scientific information in the Kol Refuge. One way to estimate the value of scientific information is to assess how much was spent on "science" in the Kol Refuge. These costs include financial resources spent on scientists and graduate students that conduct research in the Kol Refuge each year. The Wild Salmon Center conducts ongoing research on salmonid ecology with Moscow State University and University of Montana's Flathead Lake Biological Station.

The costs include administration and operating costs for Kol biostation (Figure 4), costs for research supplies and salaries for scientists. The estimated cost to complete **science research objectives was US $ 800 thousand to $ 1 million per year[8].**

**Figure 4: Kol Refuge Biostation**

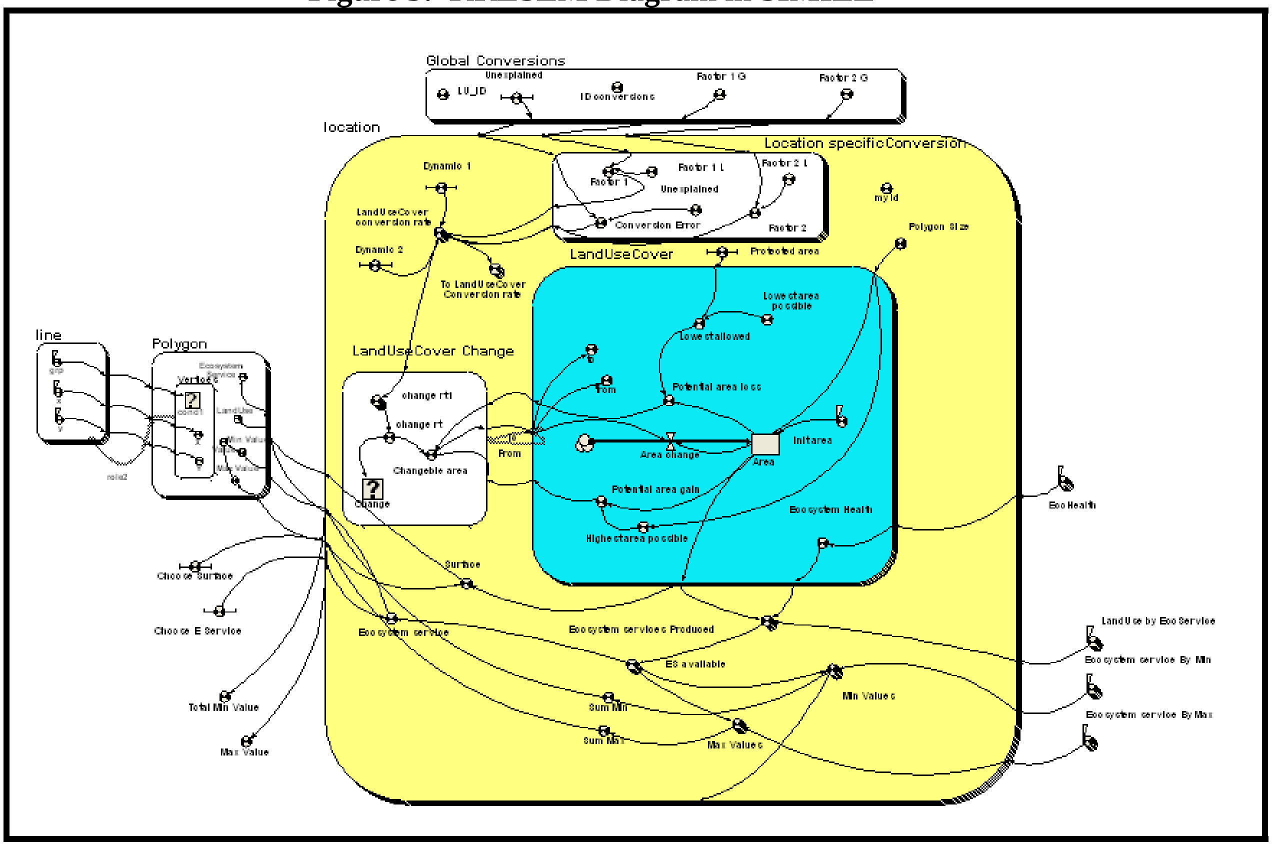
Photo Credit: Wild Salmon Center

[8] This cost does not include administrative salaries for major organizations working in the Kol Refuge. Therefore, it should be considered an overall underestimate of science information value.

### 3.3 Step 3 & 4: Kol Refuge Ecosystem Service Evaluation Model (KRESEM)

The Kol Refuge Ecosystem Service Evaluation Model (KRESEM) (Figure 5) is designed after Multiscale Integrated Model of Ecosystem Services (MIMES) to model the dynamics and valuation of ecosystem services. As mentioned earlier, ecosystem services are defined functions of ecosystems that support (directly or indirectly) human welfare. The MIMES project (Boumans and Costanza 2007,A,B) aims to integrate participatory model building, data collection and valuation, to advance the understanding of how ecosystem services contribute to human welfare. MIMES builds on the GUMBO model (Boumans *et al.* 2002; Costanza *et al.* 2006) and allows for spatial explicit modeling. MIMES and KRESEM are both programmed in SIMILE, a declarative visual modeling environment (http://www.simulistics.com/) to ensure that they were highly-transparent, easy to modify and easy to use.

**Figure 5: KRESEM Diagram in SIMILE**

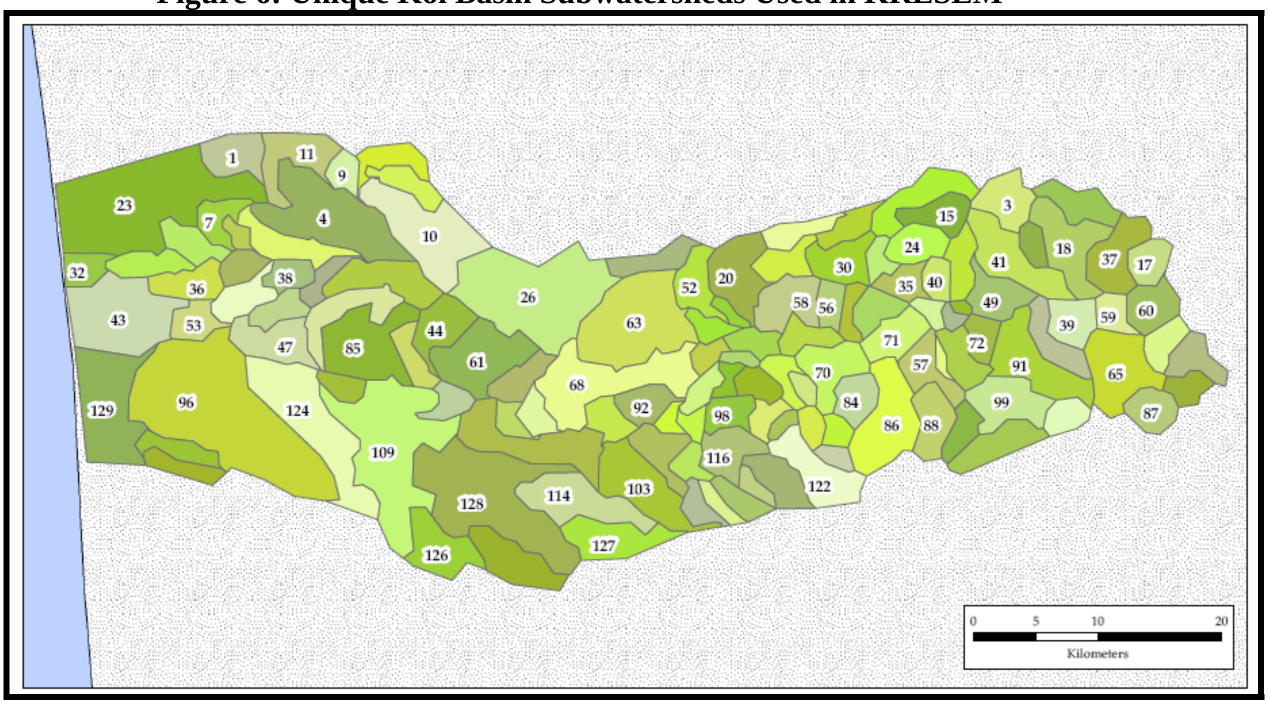



The MIMES framework follows after the Millennium Assessment Synthesis report on "Ecosystems and Human Well-being: General Synthesis", and is a general model formulation scalable in time and space to be applied to global, regional and local ecosystems. KRESEM scales the MIMES framework to the Kol Refuge where it calculates trends in 24 services (Table 4) provided by the 132 sub-watersheds of the Kol basin (Figure 6). Output of the model represents the total value of ecosystem services provided in the Kol Refuge over time and in space.

### 3.3.1 Step 3: GIS Component of KRESEM

In Step 3, subwatersheds were calculated using the D8 Flow Direction Algorithm and Area-Threshold Delineation Method (Jensen & Domingue, 1988) with the above-described SRTM digital elevation data. The resulting 132 subwatersheds (Figure 2) were node-simplified in vector format for ease of integration with the land cover change model, then they were intersected with the above-described Kol Refuge land cover data. Fractional area statistics were extracted from the resulting layer to describe the proportion of each land cover type in each subwatershed, and the vector subwatershed layer was converted to Keyhole Markup Language (KML) format to describe the polygon geometry by geographic node coordinates in the land cover change model.

**Figure 6: Unique Kol Basin Subwatersheds Used in KRESEM**

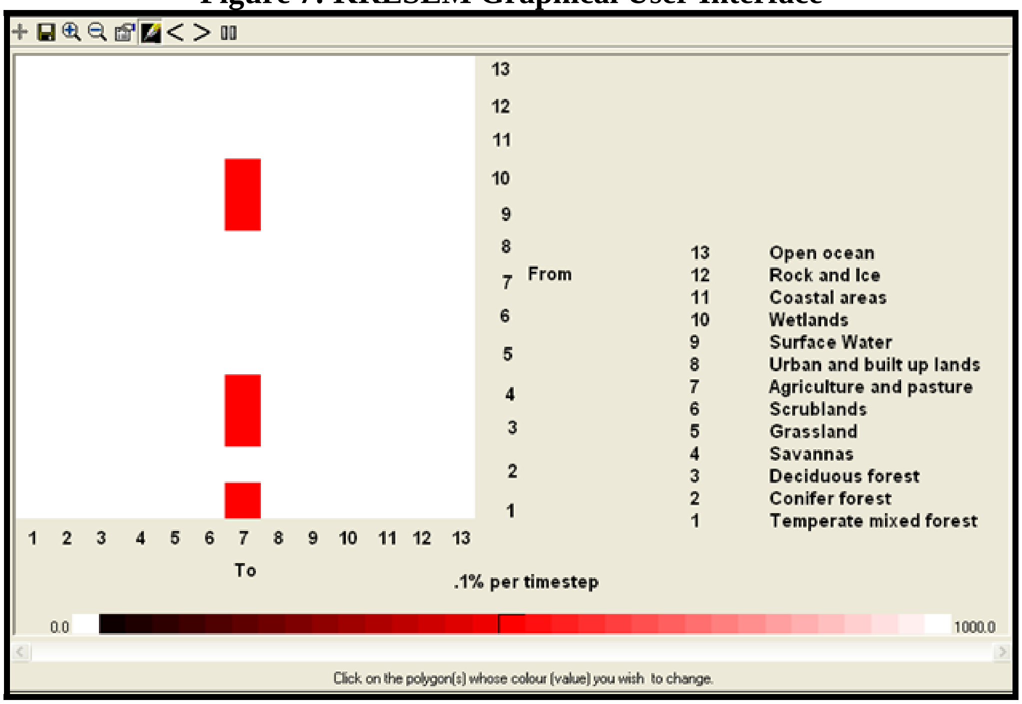



Data used by the KRESEM simulation model were from values derived in the KOL RAV model. Spatial data included the vertexes of the sub-watersheds and their initial distributions of the 13 land cover classes from the KOL RAV.

### 3.3.2 Step 4: Development of SIMILE Interface and Land Cover Change Scenarios

Within KRESEM, values of ecosystem services estimated are caused by changing land cover distributions anticipated and entered into the model through a graphical user interface (Figure 7). The interface is a matrix that allows the user to select the land cover change scenarios. In Figure 7, several land cover types are changing "from" (y axis) one land cover "to" another (x axis). This captures the land cover change over space. The interface also always the user to change the rate of land cover change per time step (sliding bar on bottom). This captures the land cover change over time. For example, Figure 7 illustrates an agricultural expansion scenario where .1 percent of the total area of temperate mixed forest, deciduous forest, savannas, surface water (buffer area), and wetlands within each polygon is converted to agriculture at each time step (set at 1,000 time steps). The unique and novel aspect of this interface is that researchers can use the interface to run various land management scenarios and see the resulting economic impact in the Kol Refuge.

**Figure 7: KRESEM Graphical User Interface**




Ten land cover change scenarios were run in the KRESEM model. All scenarios were run at a rate of 5 percent change per time step, for a 100 time steps. Scenarios were run for various land cover type conversion to urban, savanna, agriculture, forest, and shrubland.

## 4. RESULTS

The results of the KOL RAV model and KRESEM are presented in this section. Results from the KOL RAV model indicate the Kol Refuge has significant ecosystem service value. The total value of ecosystem services in the Kol Refuge range **from $784 million to $2.38 billion per year.** To put this in relative terms, the total economic value of fish exports from Kamchatka was US $326 million in 2002. The value of these ecosystem services is not surprising, considering other studies have demonstrated the total value of ecosystem services is greater than market goods (Costanza et al. 1997).

The results from KRESEM suggest that the greatest economic loss results from land cover change to agriculture and urban land cover, (e.g. built capital such as pipelines, roads etc…). Findings from KRESEM indicate that, because of pristine ecosystem health, the total value of ecosystem services is at its maximum. There is little land that can be converted to increase overall ecosystem value. On the other hand, this also means there is a great deal of monetary value that can be lost.

### 4.1 Results of KOL RAV Model

#### Land Cover Estimates

Development of the KOL RAV model had two main steps; quantification of land cover and ecosystem services, and economic valuation of ecosystem services. Using GIS technology explained in the methods section, we estimated total land cover for the Kol Refuge. Total area of the basin was approximately 220,399 ha of which 50 percent was classified as shrubland (110279 ha), 34 percent as Savannas (7609 ha), 5 percent as grassland (10785 ha), 4 percent as surface water (9194 ha)[9], and 2 percent temperate forest (5473 ha). The other land cover classes each accounted for less than 1 percent of total area (Table 19).

[9] This area includes a 60 meter buffer around all rivers in the Kol Refuge.

**Table 19: Total Area of Land Cover by Elevation in Kol Refuge (Hectares)**

| Re-Classifed Name | Sum of Hectares by Elevation Range (m) 0-200 | Sum of Hectares by Elevation Range (m) 201-500 | Sum of Hectares by Elevation Range (m) 501-900 | Sum of Hectares by Elevation Range (m) 901-1200 | Sum of Hectares by Elevation Range (m) 1201-1820 | Total Hectares | Percent of Total Land Area |
|---|---|---|---|---|---|---|---|
| Temperate Forest | 2679.1 | 2173.2 | 522.1 | 98.6 | 0.0 | 5473.0 | 2% |
| Conifer | 364.9 | 0.0 | 0.0 | 0.0 | 0.0 | 364.9 | 0% |
| Deciduous | 746.8 | 460.2 | 921.5 | 16.9 | 0.0 | 2145.4 | 1% |
| Savannas | 45366.2 | 22865.2 | 4492.1 | 2176.3 | 1109.3 | 76009.2 | 34% |
| Grasslands | 5503.8 | 5180.1 | 101.0 | 0.0 | 0.0 | 10785.0 | 5% |
| Shrubland | 42800.5 | 21044.1 | 23695.1 | 15661.7 | 7078.1 | 110279.4 | 50% |
| Croplands/Pasture | 566.6 | 190.9 | 296.1 | 340.7 | 457.3 | 1851.5 | 1% |
| Urban | 683.9 | 98.3 | 137.2 | 128.9 | 69.5 | 1117.9 | 1% |
| Surface Water | 5301.5 | 2076.1 | 1173.6 | 611.1 | 32.0 | 9194.3 | 4% |
| Wetlands | 465.4 | 102.3 | 304.0 | 211.6 | 82.1 | 1165.4 | 1% |
| Coastal | 1598.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1598.5 | 1% |
| Rock/Ice | 296.8 | 0.0 | 0.0 | 37.1 | 80.8 | 414.7 | 0% |
| Open Ocean | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0% |
| *Total Hectares* | 106374.0 | 54190.4 | 31642.7 | 19283.0 | 8909.1 | **220399.2** | 100.00% |

## Results of Economic Valuation of KOL RAV

The total value of ecosystem services in the Kol Refuge range **from $784 million to $2.38 billion per year.** The average value **per hectare per year ranges from $3,539 to $10,793**. Because many ecosystem services cannot be quantified or have not been estimated this must be considered an overall underestimate of the total ecosystem value to human well-being.

When examining land use value per ha per year, the highest minimum value is wetlands ($13,289) followed by water surface ($12,837) and shrublands ($3,733). For maximum values per ha per year, wetland is the highest ($47,489), water surface is the second highest ($31,504) and coastal area is the third highest ($30,968) (Table 20). See Appendix B for complete tables of land cover value by ecosystem service.

**Table 20: Total Ecosystem Service Value for Kol River Salmon Refuge**

| Land Cover | Total Minimum Value: $/yr | Total Maximum Value: $/yr | | Minimum Average Value: $/ha/yr | Maximum Average Value: $/ha/yr |
|---|---|---|---|---|---|
| Temperate Mixed Forests | $16,525,451 | $51,723,406 | | $3,019 | $9,451 |
| Coniferous Forest | $1,063,170 | $9,251 | | $2,914 | $9,251 |
| Deciduous Forests | $6,420,214 | $20,097,854 | | $2,992 | $9,368 |
| Savannas | $180,611,014 | $597,351,286 | | $2,376 | $7,859 |
| Grasslands | $25,310,389 | $92,746,576 | | $2,347 | $8,600 |
| Shrublands | $411,702,421 | $1,212,531,555 | | $3,733 | $10,995 |
| Agriculture and Pasture | $2,406,560 | $7,935,298 | | $1,300 | $4,286 |
| Urban | $814,780 | $1,509,513 | | $729 | $1,350 |
| Water surface | $118,029,928 | $289,661,396 | | $12,837 | $31,504 |
| Wetlands | $15,486,632 | $55,341,676 | | $13,289 | $47,489 |
| Coastal | $5,271,731 | $49,503,489 | | $3,298 | $30,968 |
| Rock | $969,695 | $2,888,230 | | $2,338 | $6,964 |
| Open Ocean | $0 | $0 | | $0.00 | $0.00 |
| **Total Values: $/yr** | **$784,611,984** | **$2,381,299,529** | **Average Value: $/ha/yr** | **$3,560** | **$10,820** |

Net present value (NPV) of these services over a 100 year period is shown in Table 21 Discounting is typically used to estimate the value of goods or services in the future. Discounting future economic benefits is controversial because it raises the moral and ethical issue of the relative importance of future generations to our own. NPV is typically used by economists to determine the ecosystem service value to us “presently” of costs and benefits that will occur in the future. For example, Table 21 shows how using different discount rates applied annually over a 100 year period will produce a range of values. The total benefit over 100 years is US $78 to $238 billion using a zero percent discount rate, US $25 to $76 billion using a 3 percent discount rate, and US $11 to $34 billion using a 7 percent discount rate.

Intuitively, discounting seems to tip the scale against future generations, but many argue it is necessary for decision making to weigh the future costs and benefits in present value. For the purpose of this study we give preference to a zero discount rate but present results of a 3 and 7 percent discount rate, as those percentages are commonly used. The U.S. Office of Management and Budget (OMB) recommends that agencies employ both a 3 percent and 7 percent discount rate when analyzing policy decisions. When calculating the costs and benefits of a Clean Air Act regulation the Environmental Protection Agency (EPA) used both a 3 percent and 7 percent discount rate (EPA, 2005). A survey of over 2,000 economists found that the median discount rate of 3 percent was the most common rate chosen (Heal, 2007).

Many feel discount rates should be much less. Take for example Sir Nicholas Stern's application of a very low positive discount rate of less than 1 percent in *The Stern Review on Economics of Climate Change*. He found that global warming would place large costs on future generations, which warrants immediate action now. Just as it makes economic sense to act now on climate change policy, rather than place greater costs on future generations, protecting Kol Refuge's ecosystem now will be more cost-effective than re-establishing a degraded ecosystem in the future.

**Table 21: Total Ecosystem Value Over 100 Years**

| Total Present Value (Discount Rate Over 100 years) | Minimum | Maximum |
|---|---|---|
| 0% Discount Rate | $78,461,198,400 | $238,466,573,800 |
| 3% Discount Rate | $24,983,558,441 | $75,932,355,154 |
| 7% Discount Rate | $11,201,906,383 | $34,045,876,047 |

Table 22 shows the value by ecosystem service. Nutrient regulation is the highest value (US $886,514,860), water supply is the second highest (US $360,266,987), and gas regulation is the third highest (US $206,925,224) (Table 22).

**Table 22: Value by Ecosystem Service**

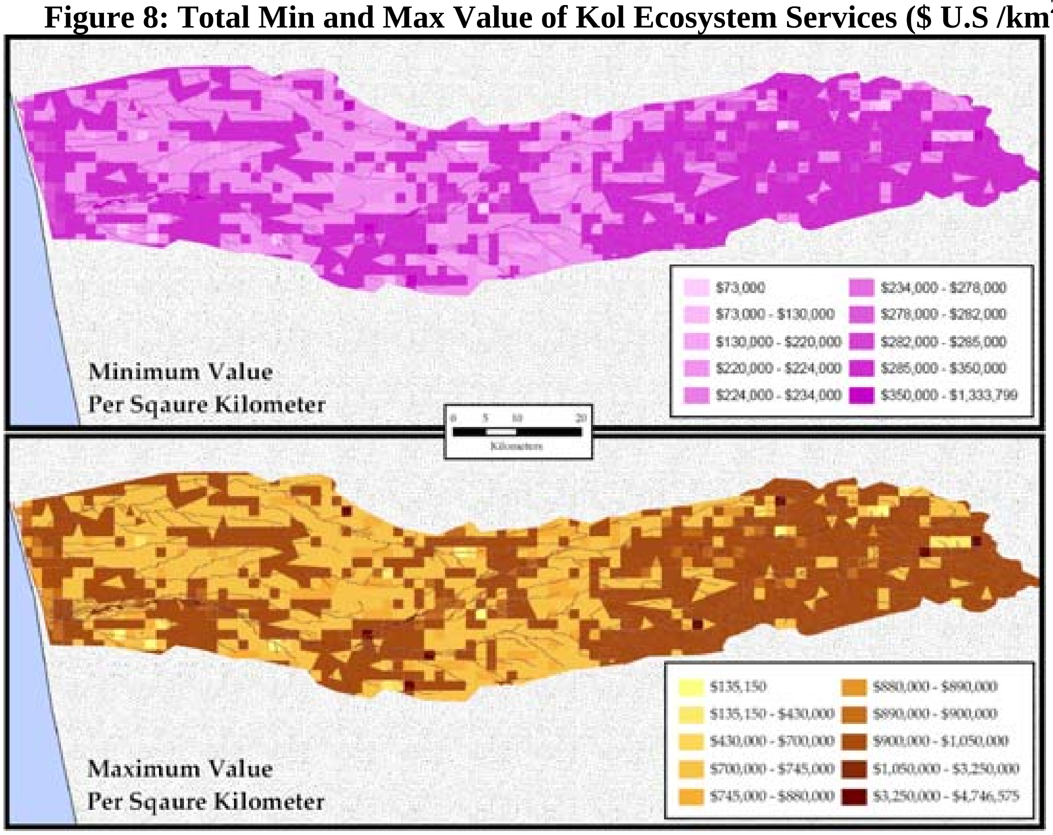
| **Ecosystem Services** | **Value by Ecosystem Service** | |
|---|---|---|
| | Min | Max |
| *Gas Regulation* | $30,875,471 | $206,925,224 |
| *Climate Regulation* | $82,520,352 | $142,686,488 |
| *Disturbance Prevention* | $19,436,370 | $76,519,476 |
| *Water Regulation* | $187,716,021 | $187,716,021 |
| *Water Supply* | $180,133,493 | $360,266,987 |
| *Soil Retention* | $10,824,497 | $21,011,062 |
| *Soil Formation* | $180,452 | $1,818,506 |
| *Nutrient Regulation* | $60,123,354 | $886,514,860 |
| *Waste Treatment* | $26,709,359 | $107,803,416 |
| *Pollination* | $5,383,816 | $5,383,816 |
| *Biological Control* | $607,620 | $1,974,764 |
| *Refugium Function* | $38,525,975 | $100,076,348 |
| *Nursery Function* | $461,749 | $6,233,605 |
| *Food* | $83,215,056 | $168,692,268 |
| *Raw Materials* | $7,466,556 | $24,685,348 |

| | | |
|---|---|---|
| *Genetic Resources* | $374,423 | $1,123,268 |
| *Medical Resources* | $281,783 | $845,350 |
| *Ornamental Resources* | $695,489 | $897,181 |
| *Aesthetic Information* | $1,379,610 | $1,379,610 |
| *Recreation* | $14,340,703 | $19,218,295 |
| *Cultural and Artistic Information* | $28,282,080 | $56,532,058 |
| *Spiritual and Historic Information* | $0 | $0 |
| *Science and Education* | $5,077,756 | $6,361,787 |
| *Navigational Services* | $0 | $0 |

Figure 8 displays total minimum and maximum value per kilometer squared ($km^2$). While we have been using ha as our unit of measurement, the GIS data in this study has a spatial resolution of 1 $km^2$ per pixel. Therefore, for visual display, the values are in $km^2$ units.

The upper watershed appears to have a greater economic value than other parts of the watershed.  Pay close attention the darker colors highlighting the rivers, indicating a high economic value. The high monetary value for water surface is mainly a function of values for nutrient regulation, water regulation, water supply, and waste treatment. Food value (e.g. salmon and caviar) has a high economic value, but is not as high as other ecosystem services provided by water surface.

**Figure 8: Total Min and Max Value of Kol Ecosystem Services ($ U.S /$km^2$)**



### 4.2 Results of Kol Refuge Ecosystem Service Evaluation Model (KRESEM)

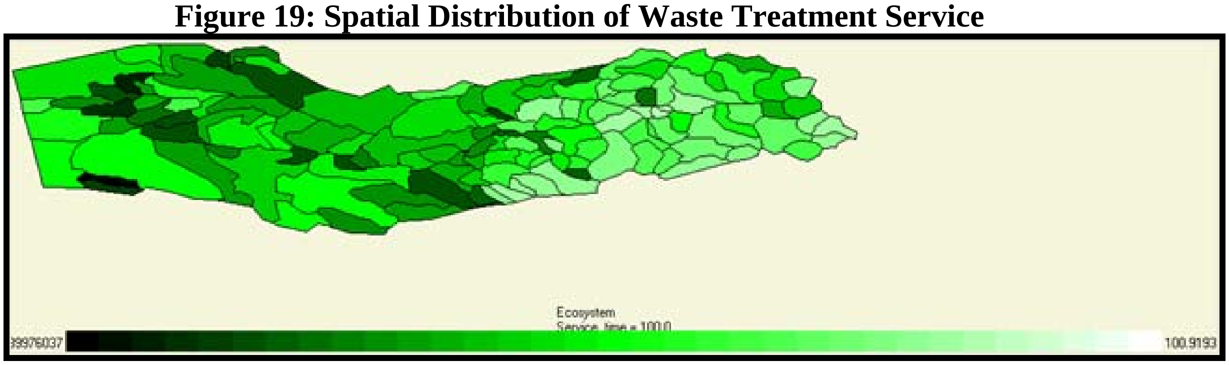
Table 23 shows the ten land cover change scenarios that were run in KRESEM. All scenarios were run at a rate of 5 percent change per time step, for a 50 time steps.

**Table 23: Land Cover Change Scenarios Run in KRESEM Model**

| Scenarios | Land Cover Changing From | Land Cover Changing To | Rate | Number of Time Steps |
|---|---|---|---|---|
| **Scenario 1** | a. Water surface & rivers (buffers) | Urban | 5% | 50 |
| **Scenario 2** | a. Temperate mixed forest | Savannas | 5% | 50 |
| **Scenario 3** | a. Wetlands | Agriculture | 5% | 50 |
| **Scenario 4** | a. Wetlands | Urban | 5% | 50 |
| **Scenario 5** | a. Coastal | Urban | 5% | 50 |
| **Scenario 6** | a. Agriculture | Savannas | 5% | 50 |
| **Scenario 7** | a. Temperate mixed forest<br>b. Savanna forest<br>c. Wetlands<br>d. Water surface & rivers (buffers)<br>e. Shrublands | Agriculture | 5% | 50 |
| **Scenario 8** | a. Water surface & rivers (buffers)<br>b. Wetlands<br>c. Coastal<br>d. Agriculture | Urban | 5% | 50 |
| **Scenario 9** | a. Agriculture<br>b. Urban | Deciduous forest | 5% | 50 |
| **Scenario 10** | a. Deciduous<br>b. Mixed Forest<br>c. Conifer | Shrubland | 5% | 50 |

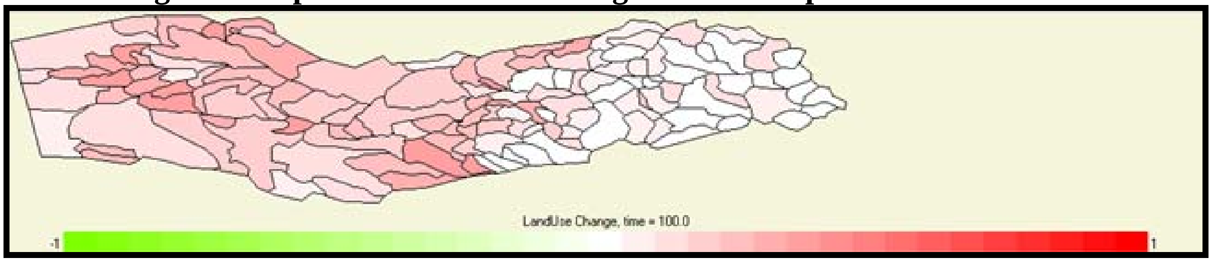
Figure 9 displays scenario 7 that simulates an agricultural expansion scenario where temperate mixed forest, savanna, wetlands, water surface (buffer area), and shrublands are converted to agriculture and pasture lands at a rate of 5 percent per time step. Figure 10 shows the spatial distribution of the waste treatment ecosystem service after the agricultural expansion scenario is run. Darker green colored subwatersheds, in the middle and lower part of the basin, indicate there is less overall percentage of waste treatment service than in lighter colored subwatersheds.

**Figure 19: Spatial Distribution of Waste Treatment Service**



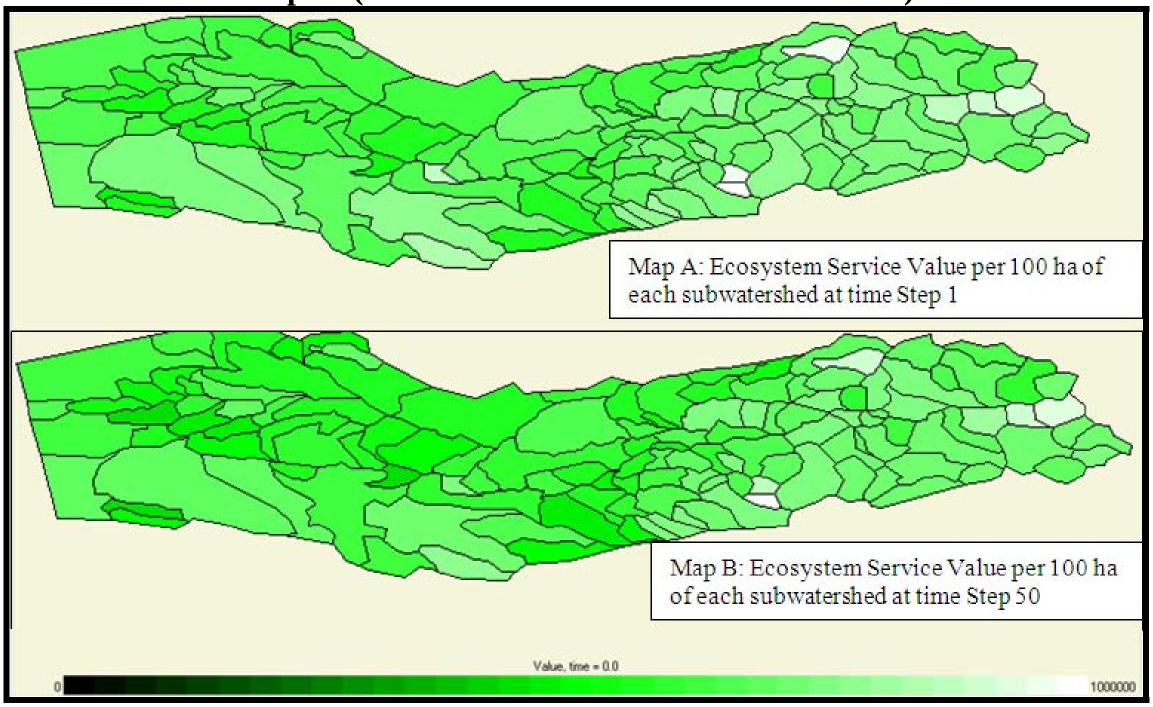
In Figure 11, darker red colored subwatersheds indicate that there was a greater percent of land that shifted to agriculture, after the model was run, compared to lighter colored subwatersheds. By viewing Figure 9 and Figure 10 there is an obvious correlation between greater expansion of agriculture land and loss of waste treatment service.

**Figure 10: Spatial Distribution of Agricultural Expansion scenario**




KRESEM allows the model user to compare subwatershed values before and after the land cover change scenario is run. For scenario 7 (conversion to agriculture) Map A of Figure 11 is a static shot of the value per 100 hectares for each subwatershed in time Step 1. Lighter colored subwatersheds have greater monetary value per 100 hectares. Map B is a static shot of the value per 100 hectares for each subwatershed in time Step 50. Some subwatersheds show a greater decrease in relative monetary value than others. At first glance, there is hardly any change in color between Map A and Map B. However, upon further examination some subwatersheds clearly lose monetary value when shifting to agriculture between time Step 1 and time Step 50. This is an extremely valuable tool for policymakers to see how monetary values of subwatersheds change in response to land management decisions.

**Figure 11: Spatial Distribution of Ecosystem Service Value at Time Step 1 and Time Step 50 (Values are for 100 ha in Subwatersheds)**

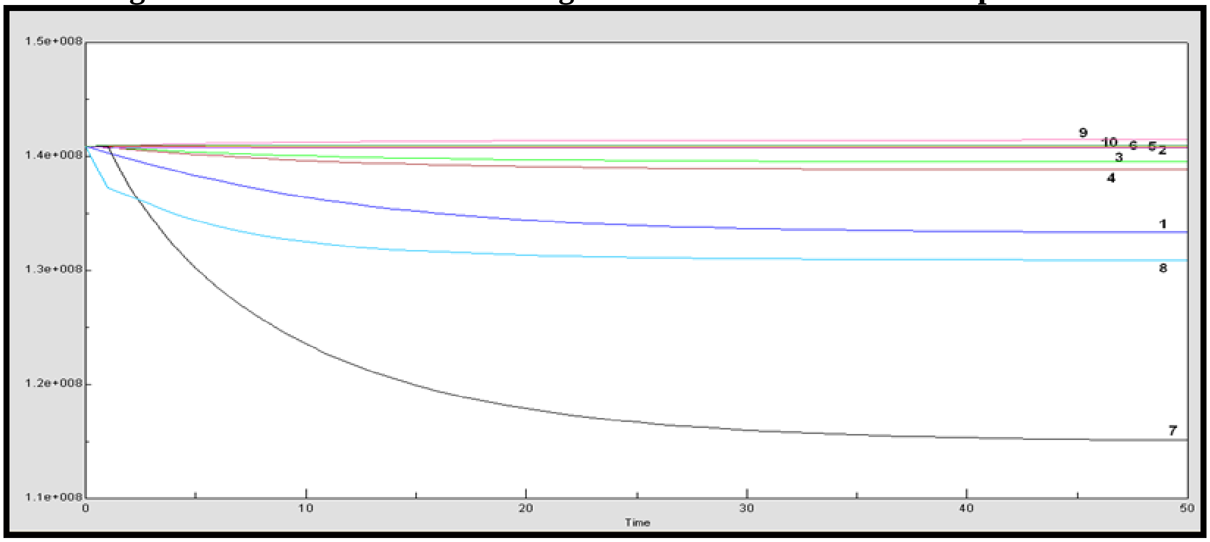



Ten land cover change scenarios were run in the KRESEM over at a 5 percent land cover change rate per time step, for 50 time steps. The impact of land cover changes on ecosystem service value various between scenarios (Figure 12). The greatest magnitude of economic loss was scenario 7 when agricultural expansion converts temperate mixed forest, savanna, wetlands, water surface (riparian buffer), and shrublands to agriculture and pasture. The fact that shrubland comprises 50 percent of total land area in the Kol Refuge was a factor in such a large economic loss.

The second greatest economic loss was scenario 8 which simulates water surface (riparian buffer), wetlands, coastal and agriculture conversion to urban land cover. Urban land cover refers to any built infrastructure or development by humans, including pipelines, roads, mining facilities or any human activity that converts natural habitat to built capital. While mining and oil industries may provide short-term economic gain, development poses a serious threat to ecosystem integrity. There is the potential for significant economic loss, much of which is not captured in the market economy, but absolutely critical for human well-being.

Scenario 1 was the third greatest economic loss from land cover change. This scenario simulates a one-to-one land cover change: water surface (riparian buffer) to urban built infrastructure. This suggests that there is the potential to lose significant economic value from converting areas near critical salmon habitat to built infrastructure.

**Figure 12: Ten Land Cover Change Scenarios and Economic Impact**[10]




There is economic losses in scenario 3 (wetland to agriculture) and 4 (wetland to urban) and relatively no loss or gain in scenario 6 (agriculture to savannas), scenario 5 (coastal to urban), scenario 2 (temperate mixed forest to savannas), and scenario 10 (deciduous forest, temperate forest, and conifer to shrubland). There was a slight economic gain converting agriculture and urban land cover to deciduous forest (scenario 9).

KRESEM illuminates the economic importance of preserving the pristine ecosystem in the Kol Refuge. Findings indicate there is not much potential economic gain from converting land cover to forest. The bottom-line is the ecosystem in the Kol Refuge is in pristine condition, which means it currently has the greatest possible economic value. On the other hand, this means that there is the potential for significant economic loss if land is converted from its natural state to built capital or agriculture. In scenario 7 above there is the potential to lose 18 percent of the total ecosystem service value if land was converted to agriculture at a 5 percent rate per year for 100 years.

The scenarios run in KRESEM also highlight the importance of ecosystem service markets. The revenue per capita in Kamchatka was US $249 per month (US $111 from fishing industry) in 2003. Given this modest income there is a need to develop a greater revenue stream for individuals. However, as the KRESEM model shows, shifting land cover to built infrastructure or agriculture significantly reduces the total ecosystem service values. The Kol Refuge is a great example how the majority of ecosystem values fall outside the market realm and are not internalized into land management decisions. In order to internalize the externalities of providing the host of ecosystem services outlined in this study, we must start paying for them. Ecosystem service markets is one such strategy that can be utilized.

[10] The Y axis is the average value of 100 ha across all watersheds multiplied by the 132 subwatersheds. X axis is the time Step for the model.

## 5. FINDINGS, RECOMMENDATIONS, AND CONCLUSIONS

### Summary of Findings: 10 Points

1. The total value of ecosystem services in the Kol Refuge range **from $784 million to $2.38 billion per year.** The average value per ha per year ranges from $3,539 to $10,793. To put this in relative terms, the total economic value of fish exports from Kamchatka was US $326 million in 2002.

2. The total benefit over 100 years is US $78 to $238 billion using a zero percent discount rate, US $25 to $76 billion using a 3 percent discount rate, and US $11 to $34 billion using a 7 percent discount rate.

3. When examining land use value per ha per year, the highest minimum value is wetlands ($13,289) followed by water surface ($12,837) and shrublands ($3,733). For maximum values per hectare per year, wetland is the highest ($47,489), water surface is the second highest ($31,504) and coastal area is the third highest ($30,968).

4. For ecosystem services, nutrient regulation is the highest value (US $886,514,860), water supply is the second highest (US $360,266,987), and gas regulation is the third highest (US $206,925,224).

5. We estimated the economic value of salmon caught in the Kol Refuge to be between US $981 thousand and US $3.7 million per year. This value range is the contribution to Russia's national wealth.

6. KRESEM, a spatially explicit model developed in this study, estimated the greatest magnitude of economic loss to be from agricultural expansion. In this scenario, temperate mixed forest, savanna, wetlands, water surface (riparian buffer area), and shrublands were converted to agriculture and pasture land at a rate of 5 percent per year for 50 years. 18 percent of Kol Refuge's total ecosystem value was lost from this scenario.

7. The simulated scenario with the second greatest economic loss was conversion of water surface (riparian buffers), wetlands, coastal and agriculture to urban (built infrastructure) land cover at a rate of 5 percent per year for 50 years. Approximately 8 percent of Kol Refuge's total ecosystem value was lost from this scenario.

8. The simulated scenario with the third greatest economic loss was conversion of water surface (riparian buffer) to urban land cover at a rate of 5 percent per year for 50 years. Approximately 5 percent of Kol Refuge's total ecosystem value was

lost. There was a slight economic gain when converting urban and agriculture land to deciduous forest at a rate of 5 percent per year for 50 years.

9. Findings from KRESEM indicate there is very little potential for economic gain from any land conversion scenario. This suggests that the pristine ecosystem in the Kol Refuge is currently at its maximum economic value.

10. While there is little potential for economic gain from land conversion, there is potential for significant economic loss. This means that unless mechanisms are developed to preserve the Kol Refuge ecosystem, we as society will most likely lose large economic value in the long-term.

**Recommendations and Conclusions**

- The scenarios run in KRESEM highlight the importance of ecosystem service markets. The revenue per capita in Kamchatka was US $249 per month (US $111 from fishing industry) in 2003. Given this modest income there is a need to develop a greater revenue stream for individuals. However, as KREMSEN demonstrates, shifting land cover to urban (built infrastructure) or agriculture land significantly reduces the total ecosystem service value. The Kol Refuge is a great example of how the majority of ecosystem values fall outside the market realm and thus are not internalized in land management decisions. To internalize the externalities of providing the host of ecosystem services outlined in this study, mechanisms must be developed to start paying for them. Developing incentives for ecosystem service protection in the Kol Refuge should be a priority for any management strategy.

- Scientists, practitioners and policymakers who work in the Kol Refuge should use KRESEM as a tool to examine how monetary values change over the landscape in response to land management decisions. This will integrate ecosystem service values in policy and management decisions, which is currently lacking in the majority of conservation projects.

- Considering beneficiaries (society) only pays for a fraction of the US $784 million - $2.38 billion dollars worth of services provided by the Kol Refuge per year, society should begin compensating stakeholders for their provision. The development of an eco-trust used to invest in natural capital in the Kol Refuge should be considered.

- The value of salmon derived from this study provides valuable information as to the opportunity cost of salmon catches. The opportunity cost is defined as the cost of a good or service measured by the alternative uses that are foregone by producing the good or service. This is a supply side valuation study, which calculates the minimum amount a conservation fund must generate, to pay a fisherman not to engage in the desired activity. One way to achieve conservation objectives is to internalize the externalities of resource depletion. This can be done by offering fishermen a financial incentive to catch less salmon than allocated by their quota.

  - The range of opportunity cost estimated is from US $296 to US $1,125 per mt of salmon. The feasibility for a program that offers fishermen an incentive to catch less salmon than what is allocated in their quota should be examined.

- Considering the marginal value of carbon sequestration for temperate forest in Russia is expected to increase from US $870 per ha per year in 2007 to US $9,890 per ha per year in 2050 (as predicted by COPI's upper bound estimates), the potential for carbon markets should be assessed.

- Because of the potential for nonrenewable industries (e.g. oil, gas, minerals etc…) in Kamchatka, Forest Trend's Business and Biodiversity Offsets Program (BBOP) should be considered as an avenue for biodiversity offsets. This study can provide important information of the economic value of these offsets.

- Poaching is one of the greatest anthropogenic influences on salmon ecosystems and threatens the security and biological diversity of the Kol Refuge. A total of 60-75 mt of caviar are poached per year and 2,000 – 2,500 mt of salmon are killed per year in the Kol and Kehta Rivers. Funding for additional park rangers and identifying other methods of enforcement should be a priority.

**References**


Alaska Department of Fish and Game. 2006. Salmon Exvessel Price Time Series by Specie. Retrieved on June 5th 2008 from http://www.cf.adfg.state.ak.us/geninfo/finfish/salmon/catchval/blusheet/84-05exvl.pdf

Batker, D., Barclay, E., Boumans, R., and Hathaway, T. 2005. Ecosystem Services Enhanced by Salmon Habitat Conservation in the Green/Duwamish and Central Puget Sound Watershed. Earth Economics. Tacoma, Washington. Retrieved in May 2008 from http://www.eartheconomics.org/resources/resources_publications.html

Boston University (2004) MODIS Land Cover Product, MOD12Q1, 2000289, Collection 4, global 30-second resolution. Boston University, Boston, Massachusetts, May 2004.

Boumans R. and R. Costanza 2007. The Multi-Scale Integrated Model of the Earth Services (MIMES) The Dynamics, Modeling and Valuation of Ecosystem Services. ECEM '07 Trieste Italy, November 27-30 2007. 6th European conference on Ecological Modeling conference proceedings.

Boumans, R. and R. Costanza. 2007. The multiscale integrated Earth Systems model (MIMES): the dynamics, modeling and valuation of ecosystem services.[13] Van Bers, C.; Petry, D.; Pahl-Wostl, C. (Editors) (2007): Global Assessments: Bridging Scales and Linking to Policy. Report on the joint TIAS-GWSP workshop held at the University of Maryland University College, Adelphi, USA, 10 and 11 May 2007. GWSP Issues in Global Water System Research, No. 2. GWSP IPO, Bonn. 2:102-106

Boumans, R.M.J., Costanza, R., Farley, J., Wilson, M.A., Rotmans, J., Villa, F., Portela, R. & Grasso, M. 2002. Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. Special issue: the dynamics and value of ecosystem services: integrating economic and ecological perspectives. *Ecological Economics*, 41(3): 529–560.

Clark, C. (1990). Mathematical Bioeconomics: the Optimal Management of Renewable Resources. John Wiley and Sons, inc. New York.

Costanza, R., D' Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253-260.

Costanza, R., Leemans, R., Boumans, R.M.J. & Gaddis, E. 2006. Integrated global models. *In Sustainability or collapse? An integrated history and future of people on earth*, ed. R. Constanza, L.J. Graumlich & W. Steffen. Cambridge, USA, MIT Press. 517 pp.

Costanza, R., Perez-Maqueo, O., Martinez, M.L., Sutton, P., Anderson, S.A. & Mulder, K. 2008. The value of coastal wetlands for hurricane protection. *Ambio,*, 37 (4): 241-248.

Costanza, R. & Ruth, M. 1998. Using dynamic modeling to scope environmental and build consensus. *Environmental Management*, 22(2): 183–195.

Daily, G.C., Alexander, S., Ehrlich, PR., Goulder, L., Lubchenco, J., Matson, PA., Mooney, HA., Postel, S., Schneider, SH., Tilman, D., Woodwell, GM (1997). Ecosystem services: Benefits supplied to human societies by natural ecosystems. *Issues in Ecology* [Issues Ecol.]. Vol. 1, no. 2, pp. 1-18. 1997.

Daly, H.E., Farley, J. (2004). *Ecological Economics: Principles and Application*. Washington, D.C.: Island Press.

De Groot, R. 1992. Functions of Nature: Evaluation of Nature in Environmental Planning , Management, Decision Making. Amsterdam: Wolters-Noordhoff.

De Groot, R.S., Wilson, M.A., Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41: 393-409.

De Groot, R. van der Perk , J., Chiesura, A., and Marguliew, S. 2000. Ecological functions and socio-economic values of critical natural capital a measure of ecological integrity and environmental health, in *Implmenting ecological integrity: Restoring regional and global environmental and human health*, ed. Crabbe, P., Holland, L., Ryszkowski, L., Westra, L. NATO-Science Series, IV. Earth of Environmental Sciences, I. Dordrecht/Boston/London: Kluwer Academic Publishers.

Desvouges, W., Johnson, F., Banzhaf, H. 1998. Environmental policy analysis with limited information: Principles and applications of the transfer method. Northampton, MA: Edward Elgar Publishing

Environmental Protection Agency (EPA). 2005. Clean Air Interstate Rule. 70 Fed. Reg. 25162

Hardin, G. (1968). The tragedy of the commons. *Science*, 162:243-48

Heal, G. 2007. Discounting: A Review of the Basic Economics. University of Chicago Law Review 74:59. Retrieved on October 15th 2008 from http://lawreview.uchicago.edu/issues/archive/v74/74_1/Heal.pdf

Jensen, S. K., Domingue, J. O. (1988) Extracting topographic structure from digital elevation data forgeographic information system analysis. Photogrammetric Engineering and Remote Sensing, 54,1593-1600.

Knapp, G., Roheim, C.A., Anderson, J.L. 2007. The Great Salmon Rund: Competition between Wild and Farmed Salmon. TRAFFIC North America, Washington USA

Kremen, C. 2005. Managing ecosystem services: what do we need to know about their ecology? *Ecological Letters*, 8(5): 468–479.

Landell-Mills, N., Porras, I.T. (2002). Silver Bullet or Fool's Gold? A Global Review of Markets for Forest Environmental Services and Their Impact on the Poor.

Millennium Ecosystem Assessment . 2005. Ecosystems and Human Well-being: Synthesis. Retrieved on July 20th, 2008 from http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Markandya, A., Chiabai, A., Ding, H., Nunes, P., and Travisi, C. 2008. Economic Valuation of Forest Ecosystem Services: Methodology and Monetary Estimates, Annex II. In The Economics of Ecosystems & Biodiversity.

Pagiola, S., Paola, A., Gobbi, J., Haan, C., Ibrahim, M, Murgueitio, E., Ramirez, E., and M. & Ruiz Rosales, J. 2004. Paying for Biodiversity Conservation Services in Agricultural Landscapes. World Bank.

Pearce, D. The economic value of forest ecosystems. *Ecosystem Health* 7(4): 284-296

Shirkov, E. 2001. Draft: Comparative Economic Analysis of the Economic Benefits of Fishery vs. Hydrocarbon Development on Kamchatka's West Coast in Relation to Energy Supply and Development of the Region. Kamchatka Institute of Ecology and Nature Management.

Sinyakov, S.A. 2005. Review of Analysis of Socioeconomic Importance of Salmon for the Far East Regions of Russia. Petropavlovsk-Kamchatka.

Stern, N. 2006. Stern Review of the Economics of Climate Change. Cambridge University Press, Cambridge

United Nations. 2005. Interim Report: On the Preparation for the Organziation of the Reka Kol (Kol River) State Biological Salmon Preserve in the Sobolevski District of the Kamchatka Region. Sobolevski Disrict.

USGS (2004), Shuttle Radar Topography Mission, 3 Arc Second scene SRTM_u03_n008e004, 2.0, Global Land Cover Facility, University of Maryland, College Park, Maryland, February 2000.

Werners, S.E. & Boumans, R. 2005. *Simulating global feedbacks between Sea Level Rise, Water for Agriculture and the complex Socio-economic Development of the IPCC Scenarios.* Proceedings Environmental Modelling and Software Society Conference: Complexity and Integrated Resources Management (IEMSS2004), Osnabrück, Germany, June 2004.

APPENDIX A

| COPI DB ref-no | Author/reference | ESS name | Biome categ. | Geographic region | Economic Value | Unit |
|---|---|---|---|---|---|---|
| 1 | Ruijgrok et al. 2006 | Food, fiber, fuel | Scrubland | EUR | 500 | EUR/ha/y |
| 2 | Ruijgrok et al. 2006 | Climate regulation | Scrubland | EUR | 337 | EUR/ha/y |
| 3 | Ruijgrok et al. 2006 | Erosion control | Scrubland | EUR | 43 | EUR/ha/y |
| 4 | Ruijgrok et al. 2006 | Water purification and waste management | Scrubland | EUR | 609 | EUR/ha/y |
| 5 | Ruijgrok et al. 2006 | Water purification and waste management | Scrubland | EUR | 170 | EUR/ha/y |
| 6 | Ruijgrok et al. 2006 | Water purification and waste management | Scrubland | EUR | 34 | EUR/ha/y |
| 7 | Ruijgrok et al. 2006 | Water purification and waste management | Scrubland | EUR | 0 | EUR/ha/y |
| 8 | Ruijgrok et al. 2006 | Air quality maintenance | Scrubland | EUR | 700 | EUR/ha/y |
| 9 | Ruijgrok et al. 2006 | Air quality maintenance | Scrubland | EUR | 70 | EUR/ha/y |
| 10 | Rodriguez et al. 2006 | Food, fiber, fuel | Scrubland | OLC | 1477 | EUR/ha/y |
| 11 | Rodriguez et al. 2006 | Cultural diversity and values | Scrubland | OLC | 1590 | Nuevos Soles/ha |
| 12 | Ruijgrok et al. 2006 | Food, fiber, fuel | Grassland | EUR | 27 | EUR/ha/y |
| 13 | Ruijgrok et al. 2006 | Climate regulation | Grassland | global | 99 | EUR/ha/y |
| 14 | Ruijgrok et al. 2006 | Erosion control | Grassland | EUR | 43 | EUR/ha/y |

| COPI DB ref-no | Author/reference | ESS name | Biome categ. | Geographic region | Economic Value | Unit |
|---|---|---|---|---|---|---|
| 15 | Ruijgrok et al. 2006 | Water purification and waste management | Grassland | EUR | 121 | EUR/ha/y |
| 16 | Ruijgrok et al. 2006 | Water purification and waste management | Grassland | EUR | 11 | EUR/ha/y |
| 20 | Costanza et al. 1997 | Climate regulation | Grassland | NAM | 7 | $/ha/yr |
| 21 | Costanza et al. 1997 | Climate regulation | Grassland | NAM | 0 | $/ha/yr |
| 22 | Costanza et al. 1997 | Water regulation | Grassland | NAM | 3 | $/ha/yr |
| 23 | Costanza et al. 1997 | Erosion control | Grassland | NAM | 29 | $/ha/yr |
| 24 | Costanza et al. 1997 | Erosion control | Grassland | NAM | 1 | $/ha/yr |
| 25 | Costanza et al. 1997 | Water purification and waste management | Grassland | global | 87 | $/ha/yr |
| 26 | Costanza et al. 1997 | Biological control and pollination | Grassland | global | 25 | $/ha/yr |
| 27 | Costanza et al. 1997 | Biological control and pollination | Grassland | global | 23 | $/ha/yr |
| 28 | Costanza et al. 1997 | Food, fiber, fuel | Grassland | NAM | 57 | $/ha/yr |
| 29 | Costanza et al. 1997 | Biochemicals, natural medicines, pharmaceuticals | Grassland | global | 0 | $/ha/yr |

| COPI DB ref-no | Author/reference | ESS name | Biome categ. | Geographic region | Economic Value | Unit |
|---|---|---|---|---|---|---|
| 32 | Fleischer et al. 2006 | Food, fiber, fuel | Grassland | MEA | 98 | $/ha |
| 82 | Eade, Jeremy D.O., and Dor | Food, fiber, fuel | Tropical forest | OLC | | $/yr |
| 83 | Eade, Jeremy D.O., and Dor | Food, fiber, fuel | Tropical forest | OLC | | $/yr |
| 84 | Eade, Jeremy D.O., and Dor | Biochemicals, natural medicines, pharmaceuticals | Tropical forest | OLC | 2000 | $/yr |
| 85 | Eade, Jeremy D.O., and Dor | Biochemicals, natural medicines, pharmaceuticals | Tropical forest | OLC | 7 | $/ha/yr |
| 86 | Eade, Jeremy D.O., and Dor | Climate regulation | Tropical forest | OLC | n.a. | 13$/ton/yr |
| 87 | Eade, Jeremy D.O., and Dor | Soil quality maintenance | Tropical forest | OLC | 1699 | $/ha/yr |
| 88 | Eade, Jeremy D.O., and Dor | Water regulation | Tropical forest | OLC | 23 | $/ha/yr |
| 89 | Eade, Jeremy D.O., and Dor | Cultural diversity and values | Tropical forest | OLC | 50 | $/ha/yr |
| 90 | Costanza et al. 1997 | Natural hazards control / mitigation | Tropical forest | AFR | 5 | $/ha/yr |
| 91 | Costanza et al. 1997 | Fresh water | Tropical forest | SOA | 8 | $/ha/yr |

| COPI DB ref-no | Author/reference | ESS name | Biome categ. | Geographic region | Economic Value | Unit |
|---|---|---|---|---|---|---|
| 92 | Costanza et al. 1997 | Primary production, nutrient cycling, soil formation | Tropical forest | global | 10 | $/ha/yr |
| 93 | Costanza et al. 1997 | Primary production, nutrient cycling, soil formation | Tropical forest | SOA | 922 | $/ha/yr |
| 94 | Costanza et al. 1997 | Water purification and waste management | Tropical forest | global | 87 | $/ha/yr |
| 95 | Costanza et al. 1997 | Biochemicals, natural medicines, pharmaceuticals | Tropical forest | NAM | 41 | $/ha/yr |
| 96 | Costanza et al. 1997 | Recreation and ecotourism | Tropical forest | NAM | 112 | $/ha/yr |
| 97 | Costanza et al. 1997 | Cultural diversity and values | Tropical forest | global | 2 | $/ha/yr |
| 98 | Costanza et al. 1997 | Climate regulation | Temperate forest | NAM | 88 | $/ha/yr |
| 99 | Costanza et al. 1997 | Water regulation | Temperate forest | OLC | 0 | $/ha/yr |
| 100 | Costanza et al. 1997 | Primary production, nutrient cycling, soil formation | Temperate forest | global | 10 | $/ha/yr |

Appendix B

**Ecosystem Service Values for Temperate Mixed Forests and Coniferous Forest**

| **Ecosystem Services** | **Temperate Mixed Forests** | | **Coniferous Forest** | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| *Gas Regulation* | $1,070,456 | $7,174,124 | $71,366 | $478,288 |
| *Climate Regulation* | $2,227,778 | $3,852,066 | $146,064 | $252,560 |
| *Disturbance Prevention* | $9,780 | $38,503 | $652 | $2,567 |
| *Water Regulation* | $3,701,915 | $3,701,915 | $246,801 | $246,801 |
| *Water Supply* | $5,097,412 | $10,194,824 | $339,837 | $679,674 |
| *Soil Retention* | $331,717 | $643,884 | $22,115 | $42,927 |
| *Soil Formation* | $6,707 | $67,591 | $447 | $4,506 |
| *Nutrient Regulation* | $1,292,740 | $19,061,373 | $86,185 | $1,270,793 |
| *Waste Treatment* | $364,046 | $1,469,351 | $24,270 | $97,959 |
| *Pollination* | $167,678 | $167,678 | $10,620 | $10,620 |
| *Biological Control* | $8,399 | $27,296 | $537 | $1,744 |
| *Refugium Function* | $1,133,503 | $2,944,426 | $71,791 | $186,485 |
| *Nursery Function* | $13,414 | $181,092 | $850 | $11,469 |
| *Food* | $410,916 | $833,002 | $4,879 | $9,890 |
| *Raw Materials* | $196,419 | $649,384 | $13,095 | $43,293 |
| *Genetic Resources* | $15,078 | $45,234 | $955 | $2,865 |
| *Medical Resources* | $15,078 | $45,234 | $955 | $2,865 |
| *Ornamental Resources* | $20,121 | $25,957 | $1,274 | $1,644 |
| *Aesthetic Information* | $46,794 | $46,794 | $2,964 | $2,964 |
| *Recreation* | $231,516 | $310,260 | $5,828 | $7,810 |
| *Cultural and Artistic Information* | $50,898 | $101,738 | $4,147 | $8,290 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 |
| *Science and Education* | $113,085 | $141,681 | $7,539 | $9,446 |
| *Navigational Services* | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$16,525,451** | | **$1,063,170** | |
| ***Total Max*** | | **$51,723,406** | | **$3,375,460** |
| ***Average Min: $/Hectare*** | **$3,019** | | **$2,914** | |
| ***Average Max: $/Hectare*** | | **$9,451** | | **$9,251** |

**Ecosystem Service Values for Deciduous Forests and Savannas**

| **Ecosystem Services** | **Deciduous Forests** | | **Savannas** | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| *Gas Regulation* | $419,627 | $2,812,311 | $11,149,963 | $74,726,264 |
| *Climate Regulation* | $873,306 | $1,510,039 | $30,939,626 | $53,497,913 |
| *Disturbance Prevention* | $3,834 | $15,093 | $135,825 | $534,733 |
| *Water Regulation* | $1,451,179 | $1,451,179 | $51,412,600 | $51,412,600 |
| *Water Supply* | $1,998,224 | $3,996,448 | $35,396,709 | $70,793,417 |
| *Soil Retention* | $130,035 | $252,407 | $4,606,916 | $8,942,326 |
| *Soil Formation* | $2,629 | $26,496 | $93,149 | $938,713 |
| *Nutrient Regulation* | $506,764 | $7,472,203 | $17,953,722 | $264,726,443 |
| *Waste Treatment* | $142,709 | $575,997 | $5,055,913 | $20,406,504 |
| *Pollination* | $65,731 | $65,731 | $1,397,238 | $1,397,238 |
| *Biological Control* | $3,155 | $10,254 | $111,779 | $363,282 |
| *Refugium Function* | $444,342 | $1,154,237 | $9,445,332 | $24,535,508 |
| *Nursery Function* | $5,258 | $70,990 | $111,779 | $1,509,018 |
| *Food* | $10,812 | $21,919 | $539,219 | $1,093,095 |
| *Raw Materials* | $76,998 | $254,564 | $2,727,885 | $9,018,720 |
| *Genetic Resources* | $5,911 | $17,732 | $125,643 | $376,929 |
| *Medical Resources* | $5,911 | $17,732 | $125,643 | $376,929 |
| *Ornamental Resources* | $7,888 | $10,175 | $167,669 | $216,293 |
| *Aesthetic Information* | $18,344 | $18,344 | $389,927 | $389,927 |
| *Recreation* | $178,764 | $239,566 | $6,333,293 | $8,487,387 |
| *Cultural and Artistic Information* | $24,463 | $48,898 | $820,645 | $1,640,358 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 |
| *Science and Education* | $44,330 | $55,540 | $1,570,539 | $1,967,687 |
| *Navigational Services* | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$6,420,214** | | **$180,611,014** | |
| ***Total Max*** | | **$20,097,854** | | **$597,351,286** |
| ***Average Min: $/Hectare*** | **$2,992** | | **$2,376** | |
| ***Average Max: $/Hectare*** | | **$9,368** | | **$7,859** |

**Ecosystem Service Values for Grasslands and Shrublands**

| Ecosystem Services | Grasslands | | Shrublands | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| *Gas Regulation* | $59,755 | $400,477 | $17,974,612 | $120,464,575 |
| *Climate Regulation* | $438,186 | $757,670 | $41,599,142 | $71,929,352 |
| *Disturbance Prevention* | $2,430,599 | $9,569,078 | $12,426,809 | $48,923,379 |
| *Water Regulation* | $59,425 | $59,425 | $66,229,011 | $66,229,011 |
| *Water Supply* | $10,044,888 | $20,089,777 | $102,712,066 | $205,424,132 |
| *Soil Retention* | $490,257 | $951,621 | $5,063,762 | $9,829,096 |
| *Soil Formation* | $7,264 | $73,206 | $67,574 | $680,976 |
| *Nutrient Regulation* | $2,458,751 | $36,254,117 | $25,141,481 | $370,709,471 |
| *Waste Treatment* | $2,224,447 | $8,978,238 | $11,210,481 | $45,247,368 |
| *Pollination* | $330,424 | $330,424 | $3,378,686 | $3,378,686 |
| *Biological Control* | $198,763 | $645,979 | $162,177 | $527,075 |
| *Refugium Function* | $2,233,666 | $5,802,245 | $22,839,920 | $59,329,733 |
| *Nursery Function* | $26,434 | $356,858 | $270,295 | $3,648,981 |
| *Food* | $1,606,706 | $3,257,089 | $78,233,614 | $158,593,968 |
| *Raw Materials* | $388,579 | $1,284,688 | $3,311,113 | $10,946,944 |
| *Genetic Resources* | $17,828 | $53,483 | $182,292 | $546,876 |
| *Medical Resources* | $9,904 | $29,713 | $100,261 | $300,782 |
| *Ornamental Resources* | $39,651 | $51,150 | $405,442 | $523,021 |
| *Aesthetic Information* | $92,211 | $92,211 | $707,167 | $707,167 |
| *Recreation* | $648,953 | $869,676 | $4,645,018 | $6,224,892 |
| *Cultural and Artistic Information* | $1,280,855 | $2,560,257 | $12,762,850 | $25,511,212 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 |
| *Science and Education* | $222,844 | $279,195 | $2,278,649 | $2,854,859 |
| *Navigational Services* | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$25,310,389** | | **$411,702,421** | |
| ***Total Max*** | | **$92,746,576** | | **$1,212,531,555** |
| ***Average Min: $/Hectare*** | **$2,347** | | **$3,733** | |
| ***Average Max: $/Hectare*** | | **$8,600** | | **$10,995** |

**Ecosystem Service Values for Agriculture and Pasture**

| Ecosystem Services | Agriculture and Pasture | | Urban | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| *Gas Regulation* | $0 | $0 | $0 | $0 |
| *Climate Regulation* | $279,477 | $483,245 | $0 | $0 |
| *Disturbance Prevention* | $439,237 | $1,729,240 | $0 | $0 |
| *Water Regulation* | $0 | $0 | $0 | $0 |
| *Water Supply* | $0 | $0 | $0 | $0 |
| *Soil Retention* | $11,813 | $22,929 | $0 | $0 |
| *Soil Formation* | $239 | $2,407 | $0 | $0 |
| *Nutrient Regulation* | $170,894 | $2,519,818 | $0 | $0 |
| *Waste Treatment* | $198,122 | $799,654 | $0 | $0 |
| *Pollination* | $33,438 | $33,438 | $0 | $0 |
| *Biological Control* | $14,331 | $46,575 | $0 | $0 |
| *Refugium Function* | $39,695 | $103,113 | $0 | $0 |
| *Nursery Function* | $2,866 | $38,693 | $0 | $0 |
| *Food* | $96,300 | $195,218 | $0 | $0 |
| *Raw Materials* | $87,776 | $290,197 | $0 | $0 |
| *Genetic Resources* | $5,369 | $16,108 | $0 | $0 |
| *Medical Resources* | $2,685 | $8,054 | $0 | $0 |
| *Ornamental Resources* | $7,165 | $9,243 | $0 | $0 |
| *Aesthetic Information* | $8,332 | $8,332 | $2,515 | $2,515 |
| *Recreation* | $586,365 | $785,801 | $177,018 | $237,226 |
| *Cultural and Artistic Information* | $420,845 | $841,213 | $635,246 | $1,269,772 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 |
| *Science and Education* | $1,611 | $2,018 | $0 | $0 |
| *Navigational Services* | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$2,406,560** | | **$814,780** | |
| ***Total Max*** | | **$7,935,298** | | **$1,509,513** |
| ***Average Min: $/Hectare*** | **$1,300** | | **$729** | |
| ***Average Max: $/Hectare*** | | **$4,286** | | **$1,350** |

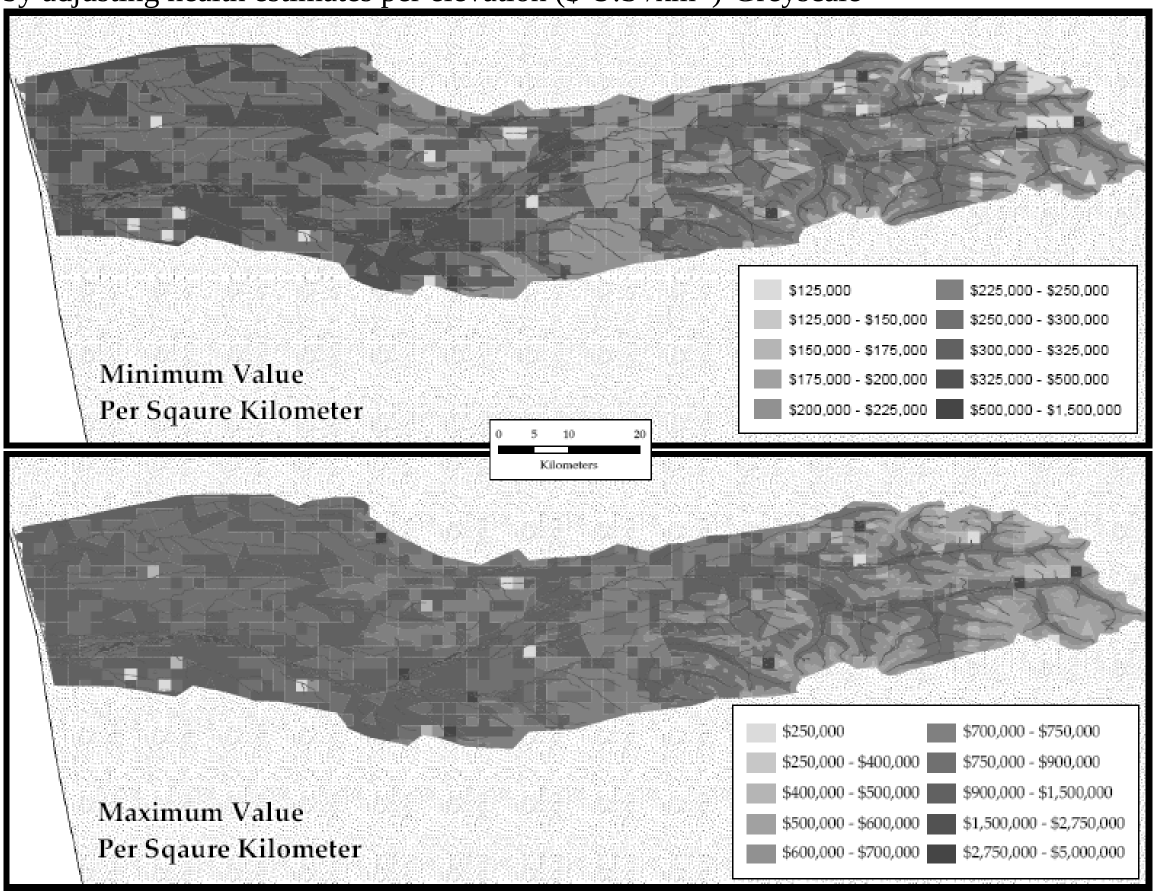
**Ecosystem Service Values for Water surface and Wetlands**

| Ecosystem Services | Water surface | | Wetlands | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| *Gas Regulation* | $0 | $0 | $129,692 | $869,185 |
| *Climate Regulation* | $4,626,115 | $7,999,046 | $586,352 | $1,013,865 |
| *Disturbance Prevention* | $0 | $0 | $2,764,599 | $10,884,011 |
| *Water Regulation* | $64,581,266 | $64,581,266 | $33,825 | $33,825 |
| *Water Supply* | $18,831,755 | $37,663,510 | $5,712,603 | $11,425,205 |
| *Soil Retention* | $146,649 | $284,656 | $18,588 | $36,080 |
| *Soil Formation* | $1,186 | $11,953 | $1,203 | $12,120 |
| *Nutrient Regulation* | $8,486,299 | $125,129,909 | $1,075,623 | $15,859,989 |
| *Waste Treatment* | $4,920,750 | $19,860,967 | $2,494,002 | $10,066,207 |
| *Pollination* | $0 | $0 | $0 | $0 |
| *Biological Control* | $56,931 | $185,026 | $21,648 | $70,355 |
| *Refugium Function* | $2,004,451 | $5,206,827 | $254,060 | $659,956 |
| *Nursery Function* | $23,721 | $320,238 | $3,007 | $40,590 |
| *Food* | $1,769,393 | $3,586,886 | $208,116 | $421,889 |
| *Raw Materials* | $581,172 | $1,921,426 | $73,663 | $243,537 |
| *Genetic Resources* | $13,332 | $39,995 | $3,380 | $10,139 |
| *Medical Resources* | $13,332 | $39,995 | $3,380 | $10,139 |
| *Ornamental Resources* | $35,582 | $45,901 | $4,510 | $5,818 |
| *Aesthetic Information* | $82,749 | $82,749 | $10,488 | $10,488 |
| *Recreation* | $606,105 | $812,254 | $738,128 | $989,182 |
| *Cultural and Artistic Information* | $10,449,237 | $20,886,613 | $1,324,422 | $2,647,340 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 |
| *Science and Education* | $799,905 | $1,002,179 | $25,347 | $31,756 |
| *Navigational Services* | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$118,029,928** | | **$15,486,632** | |
| ***Total Max*** | | **$289,661,396** | | **$55,341,676** |
| ***Average Min: $/Hectare*** | **$12,837** | | **$13,289** | |
| ***Average Max: $/Hectare*** | | **$31,504** | | **$47,489** |

**Ecosystem Service Values for Coastal, Rock and Open Ocean**

| Ecosystem Services | Coastal | | Rock | | Open Ocean | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| *Gas Regulation* | $0 | $0 | $0 | $0 | $0 | $0 |
| *Climate Regulation* | $804,307 | $1,390,732 | $0 | $0 | $0 | $0 |
| *Disturbance Prevention* | $733,106 | $2,886,180 | $491,930 | $1,936,691 | $0 | $0 |
| *Water Regulation* | $0 | $0 | $0 | $0 | $0 | $0 |
| *Water Supply* | $0 | $0 | $0 | $0 | $0 | $0 |
| *Soil Retention* | $0 | $0 | $2,646 | $5,136 | $0 | $0 |
| *Soil Formation* | $0 | $0 | $53 | $539 | $0 | $0 |
| *Nutrient Regulation* | $2,950,895 | $43,510,745 | $0 | $0 | $0 | $0 |
| *Waste Treatment* | $74,618 | $301,170 | $0 | $0 | $0 | $0 |
| *Pollination* | $0 | $0 | $0 | $0 | $0 | $0 |
| *Biological Control* | $29,901 | $97,177 | $0 | $0 | $0 | $0 |
| *Refugium Function* | $59,214 | $153,817 | $0 | $0 | $0 | $0 |
| *Nursery Function* | $4,124 | $55,677 | $0 | $0 | $0 | $0 |
| *Food* | $335,102 | $679,313 | $0 | $0 | $0 | $0 |
| *Raw Materials* | $9,859 | $32,594 | $0 | $0 | $0 | $0 |
| *Genetic Resources* | $4,636 | $13,907 | $0 | $0 | $0 | $0 |
| *Medical Resources* | $4,636 | $13,907 | $0 | $0 | $0 | $0 |
| *Ornamental Resources* | $6,186 | $7,980 | $0 | $0 | $0 | $0 |
| *Aesthetic Information* | $14,387 | $14,387 | $3,733 | $3,733 | $0 | $0 |
| *Recreation* | $189,715 | $254,241 | $0 | $0 | $0 | $0 |
| *Cultural and Artistic Information* | $37,139 | $74,235 | $471,333 | $942,131 | $0 | $0 |
| *Spiritual and Historic Information* | $0 | $0 | $0 | $0 | $0 | $0 |
| *Science and Education* | $13,907 | $17,424 | $0 | $0 | $0 | $0 |
| *Navigational Services* | $0 | $0 | $0 | $0 | $0 | $0 |
| ***Total Min*** | **$5,271,731** | | **$969,695** | | **$0** | |
| ***Total Max*** | | **$49,503,489** | | **$2,888,230** | | **$0** |
| ***Average Min: $/Hectare*** | **$3,298** | | **$2,338** | | **$0** | |
| ***Average Max: $/Hectare*** | | **$30,968** | | **$6,964** | | **$0** |

APPENDIX C. Total Minimum and Maximum Value of Kol Refuge Ecosystem Services by adjusting health estimates per elevation ($ U.S /km$^2$ )-Greyscale




Note: Higher elevations received lower health estimates than lower elevation. Therefore, the economic value is less in the upper watershed.