GEO Task US-09-01a: Critical Earth Observations Priorities

Biodiversity Societal Benefit Area

GROUP ON EARTH OBSERVATIONS

User Interface Committee

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Group on Earth Observations

GEO Task US09-01a:
Earth Observation Priorities for Biodiversity SBA

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The following person served as the Analyst for the Biodiversity Societal Benefit Area under GEO Task US-09-01a, identifying source materials, developing analytical methodologies, and providing overall coordination of the analysis and preparation of this report.

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GEO Task US-09-01a

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Group on Earth Observations

GEO Task US09-01a:
Earth Observation Priorities for Biodiversity SBA

Summary

The primary purpose of this report is to articulate the critical Earth observation priorities for the Biodiversity Societal Benefit Area (SBA). The GEO UIC will use the results of this report in combination with reports from the other eight SBAs to perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. This effort will result in an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

Although biodiversity can be considered to be comprised of three major levels of organization (genetic, species, ecosystem), this report focused on the species and ecosystem levels. One hundred sixty-five biodiversity related Earth observation needs were identified through a literature search and subsequent review of 63 publicly available documents from countries, organizations, researchers, and practitioners.

Specific ecosystems, species, and groups of species (e.g., migratory species, invasive species) were not targeted. Rather this report used an approach that looked at biodiversity holistically and cast a broad net in an attempt to identify major needs across ecosystems and species. This approach resulted in the collection of very diverse types of information. It was necessary to find a mechanism to organize these diverse and numerous biodiversity observation needs. The DPSIR (drivers, pressures, state, impacts, and responses) framework was used to categorize all the needs that were collected, and was the primary method of analysis for this report. Other analyses were conducted based on biome type, biodiversity organization level, spatial scale, observation type, user type, and type of document (organization or journal). Each of these secondary methods of analysis contained a category that indicated that a need could be applicable to all the categories within that method of analysis (e.g., Spatial Scale: global, global & regional, regional, regional & local, local, all spatial scales). To further demonstrate that the observation needs identified in this task have broad applicability, the percentages of the needs that apply to all the categories within each of the secondary methods of analysis are as follows: organization level - 26%; biome type - 39%; spatial scale – 45%; observation type – 73%; and user type – 28%. In addition, half of the documents used in task are international in scope and are not defined by a geographic region.

Using the DPSIR framework, this analysis found that identifying the current state of biodiversity is the highest need, but that a large number also considered responding to biodiversity issues as the second highest need category. Collectively they represent 85% of the identified needs. Subcategories were developed based on natural groupings of the needs identified. The largest subcategory represented19% of the total needs identified. It contained specific needs to address the current state of biodiversity for various species and ecosystems.

The second, third, and fourth largest subcategories collectively represent 35% of the total needs, and are considered responses (measures taken to address drivers, pressures, state, or impacts with the goal being an improved state of biodiversity) that respectively address information management, organizational infrastructure, and system infrastructure needs. These needs demonstrate that a higher level of commitment, organization, coordination, communication, management, data collection and analysis, and information management, integration and dissemination of Earth observations are needed at all levels within the larger biodiversity community from funding organizations to individual researchers.

The largest percentage of biodiversity observation needs identified are: relevant to both ecosystems and species; relevant to all biome types; relevant at all spatial scales; relevant to both remote and *in-situ* type observations; relevant to technical users (all user types had the second highest of observations needs). Additional analysis determined that only 17 of the needs identified address remote sensing technical needs; many recommendations at the species level are applicable to all species; journals/periodicals identified needs to address the state of biodiversity as the highest priority, while organizations identified the highest priority being the need to respond to biodiversity issues through mechanisms such as organizational infrastructure, system infrastructure, and information management.

This report identifies numerous needs that if addressed by the biodiversity community would have broad applicability across biome type, biodiversity organization level, spatial scale, observation type, and the various types of users. Many ecosystem and species specific needs were identified that are very focused, but almost as many needs require the biodiversity community to respond in a way that makes its activities and products applicable and useful to the collective biodiversity community.

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1 Introduction

This report articulates Earth observation priorities for the Biodiversity SBA based on an analysis of 165 needs identified in 63 publicly-available documents (and one personal communication source), including documents produced by Group on Earth Observations' Member Countries and Participating Organizations.

1.1 Group on Earth Observations

The Group on Earth Observations (GEO)[1] is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS)[2]. GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, airborne, and space-based instruments.

GEO is focused on enhancing the development and use of Earth observations in nine Societal Benefit Areas (SBA):

Agriculture	Biodiversity	Climate
Disasters	Ecosystems	Energy
Human Health	Water	Weather

1.2 GEO Task US-09-01a

The objective of GEO Task US-09-01a is to establish and conduct a process to identify critical Earth observation priorities within each SBA and those common to all nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. In addition, researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these *existing* materials and analyzing across the materials to determine the priority observations.

This task considers all types of Earth observations, including ground, in situ, airborne, and space-based observations. The task includes direct

[1] GEO Website: *http:// www.earthobservations.org*
[2] GEO 10-Year Implementation Plan: *http://www.earthobservations.org/documents.shtml*

measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

GEO will use the Earth observation priorities resulting from this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

1.3 Purpose of Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Biodiversity SBA. The intent of the report is to describe the overall process and specific methodologies used to identify documents, analyze them, and determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results of this report in combination with reports from the other eight SBAs. The GEO UIC will perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. Based on the nine SBA reports, the GEO UIC will produce an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

The report's authors anticipate that the GEO Secretariat, Committees, Member Countries, Participating Organizations, Observers, Communities of Practice, and the communities associated with the Biodiversity SBA are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Biodiversity SBA. Although biodiversity can be considered to be comprised of three major levels of organization (genetic, species, ecosystem), this report focused on the species and ecosystem levels. Initial literature searches for biodiversity observation needs primarily resulted in the identification of information at the species and ecosystem levels. Given the amount of time and effort needed to conduct the search and review the literature it was felt that focusing on species and ecosystems would result in identifying the greatest number of biodiversity

observation needs. In addition, given the large number of species (over a million species) and numerous ecosystems (depending on classification scheme), it was felt that selecting sub-areas (selecting specific species and ecosystems) to focus on would have been arbitrary. Rather, it was decided that by not limiting the scope of this report further it could provide a cross section and broad overview of the types of observation needs for many species and ecosystems, rather than specifics on a few selected species and ecosystems.

Although this report contains information about ecosystems, it should be noted that overlap with the Ecosystem SBA report for this task are minimal. This report focuses solely on condition and extent of biodiversity within the ecosystem, whereas the Ecosystem SBA report focuses on improving the management and protection of ecosystems.

The report provides some background and contextual information about the Biodiversity SBA. However, this report is not intended as a handbook or primer on the Biodiversity SBA and a complete description of the Biodiversity SBA is beyond the scope of this report. Please consult the GEO website for more information about the Biodiversity SBA.

The report focuses on the Earth observations within the Biodiversity SBA, independent of any specific technology or collection method. Thus, the report addresses the “demand” side of observation needs and priorities. The report does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

In this report, the term Earth observation refers to parameters and variables (e.g., physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term Earth observation priorities refers to the parameters deemed of higher significance than others for the given SBA, as determined through the methodologies described within. The report uses the terms “user needs” and “user requirements” interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the cited documents. The term “requirements” does not imply technical, engineering specifications.

Following this introduction, the report discusses the overall approach and methodologies used in this analysis (Section 2). Section 3 provides a brief description of the Biodiversity SBA and descriptions of the documents and user types used in the analysis. Section 4 articulates the specific Earth observations and results of the analysis, and Section 5 presents the priority observations across the Biodiversity SBA. Sections 6 & 7 present additional findings from the analysis of the documents and any recommendations. The Appendices include

the documents cited and sourced as well as any additional information describing aspects of the Biodiversity SBA.

2 Methodology

This section documents the general process followed and specific methodologies used to identify documents, analyze them, determine Earth observation parameters and characteristics, and establish a set of priority Earth observations for this SBA.

2.1 Task Process

The GEO UIC established a general process for each of the SBAs to follow in order to ensure some consistency across the SBAs. This general process for each SBA involves 9 steps, as summarized in the following list:

Step 1: Identify Analyst and Advisory Group for the SBA
Step 2: Determine scope of topics within the SBA
Step 3: Identify documents regarding observation priorities for the SBA
Step 4: Develop analytic methods and priority-setting criteria
Step 5: Review and analyze documents for priority Earth observations needs
Step 6: Combine the information and develop a preliminary report
Step 7: Gather feedback on the preliminary report
Step 8: Perform any additional analysis
Step 9: Complete the report on Earth observations for the SBA

A detailed description of the general US-09-01a process is available at the Task website *http://sbageotask.larc.nasa.gov* or GEO website. Some steps in the process occurred simultaneously or iteratively, such as identifying documents (Step 3) and reviewing documents (Step 5).

2.2 Analyst and Advisory Group

The Biodiversity SBA had an “Analyst” and an “Advisory Group” to conduct the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main person that collected the documents, conducted the analysis, and developed this report. The Advisory Group served to provide additional documents and feedback on the analysis and drafts of the report.

2.2.1 Analyst

For the Biodiversity SBA, the Analyst was Greg Susanke. He worked on this report on a *pro bono* basis as a representative of the U.S. Environmental Protection Agency (EPA). His understanding of GEO comes from previous work

in GEO's Biodiversity Observation Network and EPA's GEO program. Greg is a biologist with experience in wildlife and fisheries management, ecological risk assessment and management, and research planning and evaluation. Greg gained additional international policy experience through EPA programs collaborating with the Commission for Environmental Cooperation, and the Organization for Environmental Cooperation and Development.

2.2.2 Advisory Group

The Biodiversity Advisory Group consisted of eight biodiversity experts. Table 1 below lists the members and provides their country, affiliation and area of expertise.

The Analyst identified the Advisory Group members through previous participation in GEO activities, in particular the Biodiversity Observation Network. The Analyst attempted to recruit Advisory Group members from diverse geographic regions and multiple developing countries, as well as diverse areas of expertise. The Analyst contacted thirteen people to participate on the Advisory Group. Eight expressed interest; three did not respond; and two were unable to participate. Overall, the Advisory Group includes members from eight countries and six continents, including four from developing countries.

The primary roles of the Advisory Group were to assist in identifying documents, assess methodologies and analytic techniques, assess prioritization schemes, review findings, and review reports. Contact with the Advisory Group was through emails.

Table 1. Advisory Group			
Name	**GEO Country or Organization**	**Affiliation**	**Geographic Region**
Daniel P. FAITH	Australia	DIVERSITAS-bioGenesis, and The Australian Museum	Oceania/Australia
Dorothy AMWATA	Tunisia	Observatoire du Sahara et du Sahel	Africa
Eva SPEHN	Switzerland	DIVERSITAS-GMBA (Global Mountain Biodiversity Assessment), and the University of Basel	International
Patrick N. HALPIN	USA	Duke University – Nicholas School of the Environment	Global Oceans
Santiago MADRINAN (Madriñán)	Colombia	Universidad de los Andes	South/Central America
Sebastian K. HERZOG	Bolivia	Asociación Armonía - BirdLife International, and the Museo de Historia Natural Alcide d'Orbigny Cochabamba,	South/Central America
Tim O'CONNOR	South Africa	SAEON (South African Environmental Observation Network)	Africa
Yongyut TRISURAT	Thailand	Kasetsart University – Faculty of Forestry	East Asia

2.3 Methodology

This section provides a general description of the processes, analytic methods, and approaches the Analyst/Advisory Group used to identify documents, analyze them, and establish a set of priority Earth observations.

2.3.1 Documents

This section provides a general description of the approach used by the Analyst to identify documents and select a representative sampling for the analysis. The search was limited to documents made publicly available or published between the years 2000 – 2009. It was thought that needs/requirements identified before 2000 may be outdated and that needs identified at later dates most likely supersede or update those identified before 2000.

The following approaches were used to identify documents of potential relevance:

- Used full text search in peer reviewed journals using several search engines (Google, SpringerLink, ScienceDirect, Wiley InterScience).
- Used keyword search in WorldCat a worldwide library catalog of books, theses, manuscripts collections, journal articles, etc.
- Searched for relevant publications generated by all GEO Participating Organizations (http://www.earthobservations.org/ag_partorg.shtml) , the environmental agency websites associated with GEO Member Countries (http://www.earthobservations.org/ag_members.shtml), and the websites of GEO Observers (http://www.earthobservations.org/ag_observers.shtml).
- Searched for relevant documents on environmental (biodiversity focused) NGO websites.
- Searched the remote sensing and global monitoring initiatives currently underway and referenced on SEDAC's website (Remote Sensing and Environmental Treaties: Building More Effective Linkages; http://sedac.ciesin.columbia.edu/rs-treaties/initiatives.html).
- Searched for relevant documents in the U.S. Library of Congress Science Tracer Bullet Series. The prepared bibliography on biodiversity was compiled in 1997 and was considered outdated for the purpose of this report. However, the prepared bibliography on remote sensing (completed 2005) revealed several relevant biodiversity citations.
- Several documents were provided to the Analyst through personal communication by Advisory Group members and others involved in the management of this GEO task.

Thousands of potential documents were identified by the search engines using the search terms (Boolean connectors) "biodiversity" and "monitoring" and "observation". The term "remote sensing" was also used in other searches. Realizing that a review of all these documents was not possible, those documents that received higher relevance rankings according to the search terms were reviewed first.

2.3.2 Analytic Methods

This section provides a general description of the approach used to analyze documents and extract information to identify Earth observation needs. One hundred and sixty-five observation needs/recommendations were identified and these needs covered a broad spectrum of topics. To avoid misinterpreting or overstating implicit earth observation needs, only those needs that were explicitly stated were included in this report.

To assist the organization of information and subsequent analysis, each biodiversity need identified was characterized by the following categories: Biodiversity Organizational Level, Biome Type, Spatial Scale, Observation Type, User Type, and DPSIR Assessment Framework. Below is the definition for each of these categories.

Biodiversity Organizational Level
Reference to whether the need was made at the ecosystem, species, or genetic level.

Biome Type
Biomes (composed of biotic factors), are used to help characterize the type of ecosystem (composed of biotic and abiotic factors). Biomes are the major regional groupings of plants, animals, and microbes that have developed under specific soil and climatic conditions. There are numerous biome classification schemes. For purpose of this report the following major biome types were used:

- Terrestrial Biome: Desert; Forest (tiaga, temperate, tropical); Grassland; Tundra; Mountain
- Aquatic Biome: Freshwater (rivers & streams; ponds & lakes; wetlands); Marine (shoreline; temperate ocean; tropical ocean).

Spatial Scale
Reference is made to whether the need is applicable at the local, regional, or global scale or whether it can be applied to all scales.

Observation Type
Reference is made to whether the need refers to remote sensing or in-situ measurements, or whether the need is applicable to both.

User Type
Reference to who would use the information identified by the need. Three major categories of users were used for this analysis: technical, policy, and management/decision maker. Further discussion of user types is presented in section 3.3.

DPSIR
The DPSIR (Drivers – Pressures – State – Impacts – Responses) assessment framework can be used to help describe interactions between society and the environment. It is an organizational scheme that conceptually links interactive processes in a continuous causal chain. Although the elements are listed separately they are interconnected and therefore can not be regarded as being independent. DPSIR has been demonstrated to be a useful model for analyzing inter-related factors. It is described by the European Environmental Agency (2003), and is currently used by the ALTER-Net (A Long-Term Biodiversity, Ecosystem and Awareness Research Network) research community. The

International Mechanism of Scientific Expertise on Biodiversity (IMoSEB, 2007) recently called for additional operational monitoring and assessments of drivers, pressures, state, impacts, and responses relating to biodiversity and ecosystem services. Definitions of the indicator categories used are provided below.

- **Drivers** - natural and social motivations and actions that influence levels of biodiversity, e.g., food consumption/agriculture, energy use, forestry.
- **Pressures** - establish connection between ecosystems and society, e.g., habitat/land use change, climate change, pollution, over harvesting/exploitation, invasive species.
- **State** - biodiversity status, e.g., air, water, soil and habitat quality, species distribution, biodiversity assessment.
- **Impacts** - impact of drivers and pressures on biodiversity, e.g., impacts on natural systems (species/habitat loss), economic damage.
- **Responses** – measures taken to address drivers, pressures, state, or impacts with the goal being an improved state of biodiversity, e.g., policy framework, public attitudes, biodiversity conservation options, regulations.

2.3.3 Prioritization Methods

This section provides a general description of the methods used by the Analyst and Advisory Group to prioritize the Earth observations. As a means to further organize the 165 identified needs, they were placed under the appropriate indicator category of the DSPIR assessment framework. Although none of the needs identified among the 64 different references were the same, they were similar enough to aggregate, thereby creating various categories or topic areas and subcategories. The categories with the largest number of needs/requirements associated with them are considered as the biodiversity priority areas.

3 Biodiversity SBA

This section provides summary information of the Biodiversity SBA. It discusses the specific documents used in the meta-analysis (general discussion rather than specifics on each document) and the broad user-types within the SBA.

3.1 Biodiversity SBA Description

The GEOSS 10-year Plan Reference Document describes biodiversity as having “three major levels of organization (the genetic level, the species level, and the ecosystem level), within each of which there are three aspects of diversity: composition, structure and function”. Description of the Biodiversity SBA as found in the GEOSS 10-Year Implementation Plan is as follows:

Biodiversity: Understanding, monitoring and conserving biodiversity
Issues in this area include the condition and extent of ecosystems, distribution and status of species, and genetic diversity in key populations. Implementing GEOSS will unify many disparate biodiversity observing systems and create a platform to integrate biodiversity data with other types of information. Taxonomic and spatial gaps will be filled, and the pace of information collection and dissemination will be increased.

3.2 Documents

This section lists the specific documents that were found to contain biodiversity observation needs. Two major types of documents were identified, peer reviewed journal articles, and reports and documents developed by organizations. Because of the greater number of journal articles available to review it was easier to find biodiversity observation needs associated with them than with observation needs originating from organizations. Therefore, the number of documents generated by organizations that contained observation needs was the limiting factor regarding the total number of documents identified. A 50% ratio between the number of journal articles (32) and the number of documents (32) generated by organizations was maintained. This was done to help even the distribution of the various types of needs identified in case there were major differences between the types of needs found in journals and organization generated documents.

The number of journal documents reviewed and websites searched was not collected, therefore the total number of documents searched is not known. Table 2 lists the 63 documents and one source of personal communication from which biodiversity needs were collected, and includes qualitative information. They are listed alphabetically by type of document with organization type documents being listed first, then journals.

Table 2. Document Characterization

Author	Region	Type of Document	Title	Year Published
Alaska Ocean Observing System	Polar Regions	Organization	Artic Research and Monitoring Workshop: Toward a Strategy for the Chukchi and Beaufort Seas	23-Jan-09
African Pollinator Initiative	Africa	Organization	Pollinators and Pollination: a resource book for policy and practice	Feb-06

Centro del Agua del Tropico Humedo para America Latina y el Caribe (Anderson, E.R. et al)	South/ Central America	Organization	Potential Impacts of Climate Change on Biodiversity in Central America, Mexico, and the Dominican Republic	2008
Convention on Biological Diversity (1)	International	Organization	Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Waters	2006
Convention on Biological Diversity (2)	International	Organization	Recommendations from the Pre-COP9 Scientific Conference "Biodiversity Research - Safeguarding the Future"	20-May-08
Convention on Biological Diversity (3)	International	Organization	Conference of Parties (COP) 9 Decision IX/15. Follow-up to the Millenium Ecosystem Assessment	19-30-May-2008
Circumpolar Biodiversity Monitoring Program (1)	Polar Regions	Organization	Circumpolar Biodiversity Monitoring Program - Framework Document	2004
Circumpolar Biodiversity Monitoring Program (2)	Polar Regions	Organization	CBMP Partnership Workshop Summary Report	6-7-March-08
DIVERSITAS (1) (Jackson, L. et al)	International	Organization	agroBIODIVERSITY: A New Science Agenda for Biodiversity in Support of Sustainable Agroecosystems	2005
DIVERSITAS (2) (Ash, N., et al)	International	Organization	bioDISCOVERY: Assessing, Monitoring and Predicting Biodiversity Change.	2009
European Biodiversity Observation Network	Europe	Organization	Integrating in situ with Earth Observation Data: Countryside Survey, UK	May-09
European Platform for Biodiversity Research Strategy (1)	Europe	Organization	Auditing the Ark - Science Based Monitoring for Biodiversity Research Strategy	Oct-02
European Platform for Biodiversity Research Strategy (2)	Europe	Organization	Sustainable use of Biodiversity meeting concerning European Biodiversity Research and the Global Perspective	May-07

European Platform for Biodiversity Research Strategy (3)	Europe	Organization	Action Plan for Biodiversity Research in Europe	Apr-05
EU-wide Monitoring Methods and Systems of Survellience for Species and Habitats of Community Interest	Europe	Organization	Manual "Best Practice for Monitoring Species and Habitats of Community Interest"	2008
Group on Earth Observations (GEO)	International	Organization	Report on the First GEO Forest Monitoring Symposium	Nov-08
Global Change and Mountain Regions. (GLOCHA-MORE) (Björnsen Gurung A, et al.)	International	Organization	Global Change and Mountain Regions: an Integrated Assessment of Causes and Consequences	2006
A Report of the Heinz Center's State of the Nation's Ecosystems Project (1)	North America	Organization	Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition	May-06
A Report of the Heinz Center's State of the Nation's Ecosystems Project (2)	North America	Organization	Candidate Indicators - Conditions of Plant and Animal Communities	May-06
Integrated Global Observation of Land	International	Organization	An Integrated Global Observing Strategy Partnership (IGOS-P) Theme	Sep-07
International Union for Conservation of Nature	International	Organization	The Status of the World's Land and Marine Mammals: Diversity, Threat and Knowledge	10-Oct-08
King Mahendra trust for Nature Conservation - Nepal and the UNEP-World Conservation Monitoring Centre	Asia/Middle East	Organization	Guidelines for Biodiversity Assessment and Monitoring for Protected Areas	2005
Millennium Ecosystems Assessment	North America	Organization	Ecosystems and Human Well-Being: Biodiversity Synthesis Report	2005

North Pacific Research Board	Polar Regions	Organization	Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research	Dec-08
National Research Council of the National Academies	International	Organization	Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond	2007
Ornithological Society of the Middle East, the Caucasus and Central Asia	Asia/Middle East	Organization	The First Arabian Ornithological and Conservation Conference	22-25-Oct-2000
South African National Biodiversity Advisory Group	Africa	Organization	A Research Strategy for the Grasslands Biome	Nov-08
UK Biodiversity Research Advisory Group (1)	Europe	Organization	Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions	10-Jan-05
UK Biodiversity Research Advisory Group (2)	Europe	Organization	Position Statement on Monitoring & Evaluation Research Priorities	13-Jan-05
United Nations Educational, Scientific and Cultural Organization World Heritage Centre	International	Organization	Proceedings of the World Heritage Marine Biodiversity Workshop	1-Mar-02
US Climate Change Science Program	North America	Organization	The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity	11-Sep-07
U.S. Dept. of Interior -North American Bird Conservation Initiative	North America	Organization	The State of the Birds, United States of America, 2009.	2009
Becker, B.L., Lusch, D.P., and Qi, J.	North America	Journal	Identifying Optimal Spectral Bands from In Situ Measurements of Great Lakes Coastal Wetlands Using Second-Derivative Analysis	2005
Bianchi, N.D. and Morri, C.	Europe	Journal	Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research	2000

Carlson, K.M., Asner, G.P., Hughes, R.F., Ostertag, R., Martin, R.E.	Oceania/ Australia	Journal	Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests	2007
Certain, G. and Bretagnolle, V.	International	Journal	Monitoring Seabirds Population in Marine Ecosystem: The Use of Strip-transect aerial surveys	2008
Collen, B., Ram, M., Zamin, T., and McRae, L.	International	Journal	The Tropical Biodiversity Data Gap: Addressing Disparity in Global Monitoring	2008
Duro, D.C., Coops, N.C., Wulder, M.A	North America	Journal	Development of a Large Area Biodiversity Monitoring System Driven by Remote Sensing.	2007
Feehan, J., Gillmore, D.A., Culleton N.	Europe	Journal	Effects of an Agri-environment Scheme on Farmland Biodiversity in Ireland	2005
Giller, P.S., Hillebrand, H., Beringer, U.G., Gessner, M.O., Hawkins, S., Inchausti, P., Inglis, C., Leslie, H., Malmqvist, B., Monaghan, M.T., Morin, P.J., and O'Millen, G.	International	Journal	Biodiversity Effects on Ecosystem functioning: Emerging issues and their experimental test in aquatic environments	2004
Goates, M.C., Hatch, K.A., and Eggett, D.L.	International	Journal	The Need to Ground Truth 30.5m Buffers: A Case Study of the Boreal toad (*Bufo boreas)*	2007
Graf, R.F., Mathys, L., and Bollmann, K.	Europe	Journal	Habitat Assessment for Forest Dwelling Species Using LiDAR remote sensing: Capercaillie in the Alps	2009
Haberl, H., Gaube, V., Diaz-Delgado, R., Krauze, K., Neuner, A., Peterseil, J., Plutzar, C., Singh, S.J., and Vadineanu, A.	Europe	Journal	Towards an Integrated Model of Socioeconomic Biodiversity Drivers, Pressures and Impacts: A Feasibility Study Based on Three European Long-term Socio-ecological Research Platforms	2009

Henry, P.Y., Lengyel, S., Nowicki, P., Julliard, R., Clobert, J., Celik, T., Gruber, B., Schmeller, D.S., Babij, V., Henli, K.	International	Journal	Integrating Ongoing Biodiversity Monitoring: Potential Benefits and Methods	2008
Kerr, J.T., and Ostrovsky, M.	International	Journal	From Space to Species: Ecological Applications for Remote Sensing	2003
Knudby, A., LeDrew, E., and Newman, C.	International	Journal	Progress in the Use of Remote Sensing for Coral Reef Biodiversity Studies	2007
Lamb, E.G., Bayne, E., Holloway, G., Schieck, J., Boutin, S., Herbers, J., Haughland, D.L.	International	Journal	Indices for Monitoring Biodiversity Change: Are Some More Effective Than Others?	2009
Lassau, S.A., and Hochuli, D.F.	International	Journal	Associations Between Wasp Communities and Forest Structure: Do Strong Local Patterns Hold Across Landscapes?	2007
Lengyel, S. Kobler, A., Kutnar, L., Framstad, E., Henry, P. Babij, V., Gruber, B., Schmeller, D., and Henle, K.	International	Journal	A Review and Framework for the Integration of Biodiversity Monitoring at the Habitat Level	2008
Leyequien, E., Verrlest, J., Slot, M., Schaepman-Strub, G., Heitkonig, I.M.A., Skidmore, A.	International	Journal	Applying Remote Sensing to Terrestrial Animal Distribution and Diversity	2007
Nair, A., Sathyendranath, S., Platt, T., Morales, J., Stuart, V., Forget, M.H., Devred, E. and Bouman, H.	International	Journal	Remote Sensing of Phytoplankton Functional Types	2008
Nagendra, H., and Rocchini, D.	International	Journal	High Resolution Satellite Imagery for Tropical Biodiversity Studies: The Devil in the Detail	2008

Palandro, D.A., Andrefouet, S., Hu, C., Hallock, P., Mueller-Karger, F.E., Dustan, P., Callahan, M.K., Kranenburg, C., Beaver, C.R.	North America	Journal	Quantification of Two Decades of Shallow-water coral reef habitat decline in the Florida Keys National Marine Sanctuary Using Landsat Data (1984-2002)	2008
Pereira, H.M., and Cooper, H.D.	International	Journal	Towards the Global Monitoring of Biodiversity Change	2006
Phinn, S., Roelfsema, C., Dekker, A., Brando, V., Anstee, J.	Oceania/ Australia	Journal	Mapping Seagrass Species, Cover and Biomass in Shallow Waters: An Assessment of Satellite Multi-spectral and Airborne Hyperspectral Imaging Systems in Moreton Bay (Australia)	2008
Puumalainen, J., Kennedy, P., and Folving, S.	Europe	Journal	Monitoring Forest Biodiversity: A European Perspective with Reference to Temperate and Boreal Forest Zone	2003
Rouget, M., Cowling, R.M., Vlock, J., Thompson, M., Balmford, A.	International	Journal	Getting the Biodiversity Intactness Index Right: the Importance of Habitat Degradation Data	2006
Spehn, Eva. (GEO Task US-09-01a Advisory Group Member)	International	Personal Commun-ication	Needs Regarding Mountain Biodiveristy Change	2009
Teder, T., Moora, M., Roosaluste, E., Zobel, K., Partel, M., Koljalg, U., and Zobel, M.	International	Journal	Monitoring of Biological Diversity: A Common-ground Approach	2007
Thenkabail, P.S., Eclona, E.A., Ashton, M.S., Van Der Meer, B.	International	Journal	Accuracy Assessments of Hyperspectral Waveband Performance for Vegetation Analysis Application	2004
Thompson, I.D.	International	Journal	Monitoring of Biodiversity Indicators in Boreal Forests: a Need for Improved Focus	2006
Trisurat, Y., Alkemade, R. and Arets, E.	East Asia	Journal	Projecting forest tree distributions and adaptation to climate change in northern Thailand	2009

Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., and Steininger, M.	International	Journal	Remote Sensing for Biodiversity and Conservation	Jun-03
Yoccoz, N.G., Nichols, J.D., and Boulinier, T.	International	Journal	Monitoring of Biological Diversity in Space and Time	Aug-01

Table 3 lists the documents by the Region to which they are applicable. The term international is used when the need is applicable to all Regions. Half of the documents are international in scope.

Table 3. Number of Documents per Region

Region	Number of Documents/Sources
International	32
Africa	2
Asia/Middle East	2
East Asia	1
Europe	12
North America	8
Oceania/Australia	2
Polar Region	4
South/Central America	1
	64

3.3 User Types

This section discusses the broad user types within this SBA. A list of users that could potentially use the biodiversity observation needs identified in this report was created. The following is this list of users presented by job titles:

Fish & Wildlife Biologists/Managers
Forest Managers
Protected Area Managers
Botanists
Taxonomists
Conservationists
Ecologists

Land Use Planners
Land Use Managers

Land Developers
Natural Resource Extraction (Loggers, Miners, Oilman)
Policy Makers (National, State, and Local Governments; NGOs)

Academicians
Researchers

Community Based Monitoring Groups	Concerned Citizens (e.g., bird watchers/groups) Private Land Owners

In many cases, the needs identified were applicable to many of these user types. Therefore, the use of user types in the analysis would not provide useful because of the high level of overlap. It was thought that there could be less overlap with a fewer number of user types that were characterized differently. Consequently, a simpler classification scheme with three types of user groups was developed for this analysis: Technical, Policy, and Management/Decision Maker.

4 Earth Observations for Biodiversity SBA

This section contains the results from the analysis of the documents.

4.1 Earth Observation Need Categories and Subcategories

As stated in Section 2.3.2 Analytic Methods, needs were characterized according to the following categorizes: Biodiversity Organization, Biome Type, Spatial Scale, Observation Type, User Type, and DPSIR Assessment Framework. Because of the length of this information, it is presented as a spreadsheet in Appendix C.

Characterizing needs using the DPSIR Assessment Framework was the most useful for analysis purposes because it not only allowed for aggregation of similar needs into the five DPSIR categories but also allowed for further aggregation into two levels of subcategories. Subcategories were not predetermined. They represent natural groupings of all 165 needs. Although some needs may have had components of multiple subcategories, it was only listed once according the dominant theme. Titles of the subcategories are descriptive but broad enough to represent all needs in the subcategory. This information is provided below as Table 4. An abbreviation of the need's source is provided in parenthesis at the end of the need, and can be used to obtain the full reference found in Appendix B. It should be noted that some of the needs listed below do not specifically use the word biodiversity. Nonetheless, they were taken from context directly discussing or related to biodiversity.

Table 4. Biodiversity Observation Needs by Categories and Subcategories
DRIVERS
Identifying Drivers
Identifying the environmental and socioeconomic drivers of change and the consequences for ecosystem functions and services. (DIVERSITASE $_2$)
PRESSURES
Climate Change
There is a need to couple high resolution climate scenarios with future land use scenarios since land use is a major threat to species abundance and biodiversity. For example, the explicit land change scenarios developed for Belize, southern Mexico, and most of Guatemala under the UNEP and USAID-supported ICRAN-MAR project of 2004-07, could be coupled with the climate change severity index (CCSI) and critical habitat assessment to enhance current impact assessments on biodiversity. (CATHALAC)
Need species-specific or ecosystem specific monitoring systems to include climate variability, and climate change (up until now this is generally not the case). (US CCP)
Need high resolution future climate data (~1 km) for local assessment, especially in heterogeneous landscape, in addition to validate the results with long-term ecological research sites. Further research is needed to use research outputs for effective in-situ conservation. (Trisurat, et al.)
Human & Biodiversity Relationships
Need for scientific marine and socio-economic surveys in many regions to properly analyze biodiversity. (UNESCO)
Regular monitoring of marine biodiversity corresponding to appropriate ecological temporal and spatial variables, as well as social influences is needed to improve management effectiveness and adaptability. (UNESCO)
Considerable investments in monitoring and model development are needed before mathematical (computer) models can be used to demonstrate the interrelation processes between society and ecosystems. These computer models are needed because of their use in anticipating possible future biodiversity change under different future socioeconomic scenarios. (Haberl, et al.)
Need more high resolution biodiversity mapping and monitoring in support of ecosystem service assessments in conservation, management, and policy. (Carlson, et al.)
STATE
Relationship Between Ecosystem/Habitats & Species & Physical/Chemical Parameters
Need to conduct formal surveys of representative habitats in major ecosystems of the world to provide plant relationships and basic information for selecting crop pollinators. (API)
Need to extrapolate results from small-scale experiments (conducted at fine spatial – patch or local level, and temporal scales) that examine biodiversity effects on ecosystem functioning, to large scales, or experiments must be directly conducted at the larger landscape level by explicitly incorporating both the grain (the individual sampling unit) and the extent (or overall

area) of the ecosystems. (Giller, et al.)
Need studies that combine the strength of each type of observation instrument to map multiple habitat variables in order to test the ability to predict local spatial distribution of biodiversity. (Knudby, et al.)
Assessing species richness through heterogeneity based on plant chemical constituents: Leyequien et al. stated that some authors recommend that future studies should focus on monitoring seasonal changes in foliar nutrient concentration as well as extending the method to predict other macro nutrients (P, K, Na, Ma, Ca) and secondary compounds in both grass and tree canopies. (Leyequien et al)
Need more systematic monitoring of populations and habitats that focus on spatial distribution of taxa and ecosystems. (Teder, et al.)
Need data on the distribution of specific ecosystem types within a target area (e.g., a country). With regard to broad-scale types, there would be an ecosystem (vegetation, habitat) map for the whole target territory. (Teder, et al.)
Need to go beyond community ecology studies to a detailed examination of habitats and demographics of individual species that are predicted to be negatively impacted by forest management practices. (Thompson)
Beside understanding the habitat structure patterns of organisms, there is a need for active remote sensing of the organisms themselves (which focuses on studying organisms) in order to link individuals, communities and populations with their habitat structure. (Turner, et al.)
Link patterns of primary production, large scale species richness and abundance, and detailed information about functional types of organisms in their habitats. (Turner, et al.)
It is preferred to measure biological diversity focused on system functioning including rate parameters that determine system dynamics, rather than solely on the state of the system. (Yoccoz, et al.)
Improved models for predicting species distributions on existing landscapes. (IGOL)
Studies are needed to investigate in greater detail the optimum spatial scale at which habitat variables should be mapped. (Knudby, et al.)
Need to identify biodiversity composition and dynamics of both species and habitats at large spatial and temporal scales. (Henry, et al.)
Need to integrate single trajectories into indicators of biodiversity components over large spatial and temporal scales. (Henry, et al.)
For mountain ecosystems, assess and understand environmental thresholds that determine biodiversity (by collecting presence and abundance data on species along with abiotic environmental data). (GLOCHAMORE)
Method Development
Develop methods for more effective, efficient, rapid and comprehensive measurement of global biodiversity status and trends. ($EPBRS_2$)
Species and community responses to drivers and pressures: development of methods for monitoring including methods to link satellite derived parameters to on-the ground vegetation assemblages. (SANBI)
Rapid assessment methods using remote sensing techniques can be used at the ecosystem/wetland habitat level, particularly for rapid inventory assessments. There is a need for further guidance on ecosystem-level rapid assessment methods for inland, coastal, and marine waters. (CBD_2)
Develop monitoring techniques that can be adapted to work in a dynamic environment taking into account a diverse range of pressures such as climate change. Monitoring schemes need to be flexible enough to respond to changing needs. (UK $BRAG_1$)
Review the potential of all types of remote sensing (e.g., acoustic sensing of the seafloor), as well as other techniques for establishing inventories and monitoring biodiversity. (UK $BRAG_1$)
Creation of harmonized monitoring standards and protocols. ($CBMP_2$)

Need remote sensing methods to map and monitor aspects of biodiversity. Remote sensing approaches used to date usually focus on basic delineation of land-cover types without directly resolving the biochemical or structural properties of the vegetation most closely linked to taxonomic diversity. (Carlson, et al.)
Need more operational methods for quantifying biodiversity at high spatial resolution at regional scales. (Carlson, et al.)
Effort needed to address tropical biodiversity data gap: develop methods that use representative samples and/or weighting approaches to make most use of current data. (Collen, et al.)
Need to develop new methods of detecting stream and seep habitats. Remote sensing technologies have potential to increase accuracy of delineating and mapping riparian and wetland habitats. Modeling flow paths using a 10 m DEM (digital elevation model) may accurately predict stream and seep locations thereby eliminating the need to survey large areas. These locations could then be ground truthed. Locating these habitats will increase accuracy and efficiency of resource management and conservation. (Goates, et. al.)
Remote sensing is the only way to collect concurrent global distributions of phytoplankton functional types, therefore, need improved understanding of the errors associated with the satellite-derived fields (need confidence limits on the data). Need a combination of in situ and remote-sensing techniques to determine distribution of phytoplankton functional types at the global scale. (Nair, et al)
Need improvements in separating and linking appropriate aspects of continuous processes to forest biodiversity monitoring to determine proper monitoring scope. (Puumalainen, et al)
Species and Ecosystem Specific Needs
Priority Areas
Need in-depth field mapping of priority habitats (e.g., priority habitats of the Habitat Directive or habitats of high national importance). (Lengyel, et al.)
Detailed mapping is resource consuming; therefore priority should be given to the mapping of ecosystems of special interest (e.g., ecosystems unique or valuable from the point of view of nature conservation). (Teder, et al.)
Pinpointing areas where the constellations of drivers, pressures, vulnerability, resilience, create a high risk for biodiversity loss. (DIVERSITAS$_2$)
Forest
Tropical Forests: Most data-deficient species on land are in tropical forests which reflect species richness patterns. Data deficient species in tropical forests, which are declining rapidly (e.g., West Africa, Borneo, Atlantic Forest) may be close to extinction. (IUCN)
Efforts needed to address tropical biodiversity data gap: focus research and monitoring on key regions, habitats, and taxa). (Collen, et al.)
Grassland
Need to develop global remote-sensing data sets for dryland degradation. (Pereira & Cooper)
Tundra
Development of overarching conceptual frameworks that identify what is to be monitored. (CBMP$_2$)
Much research is still needed on many poorly understood boreal forest species in order to select indicators from the full range of functional groups. (Thompson)
Need to monitor local populations in boreal forests, not just species at the regional scale. (Thompson)

There are deficiencies and gaps in Arctic biodiversity monitoring. Need more comprehensive monitoring of taxonomic, geographical and temporal coverage of species: classification of some species regarding internal genetic and taxonomic diversity. ($CBMP_1$)
Need overall understanding of interactions of species, their habitats and ecosystems in a circumpolar context (e.g., biometric measurements, reproductive success, abundance and distribution, harvesting data, species' spatial, geographical and temporal coverage, analyzed together with various physical and chemical parameters). ($CBMP_1$)
Mountain
Regular inventory (monitoring) of key taxa (plants, insects, birds) in different mountain life zones (GLOCHAMORE)
Marine
Marine Mammals: 38% of marine mammals are data deficient; Species that breed in water are less understood; Marine data-deficient species are concentrated along the Antarctic Convergence (19 beaked whales species are data deficient. (IUCN)
Monitoring Recommendation: develop transboundry monitoring of the status of marine mammals and turtles in the Middle East. (OSME)
Address monitoring gap for coastal marine systems. (UK $BRAG_1$)
Need reliable long-term monitoring data for many poorly monitored bird groups and their habitats, most notably arctic-nesting shorebirds, colonial seabirds, and oceanic species. (US DOI)
Need additional research similar to that presented in this study (historical Landsat images were geographically, atmospherically, radiometerically, and bathymetrically corrected to measure habitat changes for coral reef sites) should be conducted worldwide, with the use of new high resolution sensors. (Palandro)
Usefulness of remote sensing technology for use in conservation of coral reef biodiversity depends on the ability to map relevant environmental variables and provide a scientific basis for decision making. (Knudby, et al.)
Need accurate mapping of seagrass cover, species composition and biomass, using high-spatial resolution (<5 m) and/or hyper-spectral image data. (Phinn, et, al)
Need additional research to determine if and how sea grass maps produced in this study are suitable for measuring attributes of seagrass biodiversity, and using these data for modeling floral and fauna biodiversity properties of seagrass environments, and for scaling-up seagrass ecosystem models. (Phinn, et. al)
Need to address geographic and taxonomic gaps in the north Pacific: Sampling in the region has rarely been systematic and notable geographic gaps need to be filled. (NPRB)
Need additional knowledge about marine mammal population size and major aspects of their population dynamics. (AOOS)
Strip-transect aerial surveys can be used for sampling sea bird populations at sea. To focus future work need to address: the effect of bird movement, the effect of sea state, and the direct estimate of the detection probability in the case of diving birds. (Certain, et al)
Existing programs monitoring freshwater and marine taxa need to be enhanced. (Pereira & Cooper)
Need to determine natural variability of marine ecosystems and understand the effects of change on their biodiversity at the scale of the entire Mediterranean. (Bianchi and Morri)
Species/Taxonomic Specific
The ability of remote sensing data to contribute to the mapping and prediction of occurrence of invertebrate diversity is poorly understood compared to other taxonomic groups. Invertebrates are primarily studied in the context of insect concentrations as pest and disease vectors. Very few studies are related to conservation efforts and studies are limited to local diversity within-

community component not total regional diversity. (Leyequien et al)
Need surveys at multiple scales to identify landscape units from insect perspectives to assist in examining the variation of assemblages at landscape scales. (Lassau & Hochuli)
Need to conduct formal surveys of representative habitats in major ecosystems of world to provide details on pollinator species spacial and temporal abundance. (API)
There is a need to develop model sets that can be used for ecosystem management, such as for the interaction between large carnivores, ungulates and vegetation. (Yoccoz, et al.)
Need to conduct formal surveys of representative habitats in major ecosystems of world to provide regional patterns of pollinator abundance and diversity. (API)
Improve understanding of the population structure of commercial fish species using genetic and traditional approaches, to optimize stock management. ($EPBRS_3$)
Technical Needs: Remote Sensing
Requirements for EO data to be used within EBONE will become apparent as WP5 progresses. Goal of EBONE is the development of a cost effective system for biodiversity data collection up to at least a pan-European scale. To achieve these objectives a priority for WP5 will be to develop techniques that are optimized for EO data that are widely available and not prohibitively expensive such as optical data at pixel resolutions of approximately 20m and greater. (EBONE)
Need GEO-referenced time-series of satellite imagery within all PAs, together with simple tools to detect and measure change. (GEO)
Forest Biodiversity - Requirement status and trends of habitat within protected areas: Primary Data: GEO-referenced time series in all PAs, classified imagery and simple tools to measure change EO data: Landsat, or similar and radar data for areas with high cloud cover frequency where current EO data are not available Ancillary data: PA extent, validation and calibration datasets Source: Landsat, or similar and radar data for areas with high cloud cover frequency Spatial scale: 50m or finer Temporal scale: 1970s – continuously ongoing Timeliness: annual update (and near daily for early warning system, e.g. fire detection) Gaps: information for cloud forests Descriptions: global protected areas, 106,000 sites, ca. 18,000,000 km2 (GEO)
Maintain continuity of long-term seasonal record of land-cover change and fragmentation at 30m resolution. A key attribute or derived characteristic of such a land-cover product would be the derivation of disturbance patterns and frequencies. (IGOL)
Develop a long-term record of critical land-use characteristics, at a spatial scale that is commensurate with the land-cover change product, but that includes additional information on the human use of land resources such as crop type at sufficient spatial resolution to identify small land-holders (ca. 0.5 ha). (IGOL)
Enhance availability of 30m global topography, which play a critically important role in both corrections of imagery data in habitat delineation, and as model input data. (IGOL)
An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity. (NRC/NAS)

To specifically address biodiversity, need the following satellite mission: "Mission to observe distribution and changes in ecosystem function. An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity. " (NRC/NAS)
Remote sensing of coastal wetlands requires the use of high spatial resolution imagery (i.e., pixels 1-2 m2) because coastal wetlands are often spatially complex and heterogeneous. A reduction in the number of bands without a significant information loss allows utilization of small pixels without loosing ability to differentiate botanical communities. The identification of a small number of wetland-relevant bands could reduce the cost of image acquisition, potentially increasing end-users. (Becker, et al.)
Need to establish the biophysical basis for connecting spectral variation from remote sensing to field-measured plant species diversity. (Carlson, et al.)
Need to explicitly connect chemical and physical properties of the organisms being studied with remote sensing data. This will require appropriate RS data, such as from high performance hyperspectral sensors, collected at spatial resolutions needed to meet land management and conservation goals. (Carlson, et al.)
Need LiDAR data with country-wide coverage. This will enable conservation managers to assess habitat suitability for forest dwelling species at the scale of entire populations. LiDar offers great potential for effective habitat monitoring and management of endangered species and biodiversity maintenance. (Graf et al)
Due to the lack of hyperspectral and hyperspatial imagery (archival and currently ongoing) in the tropics, there is a need to generate and make easily available hyperspectral and hyperspatial (pixel size of > 5m) satellite data of tropical biodiversity to address the urgent need to identify locations of tropical biodiversity hotspots, map the distribution of biodiversity across different habitats and landscapes, and monitor rates of change over time. (Nagendra & Rocchini)
Hyperspectral data is complex and a large amount of data can be collected in a short period of time. Need additional knowledge of: optimal narrowbands. (Thenkabail et al)
Need potential improvements of hyperspectral data accuracies over broadband sensors while considering cost. (Thenkabail et al)
Need assessment of optimal hyperspectral sensor configuration for a broad range of vegetation types in the spectral range of 0.4 - 2.5 um (studies currently done in a narrower portion of the spectrum (0.4 - 1.05 um). (Thenkabail et al)
It is important to determine the optimal short wave infrared radiometer (SWIR) bands. SWIR spectral bands are important in vegetation studies; however, broadbands are typically used. Need to use and understand the strengths of specific narrowbands. (Thenkabail et al)
IMPACTS
Effects of Change on Biodiversity
Climate Change
Impacts of climate change on aquatic and marine biodiversity can not be investigated because most of the climate change modeling requisite inputs do not exist for aquatic and marine biodiversity. Need downscaled data, i.e., georeferenced data on species distributions, marine pH, marine salinity (multi-depth), marine temperature (multi-depth). (CATHALAC)
Potential impacts from the climate change variables of temperature and precipitation on have been mapped for terrestrial biodiversity in Central America, Mexico, and the Dominican Republic. Additional maps/predictions are needed for other environmental variables (i.e., soil moisture (multi-depth), moisture content, surface temperature, sea level pressure, wind direction and velocity). (CATHALAC)

For Mountain biodiversity need: Detect and understand the shifts in species abundance and distribution driven by climate change (GLOCHAMORE)
Human Induced Change
There is a need to understand how much plant and animal communities have been altered by human activity relative to pre-settlement times. (Heinz$_2$)
There is a need to be able to distinguish natural areas from human altered areas, and to be able to classify those areas into three categories (undisturbed, disturbed and less disturbed). (Heinz$_2$)
Landscape Degradation
Need to develop cost-effective ground-truthing methods for quantifying the extent of land degradation in order to provide reliable estimates of biodiversity loss in southern Africa and elsewhere. (Rouget, et al.)
Need more detailed monitoring at landscape and stand level to detect change, especially changes in structural aspects of biodiversity dangers and habitat destruction. The value of the framework for landscape and stand level monitoring and applications needs additional testing. (Puumalainen, et al)
Recommend that it be made obligatory for EU member states to devote a fixed portion of the agri-environment budget to monitoring and evaluation. Detailed management discussion and advice regarding measurable, targeted objectives for farmland flora and fauna diversity is needed. (Feehan, et al.)
Biodiversity Change - General
Biodiversity change: Need sufficient integration at different scales. (Pereira & Cooper)
Biodiversity change: Need directly comparable sets of global land-cover data. (Pereira & Cooper)
Biodiversity change: Need taxonomic coverage of global plant species distribution. (Pereira & Cooper)
Biodiversity change: Need complete taxonomic and spatial coverage. (Pereira & Cooper)
High research priority should be to predict the consequences of ecosystem function change, both natural and anthropogenic, on regional and global distributions and abundances of species. The full range of RS techniques (identifying land covers, measuring biophysical properties of ecosystems, detecting environmental change) will need to be integrated with existing and new ecological data. (Kerr & Ostrovsky).
Need to expand temporal and spatial coverage of monitoring activities in order to measure changes in biodiversity across large scales. Need to enhance the spatial aspect of monitoring. Recommend developing field mapping and recording methods for uniform use over Europe, such as the BioHab methodology. (Lengyel, et al.)
Future monitoring designs should incorporate both spatial sampling and detectability (used to estimate abundance at each sample plot) to obtain unbiased estimates of the relevant state variables thus allowing for better understanding of the spatial component of change in biological diversity and the underlying causes. (Yoccoz, et al.)
Need to address taxonomic training and expertise: investment in taxonomic training is essential to detecting long-term change in species distributions in the north Pacific. (NPRB)
Measuring change of biodiversity at various scales and levels (genes, taxa, functional groups and communities, as well as structures and functions of ecosystems). (DIVERSITAS$_2$)
Analyzing the complex biotic mechanisms governing the dynamics, direction and intensity of change of biodiversity. (DIVERSITAS$_2$)

RESPONSES
Organizational Infrastructure
Organizational Structure
National biodiversity monitoring system for Canada driven by remote sensing at ecosystem level for purpose of providing an early warning system, indicating where areas of potential biodiversity change be occurring. Key indicators: productivity, disturbance, topography, and land cover. (Duro, et. al.)
Key factor of successful responses to biodiversity loss: Establish implementing and monitoring agencies. The establishment of subsidiary bodies with authority and resources to undertake specific activities to enhance the implementation of the agreements is vital to ensure continuity, preparation, and follow-up to complex issues. (MA)
Need institutions (federal, state, NGOs) to be stable in order to create, manage, and maintain in situ and remotely sensed long time-series observations. (US CCP)
Funding Policy
Improved funding policy is needed to support this ecosystem monitoring program. ($Heinz_1$)
Integration
Develop a core program of biodiversity monitoring across Europe in cooperation with relevant EU and national institutions and IWG-Bio-MIN. This includes developing and applying methods to integrate already existing national and regional monitoring schemes into a European monitoring programme, with specific reference to biodiversity relevant environmental legislation. ($EPBRS_1$)
Process or institution is needed to make strategic decisions across many monitoring programs. ($Heinz_1$)
Establish a programme for mapping of seafloor habitats to follow-on from the European MESH project. (UK $BRAG_1$)
Prioritization/Priority Areas
There is a need for a mechanism/way to determine the most appropriate and highest priority investments in monitoring and reporting capacity. ($Heinz_1$)
Biodiversity recommendation: Initiate the GEO Protected Areas Assessment and Monitoring program. (GEO)
Biodiversity recommendation: Initiate a Data Outreach Program for Forests. (GEO)
Need an internationally coordinated network of marine protected areas across the Mediterranean. (Bianchi and Morri)
Biodiversity change. Need Global Species Monitoring: a global sampling programme targeted to carefully selected indicator taxa. Vascular plants and birds are recommended. (Pereira & Cooper)
Need interdisciplinary research framework to monitor biodiversity, to understand ecosystem services provided by biodiversity, and to guide decision making and policies regarding biodiversity in agricultural landscapes. ($DIVERSITAS_1$)
Long Term Monitoring
Need to conduct formal surveys of representative habitats in major ecosystems of world to provide a baseline for long-term pollinator monitoring. (API)
Develop and evaluate long-term biodiversity monitoring programmes and indicators that contribute to the assessment of the global 2010 target in developing countries. ($EPBRS_3$)
Species and community responses to drivers and pressures: need long-term monitoring programs. (SANBI)

Need long-term Mediterranean marine studies (expected life-time of dominant species). (Bianchi and Morri)
Invest in local institutions that can develop the infrastructure and expertise for long-term tropical biodiversity monitoring. (Collen, et al.)
Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity gives its highest level of priority to maintaining and improving the long-term records of the productivity of terrestrial and marine ecosystems and to measure land-cover change at high spatial resolution. (NRC/NAS)
System Infrastructure
Database Interoperability
Support the implementation of the CBD by developing taxonomy, identification, inventories and monitoring of biodiversity and of globally accessible and interoperable databases. ($EPBRS_2$).
Interoperability between biogeographical, remote sensing, ecosystem process and population dynamics data is enhanced. (Spehn)
Integrated System/Network
Establish an integrated global biodiversity observation network by complementing, expanding, and linking national and regional monitoring systems to provide effective information on ecosystems, species, and genes, and the services they collectively provide. (CBD_1)
Promote as part of best practice co-operation between national and regional monitoring programmes information networks. ($EPBRS_1$)
The overall system/mechanism providing the nation's environmental monitoring information merits attention, because it has a fragmented infrastructure. Integration and coordination among local, national and other organizations involved in the monitoring process is needed. ($Heinz_1$)
Need for blending biodiversity assessment and monitoring system within a protected area management system to achieve sound and effective management of protected areas. (KMTNC & UNEP-WCMC)
Establish an online catalogue of biodiversity monitoring schemes, with links to action plans. (UK $BRAG_2$)
Address issues of proprietary data and existing data portals (i.e., avoid redundancy and capture connectivity of systems in Web portal). ($CBMP_2$)
Bring to bear knowledge derived from ENBI, GBIF and national nodes to help to monitor biodiversity, help populate relevant databases and use these systems to disseminate knowledge. ($EPBRS_1$)
Biodiversity recommendation: Initiate a Global Phenology Network. (GEO)
Establish a global biodiversity observation system which needs to be systematically designed across regions and taxa. (Collen, et al.)
Need highly standardized international monitoring networks that combine/integrate available information from ongoing monitoring efforts. (Henry, et al.)
Need to integrate monitoring efforts in order to quantify pan-European trends in habitat-level biodiversity. (Lengyel, et al.)
Given the recent arrival and their limited geographic spread of hyperspectral and hyperspatial sensors (airborne & satellite), their utility will be maximized when they are coupled with existing large scale monitoring systems that currently utilize moderate resolution mulispectral data like SPOT, ASTER, and Landsat TM/ETM+. (Nagendra & Rocchini)
Biodiversity change: Need to integrate current monitoring initiatives. (Pereira & Cooper)
Biodiversity change: Need global biomonitoring network to gather new data on abundance and distribution of population and habitat extent. (Pereira & Cooper)
Biodiversity change: Global network is needed that integrates existing and new national, regional or global sampling programmes. Network would sample taxa most relevant nationally or regionally as indicators of biodiversity change. (Pereira & Cooper)

Remote sensing data needs synthesis and distribution systems, because there is information availability problem. (Turner, et al.)
Information Management
Data Availability
Need for further improvement of the availability and interoperability of biodiversity data and information. (CBD_3)
Need to support, contribute to and promote synergy among the ongoing efforts to digitize data in a standardized format, make data and analytical tools widely available, and further develop analytical tools to use these data for policy and management purposes. (CBD_3)
Ensure availability and comparability of existing data collections. (IGOL)
Data Recommendation: develop national and regional biodiversity databases for the Middle East, the Caucasus and Central Asia. (OSME)
Data Integration
Need to integrate information from single monitoring schemes into indicators that can provide information on broader patterns of biodiversity change. (EuMon)
Need to establish links between scientific monitoring results and human systems to better inform adaptation and mitigation strategies. ($CBMP_2$)
Biodiversity change: Need Regional assessments that combine satellite remote sensing with on-the-ground monitoring and aerial photographs. (Pereira & Cooper)
Biodiversity change: Need compatibility between data sets. (Pereira & Cooper)
There is a need to acquire and synthesize scientific research data obtained thus far from biological and conservation scientists on species distribution, levels of species richness, areas of global endemism, etc., and combine it with obtained remote sensing data on global, regional and local climate, habitat structure, primary productivity….to determine species richness and distribution patterns. (Turner, et al.)
Develop and assess appropriate scientifically sound and rigorous monitoring methodologies of biodiversity based on standardized protocols and sampling strategies to maximize synergy, integration and interoperability. ($EPBRS_1$)
Experimental modeling and observation data are integrated to improve understanding of the mechanisms of mountain biodiversity change. (Spehn)
Quantitative projections of mountain related biodiversity change should include multiples sources of uncertainty (Spehn)
Analytical Tools
Biodiversity Recommendation: Support IUCN Global Species Assessments by providing baseline geospatial thematic data and web-based analytical tools. (GEO)
Develop better guidelines for using models that predict species distributions on existing landscapes, to be used by the scientific community and conservation organizations. (IGOL)
Need additional research to investigate the improvement in statistical power that occurs in biodiversity trends by incorporating equations that detect for correction error. (Lamb, et al.)
Gap Analysis
Gap analyses are necessary to determine deficiencies and information needs, and to propose means to address these deficiencies and information needs. Need compilation of existing arctic monitoring programs: type of monitoring being done, scale (e.g. regional, national, multi-national), and what types of data are available as a product of these monitoring programs. ($CBMP_1$)

Gap analyses: to determine groups of biodiversity that need additional monitoring. ($CBMP_1$)
Gap analyses on currently existing monitor linkages, especially regional and international. (CBMP)
Meta-data
Need meta-database on existing national and cross-national biodiversity monitoring programs. This already exists for some taxa, habitats and regions (e.g., Ramsar STRP, and various CBD papers), but needs to be strengthened and focused for the Arctic region. Such an overview is needed for better evaluation of needs and priorities, and choosing the best indicators of environmental changes. ($CBMP_1$)
Adopt a consensus ecosystem classification hierarchy and map product that describes how systems are mapped, how to add detail, and how to extend the classification scheme to all ecosystems (including human dominated systems). (IGOL)
Evaluation
Evaluate Effectiveness of Efforts
For given locations or ecosystems, need improved understanding of what biodiversity is there, its status, function, and whether conservation/management efforts are helping. (CBD_2)
Encourage as part of best practice the science based monitoring of effects of policies and actions on biodiversity. ($EPBRS_1$)
Assess performance of the reformed CAP in achieving the target of halting biodiversity loss by developing a harmonized framework for evaluation to support development of monitoring systems using agreed indicators. ($EPBRS_3$)
Improve design, implementation, monitoring, and evaluation of agri-environmental instruments at the scales at which they most effectively deliver on the 2010 biodiversity targets. ($EPBRS_3$)
Need biodiversity monitoring to verify the state and trends of biodiversity and the effects of policies to maintain or improve the state of biodiversity. (EuMon)
Organize observational data from in situ research sites in order to develop a validation database for existing products of relevance to biodiversity issues. (IGOL)
Need stronger monitoring and evaluation in protected areas for biodiversity conservation (i.e., comprehensive monitoring that provides information on management success or failure). (MA)

5 Priority Earth Observations for Biodiversity SBA

This section contains the results from the prioritization method(s) applied to the observations identified in section 4.

5.1 General Description

The section describes specific information about the prioritization of the Earth observations from section 4. The number of observation needs identified per category and subcategory (bulleted items) are presented below in Table 5.

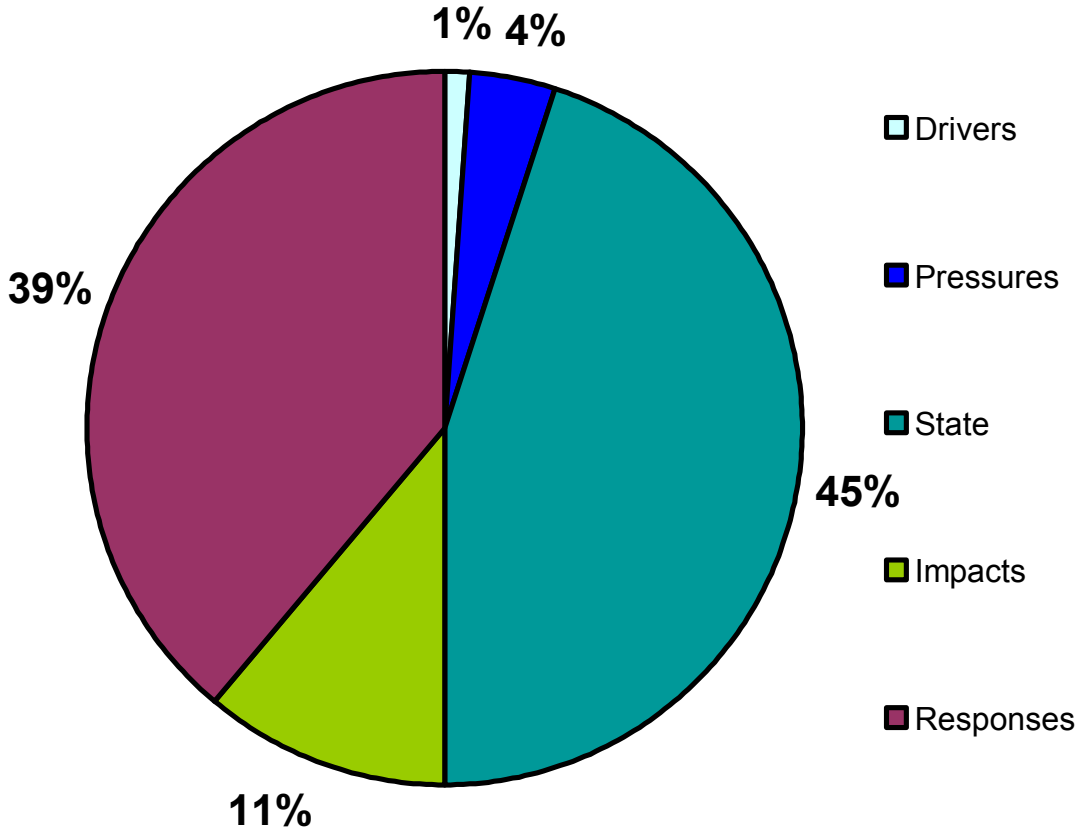
Table 5. Number of Needs per Category and Subcategory	
Categories and Subcategories	**Number of Needs**
DRIVERS	**(1)**
PRESSURES	**(7)**
• Climate Change	(3)
• Human & Biodiversity Relationships	(4)
STATE	**(75)**
• Relationship Between Ecosystem/Habitats & Species & Physical/Chemical Parameters	(15)
• Method Development	(12)
• Species and Ecosystem Specific Needs	(31)
- Priority Areas	(3)
- Forest	(2)
- Grassland	(1)
- Tundra	(5)
- Mountain	(1)
- Marine	(13)
- Species/Taxonomic Specific	(6)
• Technical Needs: Remote Sensing	(17)
IMPACTS	**(18)**
• Effects of Change on Biodiversity	(18)
- Climate Change	(3)
- Human Induced Change	(2)
- Landscape Degradation	(3)
- Biodiversity Change – General	(10)
RESPONSES	**(64)**
• Organizational Infrastructure	(19)
- Organizational Structure	(3)
- Funding Policy	(1)
- Integration	(3)
- Prioritization/Priority Areas	(6)
- Long Term Monitoring	(6)
• System Infrastructure	(18)
- Database Interoperability	(2)
- Integrated System/Network	(16)
• Information Management	(20)
- Data Availability	(4)
- Data Integration	(8)
- Analytical Tools	(3)
- Gap Analysis	(3)
- Meta-data	(2)
• Evaluation: Evaluate Effectiveness of Efforts	(7)
	165 Total Needs

5.2 Priority Observations

This section contains priority Earth observations for the Biodiversity SBA. Priority was determined by the largest number or percentage of needs identified.

Priority Category
Figure 1 below illustrates the percentage of the needs per DPSIR Framework Category. The category with the largest number of observations addresses the state of biodiversity.

Figure 1. Percentage of Needs per Category



Within these categories there are 11 first level subcategories and 22 second level subcategories (see Table 5). The first level subcategories can be divided into three priority level groupings based on the number of needs identified. They are presented below in order of decreasing quantity with a general description and the number of needs identified in parenthesis. For specific needs see Table 4.

Highest Priority Needs (31)
Species and Ecosystem Specific Needs (31) – refers to the needs that were identified for ecosystems and species.

Earth observation needs addressing the current state of species and ecosystem biodiversity was the most cited need, with 19% of the total needs identified. It can be noted that journals/periodicals and organizations identified this need relatively equally (16 and 15, respectively). Although this subcategory was divided further into biome types (forest, grassland, tundra, mountain, and marine) and species based on the needs identified, it is expected that additional searching of the literature would reveal Earth observation needs for any species or biome. Therefore, the highest priority need of addressing the current state of species and ecosystems refers to not only the species and ecosystem types listed in this analysis but all others as well.

Medium Level Priority Needs (119)
The subcategories listed here are tightly grouped with only eight needs separating them. Collectively they represent 72% of the total needs identified.

Information Management (20) – refers to models/methodologies to collect and use the Earth observation information.

Organizational Infrastructure (19) – refers to the process or institution needed to conduct the Earth observations.

System Infrastructure (18) – refers to the system/mechanism/network needed to utilize the Earth observation information.

The needs identified in the Information Management, Organizational Infrastructure, and System Infrastructure are in the Response category. They demonstrate that a higher level of commitment, organization, coordination, communication, management, data collection and analysis, and information management, integration and dissemination of Earth observations are needed at all levels within the larger biodiversity community from funding organizations to individual researchers. Collectively these three subcategories represent 34% of the total needs identified.

Effects of Change on Biodiversity (18) – refers to the needs identified to address the impacts on biodiversity caused by various pressures (i.e., climate change, human induced change, and landscape degradation).

Technical Needs: Remote Sensing (17) – refers to specific examples of remote sensing needs (i.e., spatial and temporal scale, optical sensor discrimination, and hyperspectral and hyperspatial imagery) for specific applications.

Relationship Between Ecosystem/Habitats & Species & Physical/Chemical Parameters (15) – refers to needs that focus on the inter relationships and linkages between species and their environment and the variable that affect biodiversity.

Method Development (12) – refers to needs for the development of monitoring techniques, standards and protocols, and assessment methods for remotely sensed and in situ data for specific applications.

Lower Level Needs (15)
Evaluation: Evaluate Effectiveness of Efforts (7) – refers to needs identified to assess effectiveness of action taken.

Human & Biodiversity Relationships (4) – refers to the needs that examine the pressures that humans place on biodiversity.

Climate Change (3) – refers to the needs that examine the pressures that climate change places on biodiversity.

Identifying Drivers (1) – refers to the needs to identify environmental and socioeconomic drivers of biodiversity change.

6 Additional Findings

This section describes additional findings and results of the analysis. Additional information to support the findings in this section can be found in Appendix C.

6.1 Types of Documents

As previously stated, half of the documents used for this analysis originated from biodiversity related organizations (62) and the other half came from biodiversity related journal articles (62) with specific authors. Of the 165 needs identified, approximately 54% came from organizations and 46% came from journals/periodicals. Table 5 below illustrates how the documents were distributed among the categories.

Table 6. Comparison of Recommendations by Document Source Type

Category	Number of Total Documents/Sources	Organizations	Journals
Drivers	1	1	
Pressures	7	4	3
State	75	32	43
Impacts	18	8	10
Responses	64	44	20
Total	165	89	76

- Journals indicated that addressing the state of biodiversity was their highest priority (57% of their identified needs). This finding may be because journals generally contained more research focused actions to address the state of biodiversity versus those characterized as Responses (infrastructure and management).
- Organizations indicated that responses or actions by the biodiversity community to address issues at the organization (data collection), system (data sharing), data management, and program evaluation levels were the highest biodiversity need priorities (49% of their identified needs). Addressing the state of biodiversity was the second highest priority (36% of their identified needs).

6.2 Findings Per Biodiversity Organizational Level

As previously stated, the literature search focused on the ecosystem and species levels. Biodiversity observation needs relevant to both ecosystems and species are the most prevalent, with 40% of the total needs identified. This was true for the needs identified by both organizations and journals. Sixteen percent of the needs identified are relevant to all biodiversity organizational levels (ecosystem, species, genetic).

Table 7. Number of Needs by Biodiversity Organizational Level

Organizational Level	Organizations	Journals	Total Needs (percent of total)
Ecosystem	22	23	45 (27%)
Ecosystem & Species	33	33	66 (40%)
Species	10	15	25 (15%)
Species & Genetic	1	1	2 (1%)
Genetic		1	1 (>1%)
All Levels	23	3	26 (16%)

6.3 Findings Per Biome Type

The largest percentage of biodiversity observation needs identified, 39%, are relevant to all biome types and 18% are relevant to all terrestrial biomes. These categories have the highest number of needs identified by both organizations and journals. The majority of needs identified are general enough that if they were addressed the results could have broad utilization across most biome types. However, as indicated by the table below, approximately 32% of needs are biome specific.

Table 8. Number of Needs by Biome Type			
Biome Type	**Organizations**	**Journals**	**Total Needs**
Terrestrial - all	15	14	29
Forest - all	6	2	8
Forest – temperate & tiaga		2	2
Forest - tiaga		3	3
Forest - tropical		10	10
Grassland	2	1	3
Mountain	3	3	6
Aquatic - all	4	3	7
Freshwater - wetlands		1	1
Freshwater - streams		1	1
Marine - all	11	4	15
Marine - shoreline		2	2
Marine - tropical		4	4
Aquatic & Terrestrial – tundra (Polar)	10		10
All Biomes	38	26	64

6.4 Findings Per Spatial Scale

The largest percentage of biodiversity observation needs identified, 45%, are relevant at all spatial scales. This is also true for both document sources, organizations and journals. Needs at the regional scale are the second most numerous cited at 24%.

Table 9. Number of Needs by Spatial Scale			
Spatial Scale	**Organizations**	**Journals**	**Total Needs**
Global	13	15	28
Global & Regional	2	6	8
Regional	27	13	40
Regional & Local	1	1	2
Local	3	10	13
All Spatial Scales	43	31	74

6.5 Findings Per Observation Type

The largest percentage of biodiversity observation needs identified, 73%, are relevant to both observation types, remote and *in-situ*. This is true for both document sources, organizations and journals. Twenty-four percent of the needs are specific to remotely sensed observations.

Table 10. Number of Needs by Observation Type			
Observation Type	**Organizations**	**Journals**	**Total Needs**
Remote	13	26	39
In-Situ	1	4	5
All Observation Types	75	46	121

6.6 Findings Per User Type

The largest percentage of biodiversity observation needs identified, 33%, are relevant to technical users, and 78% of these technical needs were identified by journals. Organizations listed needs applicable to all user types as 23% of the total needs, and had a higher level of distribution of needs across user types. Over half (55%) of the needs are general enough that they are applicable to more than one user type.

Table 11. Number of Needs by User Type			
User Types	**Organizations**	**Journals**	**Total Needs**
Technical	12	43	55
Policy	9	4	13
Policy & Management	19	4	23
Management	3	3	6
Management & Technical	8	13	21
All User Types	38	9	47

7 Analysts Comments and Recommendations

This section provides the Analyst's perspectives on the SBA, documents, set of observation priorities, etc.

7.1 Process and Methodology

The task process was well laid out. The nine steps were helpful in organizing the task. The analytic method and priority setting criteria used are appropriate for the broad spectrum of observation needs identified.

Assigning the identified needs to the various categories was subjective. Although the Analyst tried to be consistent in how the observations where characterized and categorized it was difficult because of the large number of observations collected and the duration of time over which this task was conducted. In addition, many needs could have been placed into multiple categories/subcategories.

7.2 Challenges

This effort may have benefited from a larger advisory group. Assistance to the analyst in identifying additional advisory group members would have been helpful. This may have resulted in additional feedback at each step of this task.

The amount of effort to complete this task was much greater than originally anticipated. It would have been helpful to have had assistance for the analyst in completing this task. The analyst changed occupational positions during this task thereby greatly reducing the amount of time directed toward completing this task, resulting in the slowing down of the task schedule.

7.3 Recommendations

The broad approach of this report resulted in useful biodiversity observation needs that are both specific and general. Since biodiversity is such a complex and diverse topic, this process could be repeated again for specific areas in order to give a more in-depth analysis to areas needing special consideration.

Appendix A: Acronyms

BioHab	A framework for the coordination of Biodiversity and Habitats
CBD	Convention on Biological Diversity
DPSIR	Drivers – Pressures – State – Impacts – Responses Assessment Framework
EEA	European Environment Agency
EPA	Environmental Protection Agency
EuMon	European Union-wide Monitoring methods and systems of surveillance for species and habitats of community interest
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
IMoSEB	International Mechanism of Scientific Expertise on Biodiversity
LIDAR	Light Detection and Ranging radar
PA	Protected Areas
SBA	Societal Benefit Area
SEDAC	Socioeconomic Data and Application Center
UIC	User Interface Committee

Appendix B: Bibliography and References

This section lists all documents referenced in the report, Section B.1, and those identified through the literature search as containing biodiversity related Earth observations and subsequently used in the analysis.

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Appendix C:

Biodiversity Earth Observation Needs by Categories: Analysis Spreadsheet (Organizations)

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
AOOS. Alaska Ocean Observing System. Arctic Research and Monitoring Workshop: Toward a Strategy for the Chukchi and Beaufort Seas. A Final Report on the January 23, 2009 Workshop.	Need additional knowledge about marine mammal population size and major aspects of their population dynamics. (AOOS)	Species	Marine	Regional	All	Technical	State
API. African Pollinator Initiative. Pollinators and Pollination: a resource book for policy and practice. Editors: Connal Eardly, et. al. February 2006. ISBN 1-86849-310-5	Need to conduct formal surveys of representative habitats in major ecosystems of world to provide a baseline for long-term monitoring. (API)	Ecosystem	Terrestrial	Regional	All	All	Responses - Organizational Infrastructure
API. African Pollinator Initiative. Pollinators and Pollination: a resource book for policy and practice. Editors: Connal Eardly, et. al. February 2006. ISBN 1-86849-310-5	Need to conduct formal surveys of representative habitats in major ecosystems of world to provide: 1) regional patterns of pollinator abundance and diversity, 2) plant relationships and basic information for selecting crop pollinators, and 3) details on species spacial and temporal abundance. (API)	Ecosystem, Species	Terrestrial	Regional	All	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CATHALAC. Centro del Agua del Trópico Húmedo para América Latina y el Caribe. Anderson, E.R.., Cherrington, E.A.., Flores, A.I.., Perez, J.B.., R. Carrillo and Sempris, E. 2008. Potential Impacts of Climate Change on Biodiversity in Central America, Mexico, and the Dominican Republic. CATHALAC/USAID. Panama City, Panama. 104pp.	Impacts of climate change on aquatic and marine biodiversity can not be investigated because most of the climate change modeling requisite inputs do not exist for aquatic and marine biodiversity. Need downscaled data, i.e., georeferenced data on species distributions, marine pH, marine salinity (multi-depth), and marine temperature (multi-depth). (CATHALAC)	Ecosystem, Species	Aquatic	All	All	Technical	Impacts
CATHALAC. Centro del Agua del Trópico Húmedo para América Latina y el Caribe. Anderson, E.R.., Cherrington, E.A.., Flores, A.I.., Perez, J.B.., R. Carrillo and Sempris, E. 2008. Potential Impacts of Climate Change on Biodiversity in Central America, Mexico, and the Dominican Republic. CATHALAC/USAID. Panama City, Panama. 104pp.	Potential impacts from the climate change variables of temperature and precipitation on have been mapped for terrestrial biodiversity in Central America, Mexico, and the Dominican Republic. Additional maps/predictions are needed for other environmental variables (i.e., soil moisture (multi-depth), moisture content, surface temperature, sea level pressure, wind direction and velocity). (CATHALAC)	Ecosystem, Species	Terrestrial	Regional	All	All	Impacts
CATHALAC. Centro del Agua del Trópico Húmedo para América Latina y el Caribe. Anderson, E.R.., Cherrington, E.A.., Flores, A.I.., Perez,	There is a need to couple high resolution climate scenarios with future land use scenarios since land use is a major threat to species abundance and biodiversity. For example, the explicit	Ecosystem, Species	Terrestrial	All	Remote	All	Pressures

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
J.B.., R. Carrillo and Sempris, E. 2008. Potential Impacts of Climate Change on Biodiversity in Central America, Mexico, and the Dominican Republic. CATHALAC/USAID. Panama City, Panama. 104pp.	land change scenarios developed for Belize, southern Mexico, and most of Guatemala under the UNEP and USAID-supported ICRAN-MAR project of 2004-07, could be coupled with the climate change severity index (CCSI) and critical habitat assessment to enhance current impact assessments on biodiversity. (CATHALAC)						
CBD[1]. Convention on Biological Diversity. Recommendations from the Pre-COP9 Scientific Conference "Biodiversity Research - Safeguarding the Future". Bonn, Germany May 12-16, 2008. UNEP/CBD/COP/9/INF/51 20 May 2008.	"Establish an integrated global biodiversity observation network by complementing, expanding, and linking national and regional monitoring systems to provide effective information on ecosystems, species, and genes, and the services they collectively provide." (CBD[1])	All	All	All	All	All	Responses - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CBD2. Convention on Biological Diversity. Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Waters. Secretariat of the Convention on Biological Diversity, Montreal, Canada, CBD Technical Series no. 22 and the Secretariat of the Ramsar Convention, Gland, Switzerland, Ramsar Technical Report no. 1. 2006.	For given locations or ecosystems, need improved understanding of what biodiversity is there, its status, function, and whether conservation/management efforts are helping. (CBD2)	Ecosystem	Aquatic	Global	All	All	Response - Evaluation
CBD2. Convention on Biological Diversity. Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Waters. Secretariat of the Convention on Biological Diversity, Montreal, Canada, CBD Technical Series no. 22 and the Secretariat of the Ramsar Convention, Gland, Switzerland, Ramsar Technical Report no. 1. 2006.	Rapid assessment methods using remote sensing techniques can be used at the ecosystem/wetland habitat level, particularly for rapid inventory assessments. There is a need for further guidance on ecosystem-level rapid assessment methods for inland, coastal, and marine waters. (CBD2)	Ecosystem	Aquatic	Global	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CBD3. Convention on Biological Diversity. Conference of Parties (COP) 9 Decision IX/15. Follow-up to the Millennium Ecosystem Assessment. Bonn, Germany. May 19-30, 2008.	"Invites Parties, other Governments and relevant organizations to: 1) Take note of the need for further improvement of the availability and interoperability of biodiversity data and information; 2) Support, contribute to and promote synergy among the ongoing efforts to digitize data in a standardized format, make data and analytical tools widely available, and further develop analytical tools to use these data for policy and management purposes; " (CBD3)	Ecosystem, Species	All	All	All	All	Response - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CBMP1. Circumpolar Biodiversity Monitoring Program. Petersen, A., Zöckler, C., Gunnarsdóttir, M.V.. 2004. Circumpolar BiodiversityMonitoring Program – Framework Document. CAFF CBMP Report No. 1. CAFFInternational Secretariat, Akureyri, Iceland. 46 ppISBN: 9979-59526-9-5.	There are deficiencies and gaps in Arctic biodiversity monitoring. Need more comprehensive monitoring of taxonomic,geographical and temporal coverage of species: 1) overall understanding of interactions of species, their habitats and ecosystems in a circumpolar context (e.g., biometric measurements, reproductive success, abundance and distribution, harvesting data, species' spatial, geographical and temporal coverage, analyzed together with various physical and chemical parameters; 2) classification of some species regarding internal genetic and taxonomic diversity. (CBMP1)	All	Aquatic, Terrestrial (Tundra)	Regional	All	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CBMP1. Circumpolar Biodiversity Monitoring Program. Petersen, A., Zöckler, C., Gunnarsdóttir, M.V.., 2004. Circumpolar BiodiversityMonitoring Program – Framework Document. CAFF CBMP Report No. 1. CAFF International Secretariat, Akureyri, Iceland. 46 ppISBN: 9979-59526-9-5.	Gap analyses are necessary to determine deficiencies and information needs, and to propose means to address these deficiencies and information needs. Need: 1) compilation of existing arctic monitoring programs: kind of monitoring being done, scale (e.g. regional, national, multi-national), and what types of data are available as a product of these monitoring programs; 2) gap analysis to determine groups of biodiversity that need additional monitoring; 3) analysis on currently existing monitor linkages, especially regional and international; 4) meta-database on existing national and cross-national biodiversity monitoring programs. This already exists for some taxa, habitats and regions (e.g., Ramsar STRP, and various CBD papers), but needs to be strengthened and focused for the Arctic region. Such an overview is needed for better evaluation of needs and priorities, and choosing the best indicators of environmental changes. (CBMP1)	All	Aquatic, Terrestrial (Tundra)	Regional	All	Policy, Management	Response - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
CBMP2. Circumpolar Biodiversity Monitoring Program. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.	Working group sessions identified user needs (key priority actions/needs to be addressed by CBMP): 1) development of overarching conceptual frameworks that identify what is to be monitored; 2) Creation of harmonized monitoring standards and protocols. (CBMP2)	Ecosystem, Species	Aquatic, Terrestrial (Tundra)	Regional	All	Management , Technical	State
CBMP2. Circumpolar Biodiversity Monitoring Program. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.	Need to address issues of proprietary data and existing data portals (i.e., avoid redundancy and capture connectivity of systems in Web portal). (CBMP2)	Ecosystem, Species	Aquatic, Terrestrial (Tundra)	Regional	All	Policy, Management	Responses - System Infrastructure
CBMP2. Circumpolar Biodiversity Monitoring Program. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.	Need to establish links between scientific monitoring results and human systems to better inform adaptation and mitigation strategies. (CBMP2)	Ecosystem, Species	Aquatic, Terrestrial (Tundra)	Regional	All	Policy, Management ,	Responses - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
DIVERSITAS[1]. Jackson, L., Bawa, K., Pascual, I., and Perrings, C. agroBIODIVERSITY: A New Science Agenda for Biodiversity in Support of Sustainable Agroecosytems. DIVERSITAS Report Nº4. 40 pp. 2005.	Need interdisciplinary research framework to monitor biodiversity, to understand ecosystem services provided by biodiversity, and to guide decision making and policies regarding biodiversity in agricultural landscapes. (DIVERSITAS[1])	Ecosystem	Terrestrial	All	All	Policy, Management	Responses - Organizational Infrastructure
DIVERSITAS[2]. Neville Ash, et, al. bioDISCOVERY: Assessing, Monitoring and Predicting Biodiversity Change. DIVERSITAS Report N°7, 40 pp. 2009.	Improving observation and understanding of biodiversity change. Goal is to develop the scientific framework to enable systems for monitoring biodiversity change that are capable of: (1) Measuring change of biodiversity at various scales and levels (genes, taxa, functional groups and communities, as well as structures and functions of ecosystems), (2)Analyzing the complex biotic mechanisms governing the dynamics, direction and intensity of change of biodiversity (DIVERSITAS[2])	Ecosystem, Species	All	All	All	All	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
DIVERSITAS$_2$. Neville Ash, et, al. bioDISCOVERY: Assessing, Monitoring and Predicting Biodiversity Change. DIVERSITAS Report N°7, 40 pp. 2009.	Pinpointing areas where the constellations of drivers, pressures, vulnerability, resilience, create a high risk for biodiversity loss.(DIVERSITAS$_2$)	Ecosystems	All	All	All	All	State
DIVERSITAS$_2$. Neville Ash, et, al. bioDISCOVERY: Assessing, Monitoring and Predicting Biodiversity Change. DIVERSITAS Report N°7, 40 pp. 2009.	Identifying the environmental and socioeconomic drivers of change and the consequences for ecosystem functions and services (DIVERSITASE $_2$)	Ecosystem, Species	All	All	All	All	Drivers
EBONE. European Biodiversity Observation Network. Work Package (WP) 5. Integrating in situ with Earth Observation data: Countryside Survey, UK. Dan Morton. EBONE Newsletter May 2009. www.ebone.wur.nl.	Requirements for EO data to be used within EBONE will become apparent as WP5 progresses. Goal of EBONE is the development of a cost effective system for biodiversity data collection up to at least a pan-European scale. To achieve these objectives a priority for WP5 will be to develop techniques that are optimized for EO data that are widely available and not prohibitively expensive such as optical data at pixel resolutions of approximately 20m and greater. (EBONE)	Ecosystem	All	Regional, Local	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
EPBRS[1]. European Platform for Biodiversity Research Strategy. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.	Develop and assess appropriate scientifically sound and rigorous monitoring methodologies of biodiversity based on standardized protocols and sampling strategies to maximize synergy, integration and interoperability. (EPBRS[1])	All	All	All	All	Policy	Responses - Information Management
EPBRS[1]. European Platform for Biodiversity Research Strategy. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.	Bring to bear knowledge derived from ENBI, GBIF and national nodes to help to monitor biodiversity, help populate relevant databases and use these systems to disseminate knowledge. (EPBRS[1])	All	All	All	All	Policy	Responses - System Infrastructure
EPBRS[1]. European Platform for Biodiversity Research Strategy. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.	Promote as part of best practice co-operation between national and regional monitoring programmes information networks. (EPBRS[1])	All	All	Regional	All	Policy	Responses - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
EPBRS$_1$. European Platform for Biodiversity Research Strategy. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.	Develop a core program of biodiversity monitoring across Europe in cooperation with relevant EU and national institutions and IWG-Bio-MIN. This includes developing and applying methods to integrate already existing national and regional monitoring schemes into a European monitoring programme, with specific reference to biodiversity relevant environmental legislation. (EPBRS$_1$)	Ecosystem, Species	All	Regional	All	Policy	Responses - Organizational Infrastructure
EPBRS$_1$. European Platform for Biodiversity Research Strategy. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.	Encourage as part of best practice the science based monitoring of effects of policies and actions on biodiversity. (EPBRS$_1$)	Ecosystem, Species	All	All	All	Policy, Management	Response - Evaluation
EPBRS$_2$. European Platform for Biodiversity Research Strategy. Sustainable use of Biodiversity meeting concerning European Biodiversity Research and the Global Perspective. Leipzig, 5-7 May, 2007.	Support the implementation of the CBD by developing taxonomy, identification, inventories and monitoring of biodiversity and of globally accessible and interoperable databases. (EPBRS$_2$).	All	All	All	All	Policy	Responses - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
EPBRS$_2$. European Platform for Biodiversity Research Strategy. Sustainable use of Biodiversity meeting concerning European Biodiversity Research and the Global Perspective. Leipzig, 5-7 May, 2007.	Develop methods for more effective, efficient, rapid and comprehensive measurement of global biodiversity status and trends. (EPBRS$_2$)	All	All	All	All	Policy	State
EPBRS$_3$. European Platform for Biodiversity Research Strategy. Action Plan for Biodiversity Research in Europe. Budapest, Hungary, 31 March - 4 April, 2005. EPBRS HU 2005 Action Plan (Release 1.1).	Improve understanding of the population structure of commercial fish species using genetic and traditional approaches, to optimize stock management. (EPBRS$_3$)	Genetic, Species	Aquatic	Regional	All	Management	State
EPBRS$_3$. European Platform for Biodiversity Research Strategy. Action Plan for Biodiversity Research in Europe. Budapest, Hungary, 31 March - 4 April, 2005. EPBRS HU 2005 Action Plan (Release 1.1).	Priorities for Biodiversity Action Plan on Agriculture: 1) Assess performance of the reformed CAP in achieving the target of halting biodiversity loss by developing a harmonized framework for evaluation to support development of monitoring systems using agreed indicators; 2) Improve design, implementation, monitoring, and evaluation of agri-environmental instruments at the scales at which they most effectively deliver on the 2010 biodiversity targets. (EPBRS$_3$)	All	All	All	All	Policy, Management	Responses - Evaluation

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
EPBRS[3]. European Platform for Biodiversity Research Strategy. Action Plan for Biodiversity Research in Europe. Budapest, Hungary, 31 March - 4 April, 2005. EPBRS HU 2005 Action Plan (Release 1.1).	Priorities for Biodiversity Action Plan on Economics and Development Cooperation: Develop and evaluate long-term biodiversity monitoring programmes and indicators that contribute to the assessment of the global 2010 target in developing countries. (EPBRS[3])	All	All	All	All	Policy, Management	Responses - Organizational Infrastructure
EuMon. EU-wide Monitoring Methods and Systems of Surveillance for Species and Habitats of Community Interest. Manual "Best Practice for Monitoring Species and Habitats of Community Interest. Compiled by Erik Framstad. Deliverable 30 of EuMon work project 6. Project No. 006463. 2008.	1) Need biodiversity monitoring to verify the state and trends of biodiversity and the effects of policies to maintain or improve the state of biodiversity. 2) Need to integrate information from single monitoring schemes into indicators that can provide information on broader patterns of biodiversity change. (EuMon)	Ecosystem, Species	All	All	All	Policy, Management	1) Response - Evaluation 2) Response - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
GEO. Group on Earth Observations. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Edited by Doug Muchoney and Michael Brady. 2009 http://www.dpi.inpe.br/geoforest/	Forest Biodiversity - Requirement status and trends of habitat within protected areas: Primary Data: GEO-referenced time series in all PAs, classified imagery and simple tools tomeasure changeEO data: Landsat, or similar and radar data for areas with high cloud cover frequency wherecurrent EO data are not availableAncillary data: PA extent, validation and calibration datasetsSource: Landsat, or similar and radar data for areas with high cloud cover frequencySpatial scale: 50m or finerTemporal scale: 1970s – continuously ongoingTimeliness: annual update (and near daily for early warning system, e.g. fire detection)Gaps: information for cloud forestsDescriptions: global protected areas, 106,000 sites, ca. 18,000,000 km2 (GEO)	Ecosystem	Forest	Global	Remote	Policy, Management	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
GEO. Group on Earth Observations. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Edited by Doug Muchoney and Michael Brady. 2009. http://www.dpi.inpe.br/geoforest/	Biodiversity Recommendations: 1) Support IUCN Global Species Assessments by providing baseline geospatial thematic data and web-based analytical tools 2) Initiate a Global Phenology Network 3) Initiate the GEO Protected Areas Assessment and Monitoring program 4) Initiate a Data Outreach Program for Forests (GEO)	Ecosystem	Forest	Global	All	All	Response 1) Information Mgt 2) System Infrastructure 3) Organizational Infrastructure 4) Organizational Infrastructure
GEO. Group on Earth Observations. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Edited by Doug Muchoney and Michael Brady. 2009. http://www.dpi.inpe.br/geoforest/	Forest Biodiversity - Observation Data Requirements. Earth observation priorities for protected areas: location of global protected areas and the status and trends of habitats and ecosystems within protected areas. Therefore need GEO-referenced time-series of satellite imagery for within all PAs, together with simple tools to detect and measure change. (GEO)	Ecosystem	Forest	Global	Remote	Policy, Management	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
GLOCHAMORE. Global Change and Mountain Regions. Björnsen Gurung A, et al. GLOCHAMORE Research Strategy. Global Change and Mountain Regions: an Integrated Assessment of Causes and Consequences. MRI, Bern Switzerland. 2006.	For Mountain biodiversity need: (1) Regular inventory (monitoring) of key taxa (plants, insects, birds) in different mountain life zones(2) Assess and understand environmental thresholds that determine biodiversity (by collecting presence, and abundance data on species along with abiotic environmental data).(GLOCHAMORE)	Ecosystem, Species	Mountain	Global	All	All	State
GLOCHAMORE. Global Change and Mountain Regions. Björnsen Gurung A, et al. GLOCHAMORE Research Strategy. Global Change and Mountain Regions: an Integrated Assessment of Causes and Consequences. MRI, Bern Switzerland. 2006.	For Mountain biodiversity need: Detect and understand the shifts in species abundance and distribution driven by climate change (GLOCHAMORE)	Ecosystem, Species	Mountain	Global	All	All	Pressures
Heinz1. A Report of the Heinz Center's State of the Nation's Ecosystems Project. "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition." The H. John Heinz III Center for Science, Economics and the	Process or institution is needed to make strategic decisions across many monitoring programs. (Heinz1)	All	All	All	All	All	Responses - Organizational Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Environment. May 2006.							
Heinz[1]. A Report of the Heinz Center's State of the Nation's Ecosystems Project. "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition." The H. John Heinz III Center for Science, Economics and the Environment. May 2006.	There is a need for a mechanism/way to determine the most appropriate and highest priority investments in monitoring and reporting capacity. (Heinz[1])	All	All	All	All	All	Responses - Organizational Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Heinz[1]. A Report of the Heinz Center's State of the Nation's Ecosystems Project. "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition." The H. John Heinz III Center for Science, Economics and the Environment. May 2006.	The overall system/mechanism providing the nation's environmental monitoring information merits attention, because it has a fragmented infrastructure. Integration and coordination among local, national and other organizations involved in the monitoring process is needed. (Heinz[1])	All	All	All	All	Management , Technical	Responses - System Infrastructure
Heinz[1]. A Report of the Heinz Center's State of the Nation's Ecosystems Project. "Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition." The H. John Heinz III Center for Science, Economics and the Environment. May 2006.	Improved funding policy is needed to support this ecosystem monitoring program. (Heinz[1])	Ecosystem	All	All	All	Policy	Responses - Organizational Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Heinz2. A Report of the Heinz Center's State of the Nation's Ecosystem Project. "Candidate Indicators – Conditions of Plant and Animal Communities." The H. John Heinz III Center for Science, Economics and the Environment. May 2006.	Overall, the 'Condition of Plant and Animal Communities' indicator should provide broad but succinct information on the level of disturbance or change in biological communities in terrestrial and aquatic systems in the U.S. (Heinz2) 1) There is a need to understand how much plant and animal communities have been altered by human activity relative to pre-settlement times. 2) There is a need to be able to distinguish natural areas from human altered areas, and to be able to classify those areas into three categories (undisturbed, disturbed and less disturbed).	Ecosystem, Species	All	All	All	Policy, Management	Impacts
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Ensure availability and comparability of existing data collections. (IGOL)	All	Terrestrial	All	All	All	Responses - Information Management
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Improved models for predicting species distributions on existing landscapes. (IGOL)	Species	Terrestrial	All	N/A	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Develop better guidelines for using models that predict species distributions on existing landscapes, to be used by the scientific community and conservation organizations. (IGOL)	Species	Terrestrial	Local	N/A	Management	Responses - Information Management
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Organize observational data from in situ research sites in order to develop a validation database for existing products of relevance to biodiversity issues. (IGOL)	All	Terrestrial	Local	In-situ	Management , Technical	Responses - Evaluation
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Maintain continuity of long-term seasonal record of land-cover change and fragmentation at 30m resolution. A key attribute or derived characteristic of such a land-cover product would be the derivation of disturbance patterns and frequencies. (IGOL)	Ecosystem	Terrestrial	All	Remote	Management , Technical	State
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Develop a long-term record of critical land-use characteristics, at a spatial scale that is commensurate with the land-cover change product, but that includes additional information on the human use of land resources such as crop type at sufficient spatial resolution to identify small land-holders (ca. 0.5 ha). (IGOL)	Ecosystem	Terrestrial	All	Remote	Management , Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Adopt a consensus ecosystem classification hierarchy and map product that describes how systems are mapped, how to add detail, and how to extend the classification scheme to all ecosystems (including human dominated systems). (IGOL)	Ecosystem	Terrestrial	All	Remote	Technical	Responses - Information Management
IGOL. Integrated Global Observation of Land. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Draft, September 6, 2007.	Enhance availability of 30m global topography, which play a critically important role in both correction of imagery data in habitat delineation, and as model input data. (IGOL)	Ecosystem	Terrestrial	All	Remote	Technical	State
IUCN. International Union for Conservation of Nature. The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. Science. Vol. 322. no. 5899: pp 225 - 230. October 10, 2008.	Most data deficient mammal species are identified. For purposes of this analysis data-deficiencies are considered areas of needed research: 1) most data-deficient species on land are in tropical forests which reflects species richness patterns. Data deficient species in tropical forests, which are declining rapidly (e.g., West Africa, Borneo, Atlantic Forest) may be close to extinction. 2) 38% of marine mammals are data deficient. Species that breed in water are less understood. Marine data-deficient species are concentrated along the Antarctic Convergence (19 beaked whales species are data deficient. (IUCN)	Species	All	Global	All	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
KMTNC & UNEP-WCMC. King Mahendra Trust for Nature Conservation - Nepal andthe UNEP-World Conservation Monitoring Centre. Tucker, G., Bubb P., de Heer M., Miles L., Lawrence A., Bajracharya S. B., Nepal R. C., Sherchan R., Chapagain N.R.. 2005. Guidelines for Biodiversity Assessment and Monitoring for Protected Areas. KMTNC, Kathmandu, Nepal.	Need for blending biodiversity assessment and monitoring system within a protected areamanagement system to achieve sound and effective management of protected areas. (KMTNC & UNEP-WCMC)	All	All	All	All	Management , Technical	Responses - System Infrastructure
MA. Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Biodiversity Synthesis Report. World Resource Institute, Washington, DC. 2005	Need stronger monitoring and evaluation in protected areas for biodiversity conservation (i.e., comprehensive monitoring that provides information on management success or failure). (MA)	Ecosystem	All	Local	All	Management	Response - Evaluation
MA. Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Biodiversity Synthesis Report. World Resource Institute, Washington, DC. 2005	Key factor of successful responses to biodiversity loss: Establish implementing and monitoring agencies. The establishment of subsidiary bodies with authority and resources to undertake specific activities to enhance the implementation of the agreements is vital to ensure continuity, preparation, and follow-up to complex issues. (MA)	All	All	All	All	Policy	Responses - Organizational Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
NPRB. North Pacific Research Board. Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research. Hopcroft, Bluhm and Gradinger (Eds), December 2008, NPRB Project #503.	Need to address geographic and taxonomic gaps: Sampling in the region has rarely been systematic and notable geographic gaps need to be filled. (NPRB)	Ecosystem, Species	Marine	Regional	All	All	State
NPRB. North Pacific Research Board. Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research. Hopcroft, Bluhm and Gradinger (Eds), December 2008, NPRB Project #503.	Need to address taxonomic training and expertise: investment in taxonomic training is essential to detecting long-term change in species distributions. (NPRB)	Species	Marine	Regional	All	All	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
NRC/NAS. National Research Council of the National Academies. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. 2007. Space Studies Board. Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity.	To specifically address biodiversity need the following satellite mission: *"Mission to observe distribution and changes in ecosystem function.* An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity. " (NRC/NAS)	Ecosystem	All	All	Remote	All	State
NRC/NAS. National Research Council of the National Academies. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. 2007. Space Studies Board. Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity.	An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity. (NRC/NAS)	Ecosystem	All	All	Remote	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
NRC/NAS. National Research Council of the National Academies. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. 2007. Space Studies Board. Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity.	Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity gives its highest level of priority to maintaining and improving the long-term records of the productivity of terrestrial and marine ecosystems and to measure land-cover change at high spatial resolution. (NRC/NAS)	Ecosystem	All	All	Remote	All	Responses - Organizational Infrastructure
OSME. Ornithological Society of the Middle East, the Caucasus and Central Asia. The First Arabian Ornithological and Conservation Conference. Manama, Bahrain 21-25 October, 2000.	Data Recommendation: develop national and regional biodiversity databases. (OSME)	Species	All	Regional	All	All	Responses - Information Management
OSME. Ornithological Society of the Middle East, the Caucasus and Central Asia. The First Arabian Ornithological and Conservation Conference. Manama, Bahrain 21-25 October, 2000.	Monitoring Recommendation: develop transboundry monitoring of the status of marine mammals and turtles. (OSME)	Species	Marine	Regional	All	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
SANBI. South African National Biodiversity Institute. A Research Strategy for the Grasslands Biome. Prepared by The Grasslands Research Team. November, 2008.	Species and community responses to drivers and pressures: need long-term monitoring programs. (SANBI)	Species	Grasslan ds	All	All	Policy, Management	Response - Organizational Infrastructure
SANBI. South African National Biodiversity Institute. A Research Strategy for the Grasslands Biome. Prepared by The Grasslands Research Team. November, 2008.	Species and community responses to drivers and pressures: development of methods for monitoring including methods to link satellite derived parameters to on-the ground vegetation assemblages. (SANBI)	Species	Grasslan ds	All	Remote	Technical	State
UK BRAG1. UK Biodiversity Research Advisory Group. Paul Rose and Richard Ferris on behalf of the Monitoring & Evaluation Sub-Group. Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. 1/10/2005.	Establish a programme for mapping of seafloor habitats to follow-on from the European MESH project. (UK BRAG1)	Ecosystem	Marine	Regional	All	Policy, Management	Response - Organizational Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
UK BRAG$_1$. UK Biodiversity Research Advisory Group. Paul Rose and Richard Ferris on behalf of the Monitoring & Evaluation Sub-Group. Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. 1/10/2005.	In reference to survey techniques and monitoring systems: 1) review the potential of all types of remote sensing (e.g., acoustic sensing of the seafloor), as well as other techniques for establishing inventories and monitoring biodiversity; 2) Address monitoring gap for coastal marine systems; 3) Develop monitoring techniques that can be adapted to work in a dynamic environment taking into account a diverse range of pressures such as climate change. Monitoring schemes need to be flexible enough to respond to changing needs. (UK BRAG$_1$)	Ecosystem, Species	Marine	Regional	All	Technical	State
UK BRAG$_2$. UK Biodiversity Research Advisory Group. Monitoring & Evaluation Sub-Group. Position Statement on Monitoring & Evaluation Research Priorities. 1/13/2005.	Establish an online catalogue of biodiversity monitoring schemes, with links to action plans. (BRAG$_2$)	Ecosystem, Species	All	All	All	All	Responses - System Infrastructure
UNESCO. United Nations Educational, Scientific and Cultural Organization World Heritage Centre. Proceedings of the World Heritage Marine Biodiversity Workshop. Hanoi, Viet Nam, February 25 - March 1, 2002.	1) Need for scientific marine and socio-economic surveys in many regions to properly analyze biodiversity. 2)Regular monitoring corresponding to appropriate ecological temporal and spatial variables, as well as social influences is needed to improve management effectiveness and adaptability. (UNESCO)	Ecosystem, Species	Marine	Global, Regional	All	All	Pressures

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale (global, regional, local)	Observation Type (remote, in-situ)	User Type (technical, policy, manage-ment/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
US CCP. US Climate Change Science Program. The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Public review draft of synthesis and assessment product 4.3., September 11, 2007.	Need species-specific or ecosystem specific monitoring systems to include climate variability, and climate change (up until now this is generally not the case). (US CCP)	Ecosystem, Species	All	All	All	Management , Technical	Pressures
US CCP. US Climate Change Science Program. The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Public review draft of synthesis and assessment product 4.3., September 11, 2007.	Need institutions (federal, state, NGOs) to be stable in order to create, manage, and maintain in situ and remotely sensed long time-series observations. (US CCP)	All	All	All	All	Policy	Responses - Organizational Infrastructure
US DOI. North American Bird Conservation Initiative, U.S. Committee, 2009. The State of the Birds, United States of America, 2009. U.S. Department of Interior. Washington, DC. 36 pages.	Need reliable long-term monitoring data for many poorly monitored bird groups and their habitats, most notably arctic-nesting shorebirds, colonial seabirds, and oceanic species. (US DOI)	Ecosystem, Species	Marine	All	All	All	State

Biodiversity Earth Observation Needs by Categories: Analysis Spreadsheet (Journals)

Information Source/ Citation	**Needs/Requirements**	**Biodiversity Organization** (ecosystem, species, genetic)	**Biome Type***	**Spatial Scale** global, regional, local)	**Observation Type** (remote, in-situ)	**User Type** (Technical, policy, management/ decision maker)	**DPSIR*** (drivers, pressures, state, impacts, responses)
Becker, B.L.., Lusch, D.P.., and Qi, J. Identifying Optimal Spectral bands from in situ measurements of Great Lakes Coastal Wetlands Using Second-derivative Analysis. Remote Sensing of Environment. 97:238-248. 2005	Remote sensing of coastal wetlands requires the use of high spatial resolution imagery (i.e., pixels 1-2 m^2) because coastal wetlands are often spatially complex and heterogeneous. A reduction in the number of bands without a significant information loss allows utilization of small pixels without loosing ability to differentiate botanical communities. The identification of a small number of wetland-relevant bands could reduce the cost of image acquisition, potentially increasing end-users. (Becker, et al.)	Ecosystem	Freshwater - wetlands	Global	Remote	Technical	State
Bianchi, N.D., and Morri, C. Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. Marine Pollution Bulletin. Vol. 40 (5): pp. 367-376. 2000.	Need to determine natural variability of marine ecosystems and understand the effects of change on their biodiversity at the scale of the entire Mediterranean. (Bianchi and Morri)	Ecosystem, Species	Marine	Regional	All	All	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Bianchi, N.D., and Morri, C. Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. Marine Pollution Bulletin. Vol. 40 (5): pp. 367-376. 2000.	1) Need an internationally coordinated network of marine protected areas across the Mediterranean. 2) Need long-term studies (expected life-time of dominant species). (Bianchi and Morri)	Ecosystem, Species	Marine	Regional	All	Policy, Management	Response - Organization Infrastructure
Carlson, K.M., Asner, G.P.., Hughes, R.F.., Ostertag, R., Martin, R.E.. Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests. Ecosystems. 10: 536-549. 2007.	Need more high resolution biodiversity mapping and monitoring in support of ecosystem service assessments in conservation, management, and policy. (Carlson, et al.)	Ecosystem	Forest - tropical	All	Remote	All	Pressures
Carlson, K.M., Asner, G.P.., Hughes, R.F.., Ostertag, R., Martin, R.E.. Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests. Ecosystems. 10: 536-549. 2007.	Need to explicitly connect chemical and physical properties of the organisms being studied with remote sensing data. This will require appropriate RS data, such as from high performance hyperspectral sensors, collected at spatial resolutions needed to meet land management and conservation goals. (Carlson, et al.)	Genetic	Forest - tropical	All	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Carlson, K.M., Asner, G.P.., Hughes, R.F.., Ostertag, R., Martin, R.E.. Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests. Ecosystems. 10: 536-549. 2007.	Need methods to map and monitor aspects of biodiversity. RS approaches used to date usually focus on basic delineation of land-cover types without directly resolving the biochemical or structural properties of the vegetation most closely linked to taxonomic diversity. (Carlson, et al.)	Genetic, Species	Forest - tropical	All	Remote	Technical	State
Carlson, K.M., Asner, G.P.., Hughes, R.F.., Ostertag, R., Martin, R.E.. Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests. Ecosystems. 10: 536-549. 2007.	Need to establish the biophysical basis for connecting spectral variation from remote sensing to field-measured plant species diversity. (Carlson, et al.)	Species	Forest - tropical	Global	Remote	Technical	State
Carlson, K.M., Asner, G.P.., Hughes, R.F.., Ostertag, R., Martin, R.E.. Hyperspectral Remote Sensing of Canopy Biodiversity in Hawaiian Lowland Rainforests. Ecosystems. 10: 536-549. 2007.	Need more operational methods for quantifying biodiversity at high spatial resolution at regional scales. (Carlson, et al.)	Ecosystem, Species	Forest - tropical	Regional	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Certain, G., and Bretagnolle, V. Monitoring Seabirds Population in Marine Ecosystem: The Use of Strip-transect aerial surveys. Remote Sensing of Environment. Vol. 112: 3314-3322. 2008.	Strip-transect aerial surveys can be used for sampling sea bird populations at sea. To focus future work need to address: the effect of bird movement, the effect of sea state, and the direct estimate of the detection probability in the case of diving birds. (Certain, et al)	Species	Marine	Local	Remote	Technical	State
Collen, B., Ram, M., Zamin, T., and McRae, L. The Tropical Biodiversity Data Gap: Addressing Disparity in Global Monitoring. Tropical Conservation Science. Vol. 1(2):75-88. 2008.	Establish a global biodiversity observation system which needs to be systematically designed across regions and taxa. (Collen, et al.)	Ecosystem, Species	Forest - tropical	Global	All	Management	Response - System Infrastructure
Collen, B., Ram, M., Zamin, T., and McRae, L. The Tropical Biodiversity Data Gap: Addressing Disparity in Global Monitoring. Tropical Conservation Science. Vol. 1(2):75-88. 2008.	Invest in local institutions that can develop the infrastructure and expertise for long-term tropical biodiversity monitoring (Collen, et al.)	Ecosystem, Species	Forest - tropical	Global	All	Policy	Response - Organization Infrastructure
Collen, B., Ram, M., Zamin, T., and McRae, L. The Tropical Biodiversity Data Gap: Addressing Disparity in Global Monitoring. Tropical Conservation Science. Vol. 1(2):75-88. 2008.	Efforts needed to address tropical biodiversity data gap: 1) develop methods that use representative samples and/or weighting approaches to make most use of current data; 2) focus research and monitoring on key regions, habitats, and taxa) (Collen, et al.)	Ecosystem, Species	Forest - tropical	Global	All	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Duro, D.C., Coops, N.C., Wulder, M.A. Development of a Large Area Biodiversity Monitoring System Driven by Remote Sensing. Progress in Physical Geography. Vol. 31 (3): 235-260. 2007.	National biodiversity monitoring system for Canada driven by remote sensing at ecosystem level for purpose of providing an early warning system, indicating where areas of potential biodiversity change be occurring. Key indicators are: productivity, disturbance, topography, and land cover. (Duro, et. al.)	Ecosystem	All	Regional	Remote	Policy	Response
Feehan, Jane, Gillmor, Desmond A., Culleton, Noel. Effects of an Agri-environment Scheme on Farmland Biodiversity in Ireland. Agriculture, Ecosystems & Environment. Vol. 107:275-286. 2005.	Recommend that it be made obligatory for EU member states to devote a fixed portion of the agri-environment budget to monitoring and evaluation. Detailed management discussion and advice regarding measurable, targeted objectives for farmland flora and fauna diversity is needed. (Feehan, et al.)	Species	Terrestrial (agriculture)	Regional	All	Policy, Management	Impacts
Giller, P.S., Hillebrand, H., Beringer, U.G.., Gessner, M.O.., Hawkins, S., Inchausti, P., Inglis, C., Leslie, H., Malmqvist, B., Monaghan, M.T.., Morin, P.J.., and O'Millen, G. Biodiversity Effects on Ecosystem functioning: Emerging issues and their experimental test in aquatic environments. Oikos 104: 423-436. 2004.	Need to extrapolate results from small-scale experiments (conducted at fine spatial – patch or local level, and temporal scales) that examine biodiversity effects on ecosystem functioning, to large scales, or experiments must be directly conducted at the larger landscape level by explicitly incorporating both the grain (the individual sampling unit) and the extent (or overall area) of the ecosystems. (Giller, et al.)	Ecosystem	Aquatic	Local	All	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Goates, M.C.., Hatch, K.A.., and Eggett, D.L.. The Need to Ground Truth 30.5 m Buffers: A Case Study of the Boreal toad (*Bufo boreas*). Biological Conservation 138: 474-483. 2007.	Need to develop new methods of detecting stream and seep habitats. Remote sensing technologies have potential to increase accuracy of delineating and mapping riparian and wetland habitats. Modeling flow paths using a 10 m DEM (digital elevation model) may accurately predict stream and seep locations thereby eliminating the need to survey large areas. These locations could then be ground truthed. Locating these habitats will increase accuracy and efficiency of resource management and conservation.. (Goates, et. al.)	Ecosystem	Freshwater -streams	All	Remote	Technical	State
Graf, R.F.., Mathys, L., and Bollmann, K. Habitat Assessment for Forest Dwelling Species Using LiDAR remote sensing: Capercaillie in the Alps. Forest Ecology and Management. Vol. 257:160-167. 2009.	Need LiDAR data with country-wide coverage. This will enable conservation managers to assess habitat suitability for forest dwelling species at the scale of entire populations. LiDar offers great potential for effective habitat monitoring and management of endangered species and biodiversity maintenance. (Graf et al)	Ecosystem	Forest	Regional	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Haberl, H., Gaube, V., Diaz-Delgado, R., Krauze, K., Neuner, A., Peterseil, J., Plutzar, C., Singh, S.J.., and Vadineanu, A. Towards an Integrated Model of Socioeconomic Biodiversity Drivers, Pressures, and Impacts. A Feasibility Study Based on Three European Long-term Socio-ecological Research Platforms. Ecological Economics. Vol. 68: 1797-1812. 2009.	Considerable investments in monitoring and model development is needed before mathematical (computer) models can be used to demonstrate the interrelation processes between society and ecosystems. These computer models are needed because of their use in anticipating possible future biodiversity change under different future socioeconomic scenarios. (Haberl, et al.)	Ecosystem	All	Local	All	All	Pressures
Henry, P.Y.., Lengyel, S., Nowicki, P., Julliard, R., Clobert, J., Celik, T., Gruber, B., Schmeller, D.S., Babij, V., Henli, Klaus. Integrating Ongoing Biodiversity Monitoring: Potential Benefits and Methods. Biodiversity and Conservation. Vol 17(14): 3357-3382. 2008	Need highly standardized international monitoring networks that combine/integrate available information from ongoing monitoring efforts. (Henry, et al.)	All	All	All	All	Policy, Management	Response - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Henry, P.Y.., Lengyel, S., Nowicki, P., Julliard, R., Clobert, J., Celik, T., Gruber, B., Schmeller, D.S., Babij, V., Henli, Klaus. Integrating Ongoing Biodiversity Monitoring: Potential Benefits and Methods. Biodiversity and Conservation. Vol 17(14): 3357-3382. 2008	Need to identify biodiversity composition and dynamics of both species and habitats at large spatial and temporal scales. (Henry, et al.)	Ecosystem, Species	All	Global, Regional	All	Technical	State
Henry, P.Y.., Lengyel, S., Nowicki, P., Julliard, R., Clobert, J., Celik, T., Gruber, B., Schmeller, D.S., Babij, V., Henli, Klaus. Integrating Ongoing Biodiversity Monitoring: Potential Benefits and Methods. Biodiversity and Conservation. Vol 17(14): 3357-3382. 2008	Separate, spatially restricted trajectories on the state and trends of single species and single communities are not generally indicative of general trends of biodiversity. Therefore, need to integrate single trajectories into indicators of biodiversity components over large spatial and temporal scales. (Henry, et al.)	Species	All	Global, Regional	All	Technical	State
Kerr, J.T.., and Ostrovsky, M. From Space to Species: Ecological Applications for Remote Sensing. TRENDS in Ecology and Evolution. Vol. 18(6): 299-305. June 2003.	High research priority should be to predict the consequences of ecosystem function change, both natural and anthropogenic, on regional and global distributions and abundances of species. The full range of RS techniques (identifying land covers, measuring biophysical properties of ecosystems, detecting environmental change) will need to be integrated with existing and new ecological data. (Kerr & Ostrovsky).	Ecosystem	Terrestrial	Global, Regional	All	Management, Technical	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Knudby, A., LeDrew, E., and Newman, C. Progress in the Use of Remote Sensing for Coral Reef Biodiversity Studies. Progress in Physical Geography. 31(4):421-434. 2007.	Usefulness of remote sensing technology for use in conservation of coral reef biodiversity depends on the ability to map relevant environmental variables and provide a scientific basis for decision making. (Knudby, et al.)	Ecosystem	Marine - tropical	All	Remote	Management	State
Knudby, A., LeDrew, E., and Newman, C. Progress in the Use of Remote Sensing for Coral Reef Biodiversity Studies. Progress in Physical Geography. 31(4):421-434. 2007.	Need studies that combine the strength of each type of observation instrument to map multiple habitat variables in order to test the ability to predict local spatial distribution of biodiversity. (Knudby, et al.)	Ecosystem	Marine - tropical	Local	All	Management, Technical	State
Knudby, A., LeDrew, E., and Newman, C. Progress in the Use of Remote Sensing for Coral Reef Biodiversity Studies. Progress in Physical Geography. 31(4):421-434. 2007.	Studies are needed to investigate in greater detail the optimum spatial scale at which habitat variables should be mapped. (Knudby, et al.)	Ecosystem	Marine - tropical	All	All	Technical	State
Lamb, E.G., Bayne, E., Holloway, G., Schieck, J., Boutin, S., Herbers, J., Haughland, D.L.. Indices for Monitoring Biodiversity Change: Are Some More Effective Than Others? Ecological Indicators. Vol. 9: 432-444. 2009.	Need additional research to investigate the improvement in statistical power that occurs in biodiversity trends by incorporating equations that detect for correction error. (Lamb, et al.)	Species	All	All	All	All	Response - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Lassau, S.A.., and Hochuli, D.F.. Associations Between Wasp Communities and Forest Structure: Do Strong Local Patterns Hold Across Landscapes? Austral Ecology. 32:656-662. 2007.	Need surveys at multiple scales to identify landscape units from insect perspectives to assist in examining the variation of assemblages at landscape scales. (Lassau & Hochuli)	Ecosystem	Forest	All	All	Technical	State
Lengyel, S., Kobler, A., Kutnar, L., Framstad, E., Henry, P., Babij, V., Gruber, B., Schemeller, D., and Henle, K. A Review and a Framework for the Integration of Biodiversity Monitoring at the Habitat Level. Biodiversity Conservation. Vol., 17: 3341-3356. 2008.	Need to integrate monitoring efforts in order to quantify pan-European trends in habitat-level biodiversity. (Lengyel, et al.)	Ecosystem	All	Regional	All	Management, Technical	Response - System Infrastructure
Lengyel, S., Kobler, A., Kutnar, L., Framstad, E., Henry, P., Babij, V., Gruber, B., Schemeller, D., and Henle, K. A Review and a Framework for the Integration of Biodiversity Monitoring at the Habitat Level. Biodiversity Conservation. Vol., 17: 3341-3356. 2008.	Need in-depth field mapping of priority habitats (e.g., priority habitats of the Habitat Directive or habitats of high national importance. (Lengyel, et al.)	Ecosystem	All	Regional	In-situ	Policy	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Lengyel, S., Kobler, A., Kutnar, L., Framstad, E., Henry, P., Babij, V., Gruber, B., Schemeller, D., and Henle, K. A Review and a Framework for the Integration of Biodiversity Monitoring at the Habitat Level. Biodiversity Conservation. Vol., 17: 3341-3356. 2008.	Need to expand temporal and spatial coverage of monitoring activities in order to measure changes in biodiversity across large scales. Need to enhance the spatial aspect of monitoring. Recommend developing field mapping and recording methods for uniform use over Europe, such as the BioHab methodology. (Lengyel, et al.)	Ecosystem	All	Regional	In-situ	Technical	Impacts
Leyequien, E., Verrlest, J. Slot, M., Schaepman-Strub, G., Heitkonig, I.M.A.., Skidmore, A. Capturing the Fugitive: Applying Remote Sensing to Terrestrial Animal Distribution and Diversity. International Journal of Applied Earth Observation and Geoinformation. Vol., 9: 1-20. 2007.	The ability of remote sensing data to contribute to the mapping and prediction of occurrence of invertebrate diversity is poorly understood compared to other taxonomic groups. Invertebrates are primarily studied in the context of insect concentrations as pest and disease vectors. Very few studies are related to conservation efforts and studies are limited to local diversity within-community component not total regional diversity. (Leyequien et al)	Ecosystem	Terrestrial	All	Remote	Management, Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Leyequien, E., Verrlest, J. Slot, M., Schaepman-Strub, G., Heitkonig, I.M.A.., Skidmore, A. Capturing the Fugitive: Applying Remote Sensing to Terrestrial Animal Distribution and Diversity. International Journal of Applied Earth Observation and Geoinformation. Vol., 9: 1-20. 2007.	Assessing species richness through heterogeneity based on plant chemical constituents: Leyequien et al. stated that some authors recommend that future studies should focus on monitoring seasonal changes in foliar nutrient concentration as well as extending the method to predict other macro nutrients (P, K, Na, Ma, Ca) and secondary compounds in both grass and tree canopies. (Leyequien et al)	Ecosystem	Terrestrial	All	Remote	Technical	State
Nagendra, Harini, and Rocchini, Duccio. High Resolution Satellite Imagery for Tropical Biodiversity Studies: The Devil is in the Detail. Biodiversity Conservation. Vol. 17: 3431-3442. 2008.	Given the recent arrival and their limited geographic spread of hyperspectral and hyperspatial sensors (airborne & satellite), their utility will be maximized when they are coupled with existing large scale monitoring systems that currently utilize moderate resolution multispectral data like SPOT, ASTER, and Landsat TM/ETM+. (Nagendra & Rocchini)	Ecosystem, Species	All	Global	All	All	Response - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Nagendra, Harini, and Rocchini, Duccio. High Resolution Satellite Imagery for Tropical Biodiversity Studies: The Devil is in the Detail. Biodiversity Conservation. Vol. 17: 3431-3442. 2008.	Due to the lack of hyperspectral and hyperspatial imagery (archival and currently ongoing) in the tropics, there is a need to generate and make easily available hyperspectral and hyperspatial (pixel size of $\geq$ 5m) satellite data of tropical biodiversity to address the urgent need to identify locations of tropical biodiversity hotspots, map the distribution of biodiversity across different habitats and landscapes, and monitor rates of change over time. (Nagendra & Rocchini)	Ecosystem, Species	Forest - tropical	Global	Remote	Technical	State
Nair, A., Sathyendranath, S., Platt, T., Morales, J., Stuart, V., Forget, M.H.., Devred, E., and Bouman, H. Remote Sensing of Phytoplankton Functional Types. Remote Sensing of Environment. Vol. 112: 3366-3375. 2008.	Remote sensing is the only way to collect concurrent global distributions of phytoplankton functional types, therefore, need improved understanding of the errors associated with the satellite-derived fields (need confidence limits on the data). Need a combination of in situ and remote-sensing techniques to determine distribution of PFTs at the global scale. (Nair, et al)	Species	Aquatic	Global	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Palandro, D.A., Andrefouet, S., Hu, C., Hallock, P., Mueller-Karger, F.E.., Dustan, P., Callahan, M.K.., Kranenburg, C., Beaver, C.R. Quantification of Two Decades of Shallow-water coral reef habitat decline in the Florida Keys National Marine Sanctuary Using Landsat Data (1984-2002). Remote Sensing of Environment. Vol., 112: 3388-3399. 2008.	Need additional research similar to that presented in this study (historical Landsat images were geographically, atmospherically, radiometerically, and bathymetrically corrected to measure habitat changes for coral reef sites) should be conducted worldwide, with the use of new high resolution sensors. (Palandro)	Ecosystem	Marine - tropical	Global, Regional	Remote	Technical	State
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need global biomonitoring network to gather new data on abundance and distribution of population and habitat extent. (Pereira & Cooper)	Ecosystem, Species	All	Global	All	All	Responses - System Infrastructure
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need compatibility between data sets. (Pereira & Cooper)	All	All	All	All	Management, Technical	Responses - Information Management

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Global network is needed that integrates existing and new national, regional or global sampling programmes. Network would sample taxa most relevant nationally or regionally as indicators of biodiversity change. (Pereira & Cooper)	Species	All	All	In-situ	Management, Technical	Responses - System Infrastructure
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change. Need Global Species Monitoring: a global sampling programme targeted to carefully selected indicator taxa. Vascular plants and birds are recommended. (Pereira & Cooper)	Species	Terrestrial	Global	All	Policy	Responses - Organizational Infrastructure
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need to integrate current monitoring initiatives. (Pereira & Cooper)	All	All	All	All	Technical	Responses - System Infrastructure
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Existing programmes monitoring freshwater and marine taxa need to be enhanced. (Pereira & Cooper)	Species	Aquatic	All	All	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need directly comparable sets of global land-cover data. (Pereira & Cooper)	Ecosystem	Terrestrial	Global	All	Technical	Impacts
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need taxonomic coverage of global plant species distribution. (Pereira & Cooper)	Species	Terrestrial	Global	All	Technical	Impacts
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need complete taxonomic and spatial coverage . (Pereira & Cooper)	Ecosystem, Species	All	Global, Regional	All	Technical	Impacts
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need sufficient integration at different scales. (Pereira & Cooper)	Ecosystem, Species	All	Global, Regional	All	Technical	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need Regional assessments that combine satellite remote sensing with on-the-ground monitoring and aerial photographs. (Pereira & Cooper)	Ecosystem, Species	All	Regional	All	Technical	Response - Information Management
Pereira, Henrique M., and H. David Cooper. Towards the Global Monitoring of Biodiversity Change. TRENDS in Ecology and Evolution. Vol. 21(3). March 2006.	Biodiversity change: Need to develop global remote-sensing data sets for dryland degradation. (Pereira & Cooper)	Ecosystem	Desert, Grassland	Global	Remote	Technical	State
Phinn, S., Roelfsema, C., Dekker, A., Brando, V., Anstee, J. Mapping Seagrass Species, Cover and Biomass in Shallow Waters: An Assessment of Satellite Multi-spectral and Airborne Hyper-spectral Imaging Systems in Moreton Bay (Australia). Remote Sensing of Environment. Vol. 112: 3413-3425. 2008.	Need: 1) accurate mapping of seagrass cover, species composition and biomass, using high-spatial resolution (<5 m) and/or hyper-spectral image data. 2) additional research to determine if and how sea grass maps produced in this study are suitable for measuring attributes of seagrass biodiversity, and using these data for modeling floral and fauna biodiversity properties of seagrass environments, and for scaling-up seagrass ecosystem models. (Phinn, et. al)	Ecosystem, Species	Marine - shore line	All	Remote	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Puumalainen, J., Kennedy, P., and Folving, S. Monitoring Forest Biodiversity: a European Perspective with Reference to Temperate and Boreal Forest Zone. Journal of Environmental Management. Vol 67: pp5-14. 2003.	Need more detailed monitoring at landscape and stand level to detect change, especially changes in structural aspects of biodiversity dangers and habitat destruction. The value of the framework for landscape and stand level monitoring and applications needs additional testing. (Puumalainen, et al)	Ecosystem, Species	Forest - temperate, tiaga	Regional (national)	All	Technical	Impacts
Puumalainen, J., Kennedy, P., and Folving, S. Monitoring Forest Biodiversity: a European Perspective with Reference to Temperate and Boreal Forest Zone. Journal of Environmental Management. Vol 67: pp5-14. 2003.	Need improvements in separating and linking appropriate aspects of continuous processes to forest biodiversity monitoring to determine proper monitoring scope. (Puumalainen, et al)	Ecosystem, Species	Forest - temperate, tiaga	Regional (national)	All	Technical	State
Rouget, Mathieu, Cowling, R.M.., Vlock, J., Thompson, M., Balmford, A.. Getting the Biodiversity Intactness Index Right: the Importance of Habitat Degradation Data. Global Change Biology. Vol. 12 (11): pp2032-2036.	Need to develop cost-effective ground-truthing methods for quantifying the extent of land degradation in order to provide reliable estimates of biodiversity loss in southern Africa and elsewhere. (Rouget, et al.)	Ecosystem	Terrestrial	Local	In-situ	Technical	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Spehn, Eva. DIVERSITAS-Global Mountain Biodiversity Assessment and the University of Basel, Switzerland. GEO Task US-09-01a Advisory Group Member. Personal Communication. 2009.	Observation needs relevant for mountain biodiversity: Interoperability between biogeographical, remote sensing, ecosystem process and population dynamics data is enhanced. (Spehn)	Ecosystem, Species	Mountain	All	All	All	Response - System Infrastructure
Spehn, Eva. DIVERSITAS-Global Mountain Biodiversity Assessment and the University of Basel, Switzerland. GEO Task US-09-01a Advisory Group Member. Personal Communication. 2009.	Observation needs relevant for mountain biodiversity: (1)Experimental modeling and observation data are integrated to improve understanding of the mechanisms of biodiversity change. (2)Quantitative projections of biodiversity change should include multiples sources of uncertainty (Spehn)	Ecosystem, Species	Mountain	All	All	All	Response - Information Management
Teder, T., Moora M., Roosaluste E., Zobel K., Partel M., Koljalg U., and Zobel M. Monitoring of Biological Diversity: a Common-ground Approach. Conservation Biology: the Journal of the Society for Conservation Biology. Vol. 21(2): 313-317. 2007.	Need data on the distribution of specific ecosystem types within a target area (e.g., a country). With regard to broad-scale types, there would be an ecosystem (vegetation, habitat) map for the whole target territory. (Teder, et al.)	Ecosystem	All	All	All	Management, Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Teder, T., Moora M., Roosaluste E., Zobel K., Partel M., Koljalg U., and Zobel M. Monitoring of Biological Diversity: a Common-ground Approach. Conservation Biology: the Journal of the Society for Conservation Biology. Vol. 21(2): 313-317. 2007.	Detailed mapping is resource consuming, therefore priority should be given to the mapping of ecosystems of special interest (e.g., ecosystems unique or valuable from the point of view of nature conservation). (Teder, et al.)	Ecosystem	All	All	All	Management, Technical	State
Teder, T., Moora M., Roosaluste E., Zobel K., Partel M., Koljalg U., and Zobel M. Monitoring of Biological Diversity: a Common-ground Approach. Conservation Biology: the Journal of the Society for Conservation Biology. Vol. 21(2): 313-317. 2007.	Need more systematic monitoring of populations and habitats that focus on spatial distribution of taxa and ecosystems. (Teder, et al.)	Ecosystem, Species	All	All	All	Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Thenkabail, P.S., Eclona, E.A.., Ashton, M.S., Van Der Meer, B. Accuracy Assessments of Hyperspectral Waveband Performance for Vegetation Analysis Application. Remote Sensing of Environment. Vol. 91(3-4): 354-376. 2004.	Hyperspectral data is complex and a large amount of data can be collected in a short period of time. Need additional knowledge of: 1) optimal narrowbands, 2) potential improvements in accuracies over broadband sensors while considering cost, 3) assessment of optimal hyperspectral sensor configuration for a broad range of vegetation types in the spectral range of 0.4 - 2.5 um (studies currently done in a narrower portion of the spectrum (0.4 - 1.05 um). (Thenkabail et al.)	Ecosystem, Species	Terrestrial	All	Remote	Technical	State
Thenkabail, P.S., Eclona, E.A.., Ashton, M.S., Van Der Meer, B. Accuracy Assessments of Hyperspectral Waveband Performance for Vegetation Analysis Application. Remote Sensing of Environment. Vol. 91(3-4): 354-376. 2004.	It is important to determine the optimal short wave infrared radiometer (SWIR) bands. SWIR spectral bands are important in vegetation studies, however, broadbands are typically used. Need to use and understand the strengths of specific narrowbands. (Thenkabail et al)	Ecosystem, Species	Terrestrial	All	Remote	Technical	State
Thompson, Ian, D. Monitoring of Biodiversity Indicators in Boreal Forests: a Need for Improved Focus. Environmental Monitoring and Assessment. Vol. 121:263-273. 2006.	Need to go beyond community ecology studies to a detailed examination of habitats and demographics of individual species that are predicted to be negatively impacted by forest management practices. (Thompson)	Species	Forest - tiaga	Local	All	Management, Technical	State

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Thompson, Ian, D. Monitoring of Biodiversity Indicators in Boreal Forests: a Need for Improved Focus. Environmental Monitoring and Assessment. Vol. 121:263-273. 2006.	Much research is still needed on many poorly understood boreal forest species in order to select indicators from the full range of functional groups. (Thompson)	Species	Forest - tiaga	Global	All	Technical	State
Thompson, Ian, D. Monitoring of Biodiversity Indicators in Boreal Forests: a Need for Improved Focus. Environmental Monitoring and Assessment. Vol. 121:263-273. 2006.	Need to monitor local populations, not just species at the regional scale. (Thompson)	Species	Forest - tiaga	Local	All	Technical	State
Trisurat, Y., Alkemade, R. and Arets, E. Projecting forest tree distributions and adaptation to climate change in northern Thailand. Journal of Ecology and Natural Environment, Vol 1(3): 55-63. June 2009	High resolution future climate data (~1 km) for local assessment, especially in heterogeneous landscape, in addition to validate the results with long-term ecological research sites. Further research is needed to use research outputs for effective *in-situ* conservation. (Trisurat, et al.)	Ecosystem, Species	Terrestrial	Local and regional	All	Management, Technical	Pressures

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Turner, Woody, Spector, Sacha, Gardiner, Ned, Fladeland, Matthew, Sterling, Eleanor, and Steininger, Marc. Remote Sensing for Biodiversity and Conservation. TRENDS in Ecology and Evolution. Vol. 18(6). June 2003.	There is a need to acquire and synthesize scientific research data obtained thus far from biological and conservation scientists on species distribution, levels of species richness, areas of global endemism, etc., and combine it with obtained remote sensing data on global, regional and local climate, habitat structure, primary productivity….to determine species richness and distribution patterns. (Turner, et al.)	Ecosystem, Species	All	All	Remote	Management	Responses - Information Management
Turner, Woody, Spector, Sacha, Gardiner, Ned, Fladeland, Matthew, Sterling, Eleanor, and Steininger, Marc. Remote Sensing for Biodiversity and Conservation. TRENDS in Ecology and Evolution. Vol. 18(6). June 2003.	Link patterns of primary production, large scale species richness and abundance, and detailed information about functional types of organisms in their habitats. (Turner, et al.)	Ecosystem, Species	All	All	All	Management, Technical	State
Turner, Woody, Spector, Sacha, Gardiner, Ned, Fladeland, Matthew, Sterling, Eleanor, and Steininger, Marc. Remote Sensing for Biodiversity and Conservation. TRENDS in Ecology and Evolution. Vol. 18(6). June 2003.	Remote sensing data needs synthesis and distribution systems, because there is information availability problem. (Turner, et al.)	Ecosystem, Species	All	All	Remote	Management, Technical	Responses - System Infrastructure

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Turner, Woody, Spector, Sacha, Gardiner, Ned, Fladeland, Matthew, Sterling, Eleanor, and Steininger, Marc. Remote Sensing for Biodiversity and Conservation. TRENDS in Ecology and Evolution. Vol. 18(6). June 2003.	Beside understanding the habitat structure patterns of organisms, there is a need for active remote sensing of the organisms themselves (which focuses on studying organisms) in order to link individuals, communities and populations with their habitat structure. (Turner, et al.)	Ecosystem, Species	All	All	Remote	Management, Technical	State
Yoccoz, Nigel G., Nichols, James D., and Boulinier, Thierry. Monitoring of Biological Diversity in Space and Time. TRENDS in Ecology and Evolution. Vol. 16 (8). August 2001	It is preferred to measure biological diversity focused on system functioning including rate parameters that determine system dynamics, rather than solely on the state of the system. (Yoccoz, et al.)	Ecosystem, Species	All	Local	All	Technical	State
Yoccoz, Nigel G., Nichols, James D., and Boulinier, Thierry. Monitoring of Biological Diversity in Space and Time. TRENDS in Ecology and Evolution. Vol. 16 (8). August 2001	Future monitoring designs should incorporate both spatial sampling and detectability (used to estimate abundance at each sample plot) to obtain unbiased estimates of the relevant state variables thus allowing for better understanding of the spatial component of change in biological diversity and the underlying causes. (Yoccoz, et al.)	Species	All	Local	All	Technical	Impacts

Information Source/ Citation	Needs/Requirements	Biodiversity Organization (ecosystem, species, genetic)	Biome Type*	Spatial Scale global, regional, local)	Observation Type (remote, in-situ)	User Type (Technical, policy, management/ decision maker)	DPSIR* (drivers, pressures, state, impacts, responses)
Yoccoz, Nigel G., Nichols, James D., and Boulinier, Thierry. Monitoring of Biological Diversity in Space and Time. TRENDS in Ecology and Evolution. Vol. 16 (8). August 2001	There is a need to develop model sets that can be used for ecosystem management, such as for the interaction between large carnivores, ungulates and vegetation. (Yoccoz, et al.)	Species	Terrestrial	Local	All	Technical	State

Category Definitions

Biome Types*

Terrestrial Biome
- Desert
- Forest (tiaga, temperate, tropical)
- Grassland
- Tundra

Aquatic Biome
- Freshwater (rivers & streams; ponds & lakes; wetlands)
- Marine (shoreline; temperate ocean; tropical ocean)

DPSIR* (Drivers – Pressures – State – Impacts – Responses) is an assessment framework, as described by the European Environmental Agency (2003), and currently used by the ALTER-Net (A Long-Term Biodiversity, Ecosystem and Awareness Research Network) research community. This framework identifies each element of a continuous causal chain. Although the elements are listed separately they are interconnected and therefore can not be regarded as being independent. DPSIR has been demonstrated to be a useful model for analyzing inter-related factors.

Drivers - natural and social motivations and actions that influence levels of biodiversity

Pressures - establish connection between ecosystems and society, e.g., habitat/land use change, climate change, pollution, over harvesting/exploitation, invasive species.

State - biodiversity status, e.g., air, water, and soil quality, biodiversity assessment, network of long-term research sites.

Impacts - impact of drivers and pressures on biodiversity, e.g., impacts on natural systems, economic damage.

Responses - actions that can target any step in the chain with goal being an improved state of biodiversity, e.g., policy framework, public attitudes, biodiversity conservation options, regulations, pollution prevention. For our purposes I have created three subcategories:

- Organizational Infrastructure - refers to the process or institution needed to conduct the EO
- System Infrastructure - refers to the system/mechanism/network needed to utilize the EO information
- Information Management - refers to the models/methodologies to collect and use the EO information
- Evaluation - refers to needs identified to access effectiveness of action taken