System of Environmental Economic Accounting

Biodiversity Accounting

(Levels 1 & 2)

October 2017

United Nations

Structure: biodiversity accounting

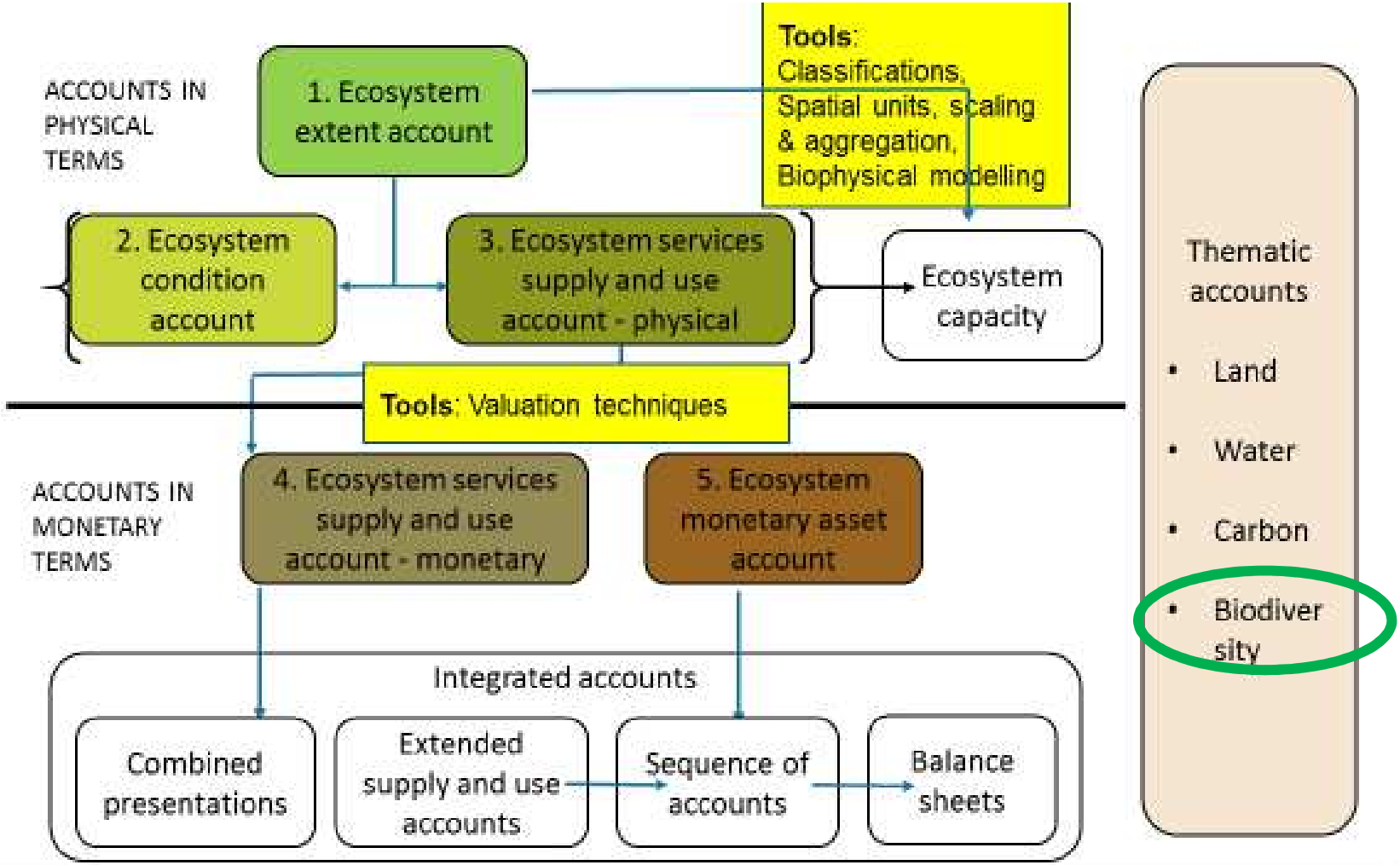
1. **Learning objectives**
2. **Review of level 0 (main concepts)**
   - > Summary
   - > Links to related training materials
3. **Level 1 (compilers)**
   - > Main concepts
   - > Group exercise and discussion
4. **Level 2 (data providers)**
   - > Data options, examples and issues
   - > Group exercise and discussion
5. **Closing discussion**

Learning objectives

- Level 0 – Overview:
  - Provide an overview of biodiversity accounting
- Level 1 – Compilers:
  - Understand the basic concepts of measuring biodiversity
  - Learn the steps of compiling a biodiversity account
- Level 2 – Data providers:
  - Understand the data options and sources
  - Understand the important conceptual issues
  - Be aware of how other countries have approached measuring biodiversity

Biodiversity accounting (level 0): review of basic concepts

SEEA EEA accounts, tools and linkages



Biodiversity accounting: What?

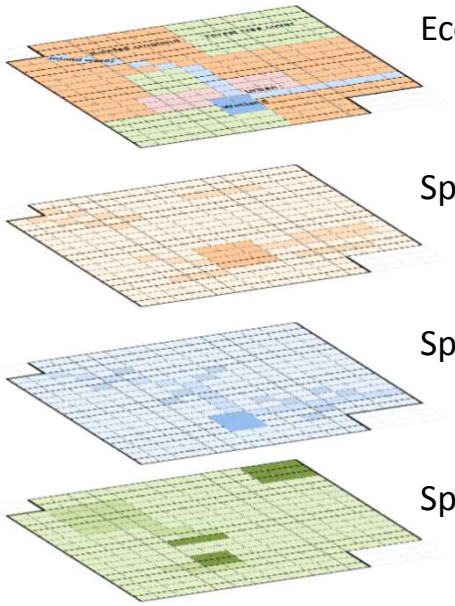
- **What do biodiversity accounts contain?**
  - Biodiversity information linked to areas of ecosystems (from extent account)
  - Spatially detailed information on key species:
    - Abundance
    - Richness
    - Conservation status
    - Other characteristics (e.g. health)
  - Spatially detailed summary statistics (index) on species diversity (used in condition account)

Biodiversity accounting: Why?

- **Why would you create biodiversity accounts?**
  - To compare trends in biodiversity with economic and social activity in a spatially explicit manner
  - To link biodiversity information with other SEEA accounts (condition, services supply)
  - To meet global commitments under the Convention on Biological Diversity's Strategic Plan for Biodiversity (2011-2020)
  - To support sustainable development

What does a biodiversity account look like?

Maps



Tables

	Priority species and ecosystems								Index
	Species 1		Species 2		Species 3		Species ...		
	Pop.	Ecosys. Area	Pop.	Ecosys. Area	Pop.	Ecosys. Area	Pop.	Ecosys. Area	
Reference									
Opening									
Closing									
Net change									

Species data:
- abundance
- richness
- classification
- conservation status
- characteristics
- health

Biodiversity account: requirements

- **What do you need to produce a biodiversity account?**
  - The key policy questions & goal of the biodiversity account
  - List of key or priority species
  - List of data sources (e.g., national, global) supported by a dialogue with data providers to ascertain data availability.
  - Expertise to mobilise data and plug data gaps:
    - Species measurement
    - Biophysical modelling, GIS
    - Indicator development
    - Statistical analysis

Biodiversity account: requirements

- **What do you need to produce a biodiversity account?**
  - Information on key or priority species
    - Species classifications (family, genus)
    - Species measures (ranges, richness, population counts over time)
    - Characteristics (e.g., habitat, specialist/generalist, health)
    - Conservation status
  - **Extent account** or some form of spatial infrastructure for ecosystems (**spatial units**)

Biodiversity accounting (level 1): compilers

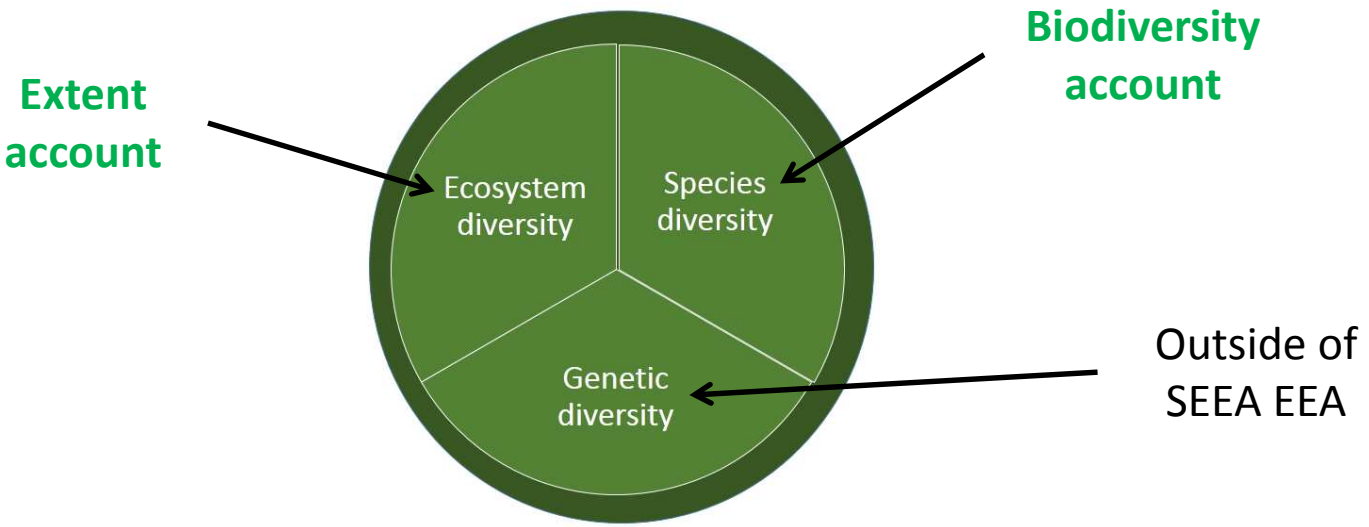
What is biodiversity?

Convention on Biological Diversity (CBD), 1992 defines biodiversity as:

> *"Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"*

Biodiversity in the SEEA-EEA

- Three components to biodiversity:



- …the measurement of biodiversity is focused on the assessment of diversity of species, although changes in the diversity of ecosystems is also an important output, derived from the measurement of changes in ecosystem extent and condition. (SEEA EEA, p 152).

Measurement of biodiversity

- **How do we measure biodiversity for inclusion in ecosystem accounts?**
  - **Ecosystem diversity** (mainly **extent account**):
    - Heterogeneity of ecosystems found in an area (e.g., number and extent of ecosystem types within a landscape)
  - **Species diversity** (**biodiversity account**):
    - **Species richness**: number of species within a given sample, area or community
    - **Species abundance**: total number of individuals of a species in an area, community or population
    - The dissimilarity between richness and abundance between areas

Measurement of biodiversity

- **Biodiversity measures:**
  - Species abundance: more sensitive thank richness
  - Species richness: most often used, but abundance is preferred
  - Species characteristics: health of biodiversity (e.g., disease prevalence)
  - Conservation status: extinction risk, a combination of distribution, population trends and threats (use IUCN's Red List methodology)

Measurement of biodiversity

- **How do we select species to prioritise?**
  - > species that directly deliver particular ecosystem services (e.g. pollinators)
  - > economically important species (e.g. game species related to tourism)
  - > culturally important species (e.g. sacred plants/animals)
  - > ecologically important species (e.g. keystone species)
  - > endemic species
  - > threatened species that face risk of extinction in the wild
  - > species selected should represent different taxonomic and trophic groups (e.g. mammals, birds etc.)

Measurement of biodiversity

- **How do we select species to prioritise?**
  - > **Taxonomic groups**:

    refers to the units of a rank that designates an organism to particular rank based on shared characteristics. 5 ranks:

    Kingdom, e.g., animals
    Phylum, e.g., vertebrates
    Class, e.g., mammals, birds, amphibians...
    Order, e.g., carnivores
    Family, e.g., cats
    Genus, e.g., panthers
    Species, e.g., lions

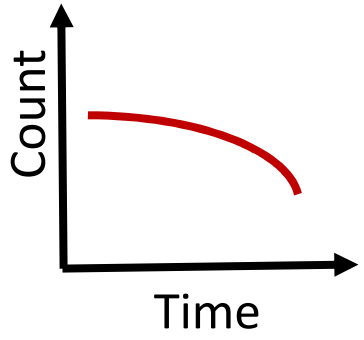
  - > **Trophic groups**:

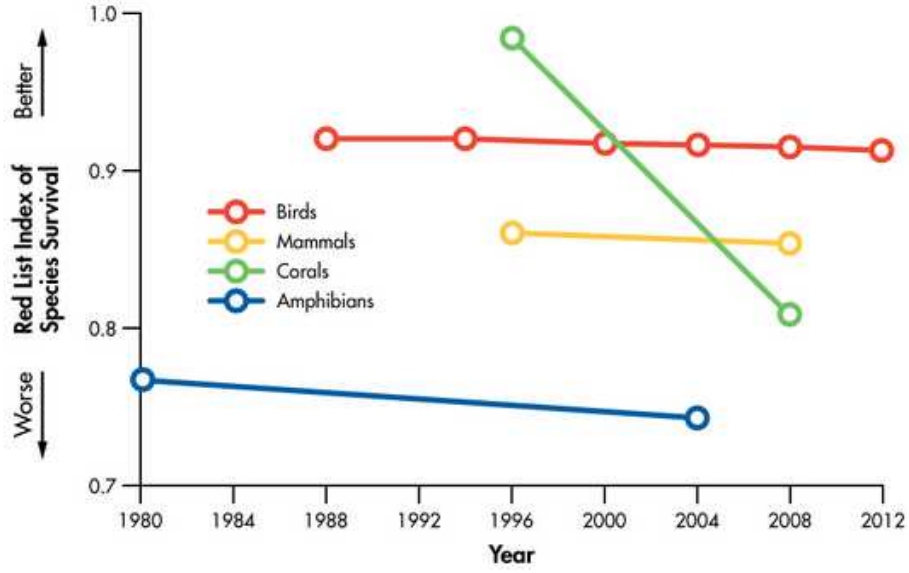
    refers to the level an organism occupies in a food chain:

    Producers, i.e., plants
    Consumers, i.e., animals that eat plants (herbivores) or other animals (carnivores)
    Decomposers, i.e., organisms that break down dead plants and animals

Measurement of biodiversity

- **How do we communicate measures of biodiversity?**
  - **Measure** is the phenomenon to be measured in a data set and are the basis for deriving indicators.
  - **Indicator** is a data element that represents statistical data for a specified time, place, and other characteristics.
  - **Index** is composed when a number of measures or indicators is combined.





Measurement of biodiversity

- **How do we use data and information in Biodiversity Accounts?**
  - **Measures**
    - Main data in the biodiversity account
    - Opening and closing measures of species richness, abundance or other information for priority species
    - May be supplemented with information on the sources of additions (e.g. births) and reductions (e.g. migrations or deaths)
  - **Indicators**
    - Output indicators captured from biodiversity accounts can link information on biodiversity to the ecosystem condition account (or progress to policy goals).
    - Constructing an index from relevant information in the biodiversity account can generate a biodiversity output indicator for the **ecosystem condition account**.

Biodiversity index

- **The Shannon Index**
  - Provides information on the richness and proportion of each species in a community

$$H' = -\sum_{i=1}^{R} p_i \, ln(p_i)$$

    - H' is the Shannon index
    - R is the total number of species in the sample
    - ln is the *natural logarithm*
    - p_i is the proportion of individuals in the i^{th} species in the sample
  - Maximum value depends on number of species = $ln(R)$

Biodiversity index

- **Shannon's equitability** (species evenness)
  - > Can provide information on the species evenness

$$E_{H'} = \frac{H'}{\ln(R)}$$

  - $E_{H'}$ is the equitability, with a value between 0 and 1, 1 is complete evenness
  - R is the number of species in the sample
  - *ln* is the *natural logarithm*
  - H' is the Shannon diversity index value

Biodiversity index (example)

- **The Shannon Index**
  - > Example: two ecosystems, three species, 270 individuals

Species	Ecosystem A			Ecosystem B		
	Individuals	p_i	$[p_i * ln(p_i)]$	Individuals	p_i	$[p_i * ln(p_i)]$
Lions	50	0.185	-0.31	90	0.333	-0.37
Tigers	200	0.741	-0.22	140	0.519	-0.34
Bears	20	0.074	-0.19	40	0.148	-0.28
Total	**270**		**H' = 0.73**	**270**		**H' = 0.99**

  - > Calculation: Ecosystem A, lions

$$[pi*\ln(pi)] = [(50/270) * \ln(50/270)]$$
$$= [0.19 * -1.69]$$
$$= -0.31$$

Biodiversity index (example)

- **Shannon's equitability**
  - > Example: two ecosystems, three species, 270 individuals

$$Evenness = \frac{Shannon\ index}{\ln(no.\ of\ species)}$$

	Ecosystem A	Ecosystem B
No. species	3	3
No. of individuals	270	270
Shannon Index	0.73	0.99
Evenness	0.66	0.90

  - > Both the diversity and evenness is greater in Ecosystem B

Compilation group exercise

- Situation:
  - > EAs defined in spatial units
  - > Have population counts for three key species
  - > Need to calculate Shannon Index for three forest EAs
- Objective (in groups of 3-5):
  1. Decide which three species you will prioritise and why
  2. Record species population data in appropriate cells in species table for each forest EA
  3. Using formulae provided, calculate a Shannon index and the species evenness for each forested EA
  4. Record this in the summary table

Step 1: Choose three species

Species prioritization and rationale

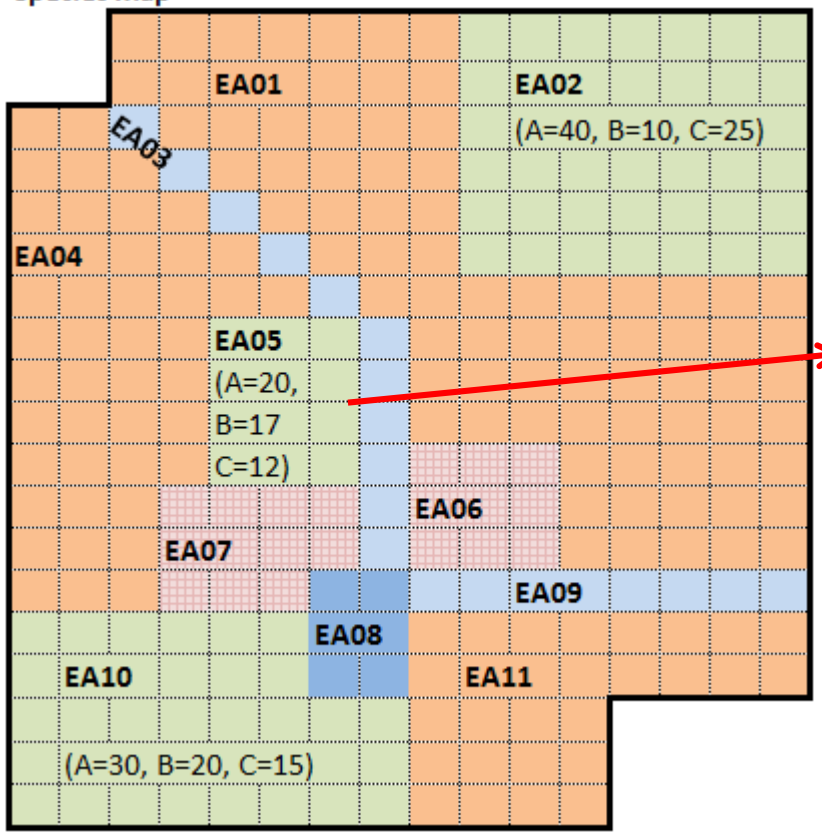
Species	Species name	Reason for selection
A		
B		
C		

Instructions:

Write down the three key species you will prioritize and why. When picking your key species, keep in mind the goal of the biodiversity account and how including that species will provide information to achieve that goal.

Step 2: Transfer data for forest EAs

Species Map



Species Table

EA	Individuals	p_i	$\ln(p_i)$	$p_i * \ln(p_i)$
EA02 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA05 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA10 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				

Step 3: Fill the table

Total individuals =
A + B + C

p_i is proportion of individuals
(e.g., 40 Species (A) /75 individuals = 0.53)

ln(p_i) is natural logarithm
(e.g., *ln*(0.53) = -0.63)

Multiply p_i by *ln*(p_i)
(e.g., 0.53 * -0.63 = -0.34)

Species Table

EA	Individuals	p_i	$\ln(p_i)$	$p_i * \ln(p_i)$
EA02 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA05 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA10 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				

Step 4: Calculate Shannon Index and Evenness

Add results for [$p_i * ln(p_i)$] for each forest EA

Multiply by -1

Record in summary table for each forest EA

Calculate

$$Evenness = \frac{Shannon\ index}{\ln(no.of\ species)}$$

Species Table

EA	Individuals	p_i	$\ln(p_i)$	$p_i * \ln(p_i)$
EA02 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA05 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				
EA10 = Forest tree cover				
Species (A)				
Species (B)				
Species (C)				

Summary Table

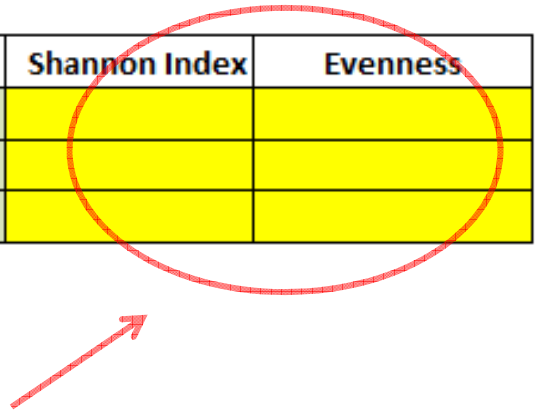
EA	Shannon Index	Evenness
EA02 = Forest tree cover		
EA05 = Forest tree cover		
EA10 = Forest tree cover		

Finalization

- Is everyone clear on the objectives?
- 30 minutes group work
- Please ask questions
- Results:
  - > Each group report:
    - Shannon Index result for each forest EA
    - Species evenness
  - > Which is the least diverse (lowest Shannon Index)?
  - > Why is this less diverse than the other two EAs?

Summary Table

EA	Shannon Index	Evenness
EA02 = Forest tree cover		
EA05 = Forest tree cover		
EA10 = Forest tree cover		



Answers

EU02 is the least diverse

This is because species A dominates the number of individuals (p_i = 0.53), giving a lower evenness score (0.88)

Species Table

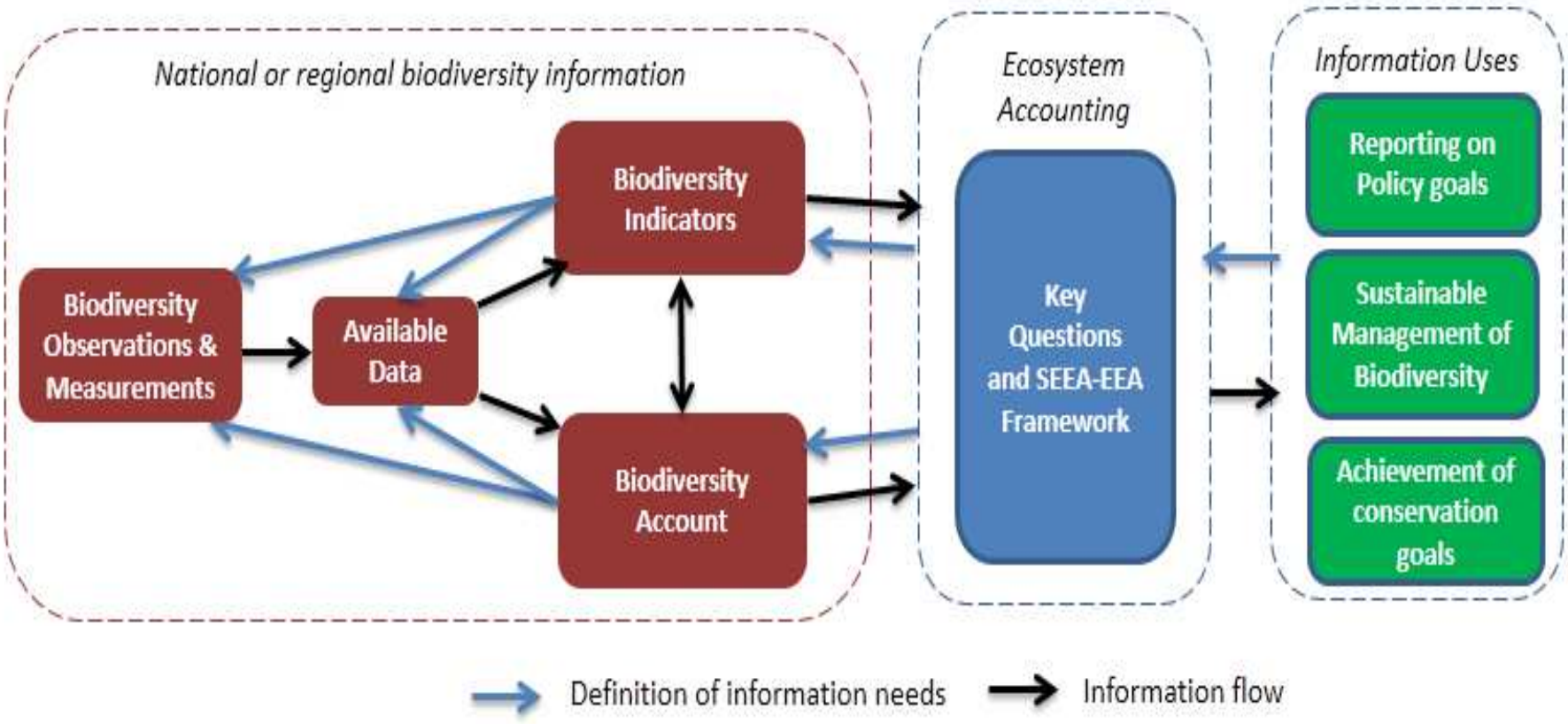
EA	Individuals	p_i	$\ln(p_i)$	$p_i * \ln(p_i)$
EA02 = Forest tree cover	75			
Species (A)	40	0.53	-0.63	-0.34
Species (B)	10	0.13	-2.01	-0.27
Species (C)	25	0.33	-1.10	-0.37
EA05 = Forest tree cover	49			
Species (A)	20	0.41	-0.90	-0.37
Species (B)	17	0.35	-1.06	-0.37
Species (C)	12	0.24	-1.41	-0.34
EA10 = Forest tree cover	65			
Species (A)	30	0.46	-0.77	-0.36
Species (B)	20	0.31	-1.18	-0.36
Species (C)	15	0.23	-1.47	-0.34

Summary Table

EA	Shannon Index	Evenness
EA02 = Forest tree cover	0.97	0.88
EA05 = Forest tree cover	1.08	0.98
EA10 = Forest tree cover	1.06	0.96

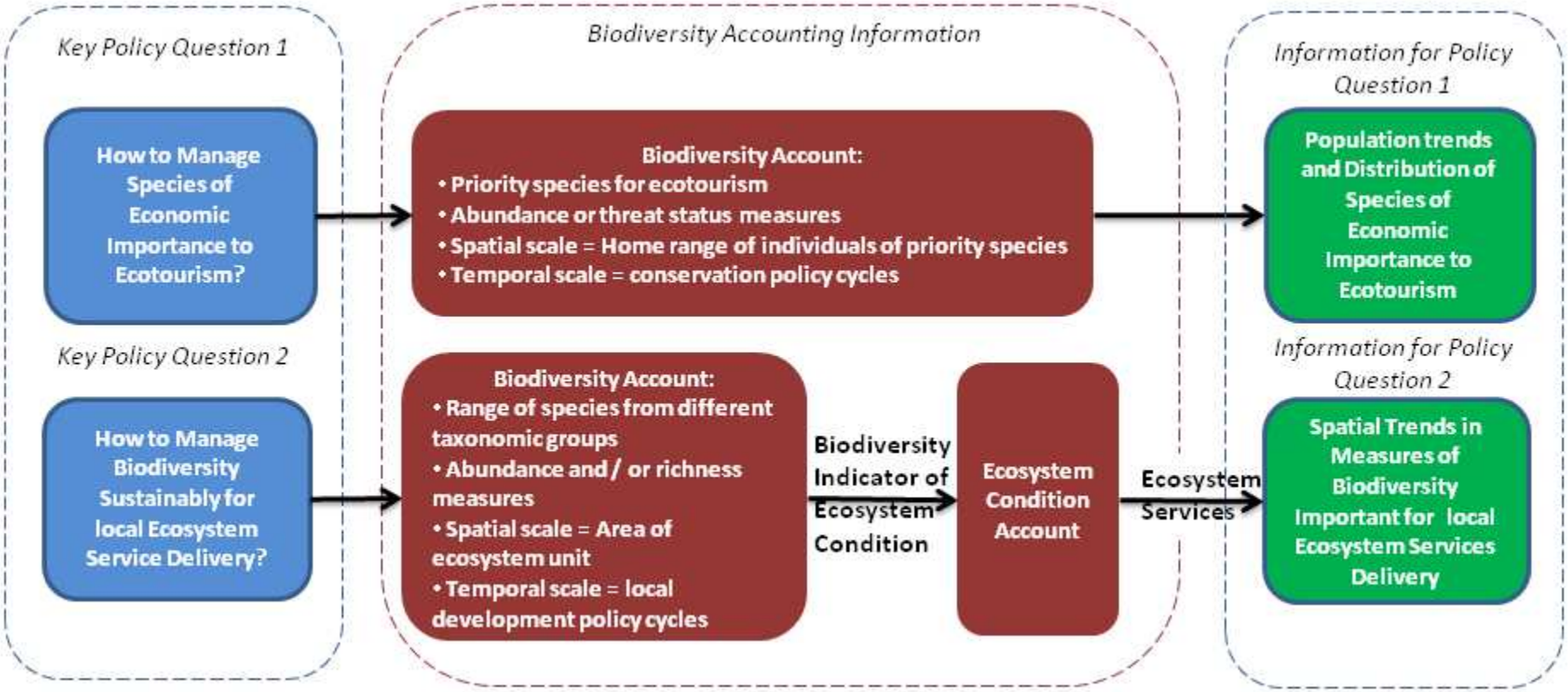
Biodiversity accounting (level 2): data providers

Information uses and data requirements



Adapted from a diagram produced in the EU BON Project

Example policy questions



Data options and sources

- Conduct an inventory of existing species diversity information, including:
  - National and sub-national monitoring schemes
  - National Red List
  - Governmental agencies, NGOs, universities and museums
  - Reporting to regional processes and international conventions
- Ecosystem diversity
  - Some information captured by the extent account
    - Land cover, vegetation maps (spatially-detailed)
    - River system maps (e.g., linearly delineated by Strahler stream order)
    - Marine habitat maps (spatially delineated on basis of Bathymetry and others characteristics)

Format of biodiversity data

- Measures
  - This includes raw, on the ground data (e.g. species abundance or richness for different taxonomic groups)
- Relative Measures
  - This compares the measure to a reference condition.
  - Normalized around 1 or 100
  - Sources: minimal human disturbance (SEEA), ecological sustainability (NNI), first accounting period (accrual, Living Planet Index) or aspirational.
- Headline output indicator(s)
  - Index of all relevant biodiversity data in account
  - May need more than one (e.g., one for ecosystem condition, one conservation goals)
  - Will need expert ecological knowledge

Plugging Species Diversity Data Gaps

- Develop national species monitoring programme
- Estimation approaches
  - > Human drivers based models (e.g. Alkemade, 2009)
  - > Statistical habitat suitability models (Phillips, 2006)
  - > Expert judgement (e.g. Scholes and Biggs, 2005)
  - > Species-area curve (Brooks et al., 2002).
  - > Issues: Species may not exist in areas of suitable habitat.
  - > Solutions: Validation and calibration of species diversity measures using targeted monitoring programmes
- Qualitative Approaches
  - > For example 'very abundant', 'abundant', 'common', 'rare' and 'very rare' as broad classes for species abundance.

Conceptual issues

- Data on species **ranges and characteristics** are often incomplete
- **Migration and mobility** (e.g., birds are often recorded where they breed and bears can range over many habitat types)
- **Functional diversity**: some species are more important to the functioning of the ecosystem; some overlap in function
- **Conservation priority** species may not be of high importance for ecosystem condition
- May need **more than one account** to answer different policy questions
- **Invasive species** (more information required)
- **Reference conditions** (more information required)
- May need **more than one indicator** to track policy progress and report ecosystem condition
- How to aggregate biodiversity measures across ecosystems?

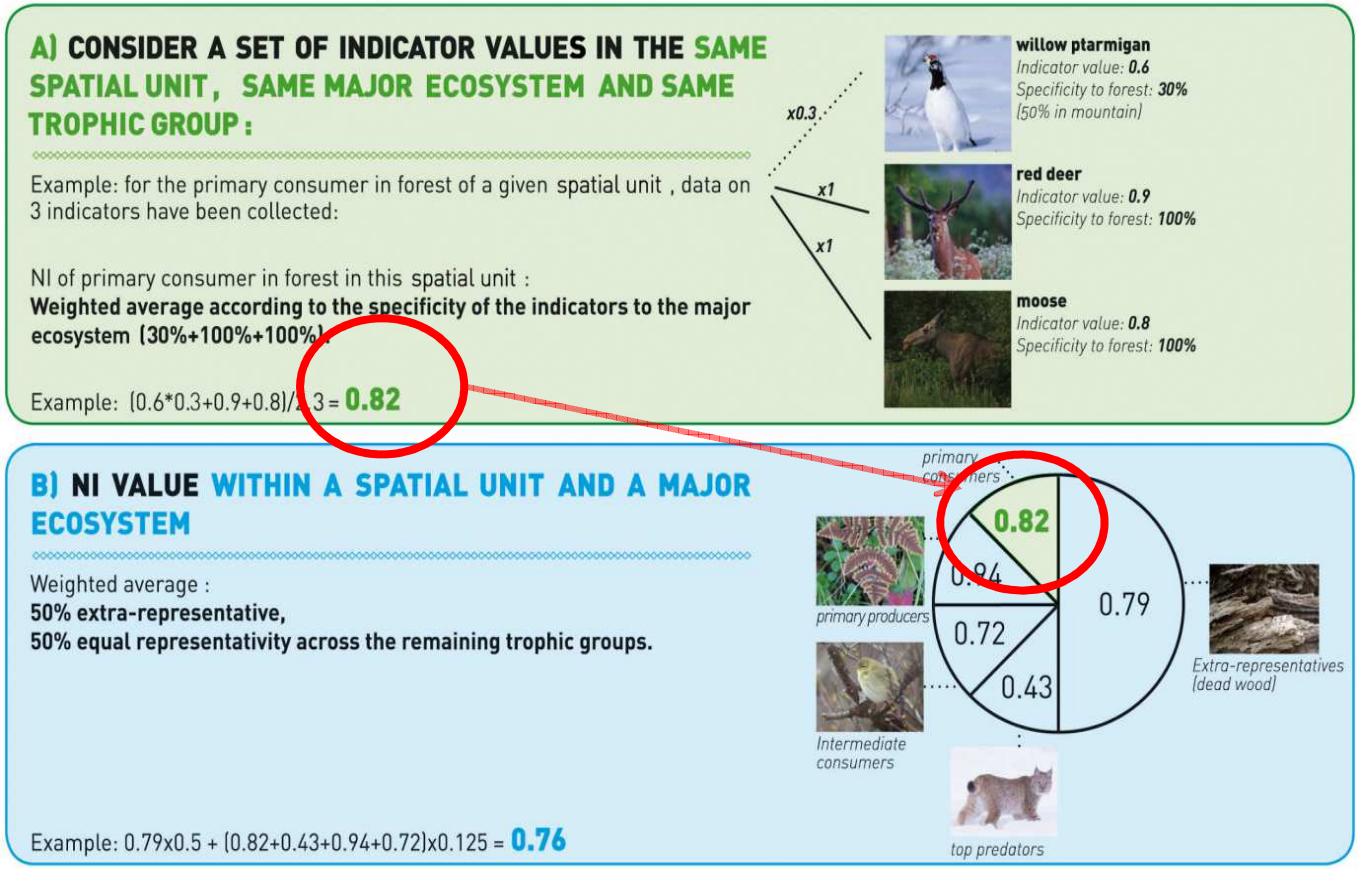
Biodiversity accounting: examples

Example 1: Norway's Nature Index

- Norway's Nature Index (Certain and Skarpaas, 2011) records for each species in index (of about 300):
  - Taxonomic group
  - Red list status
  - Presence in region
  - Specificity to habitat
  - Trophic group (primary producer, herbivore, predator, carnivore)
  - Keystone species
  - Generality (specialist or generalist species)
  - Community (indicator refers to population or community),
  - Sub-habitat (description)
  - Ecosystem service (contributing to)
  - Quick response to environmental change
  - Sensitive to which pressure
  - Migrating
  - Multiple major habitats
  - Reference value (i.e., value of "reference state" chosen)

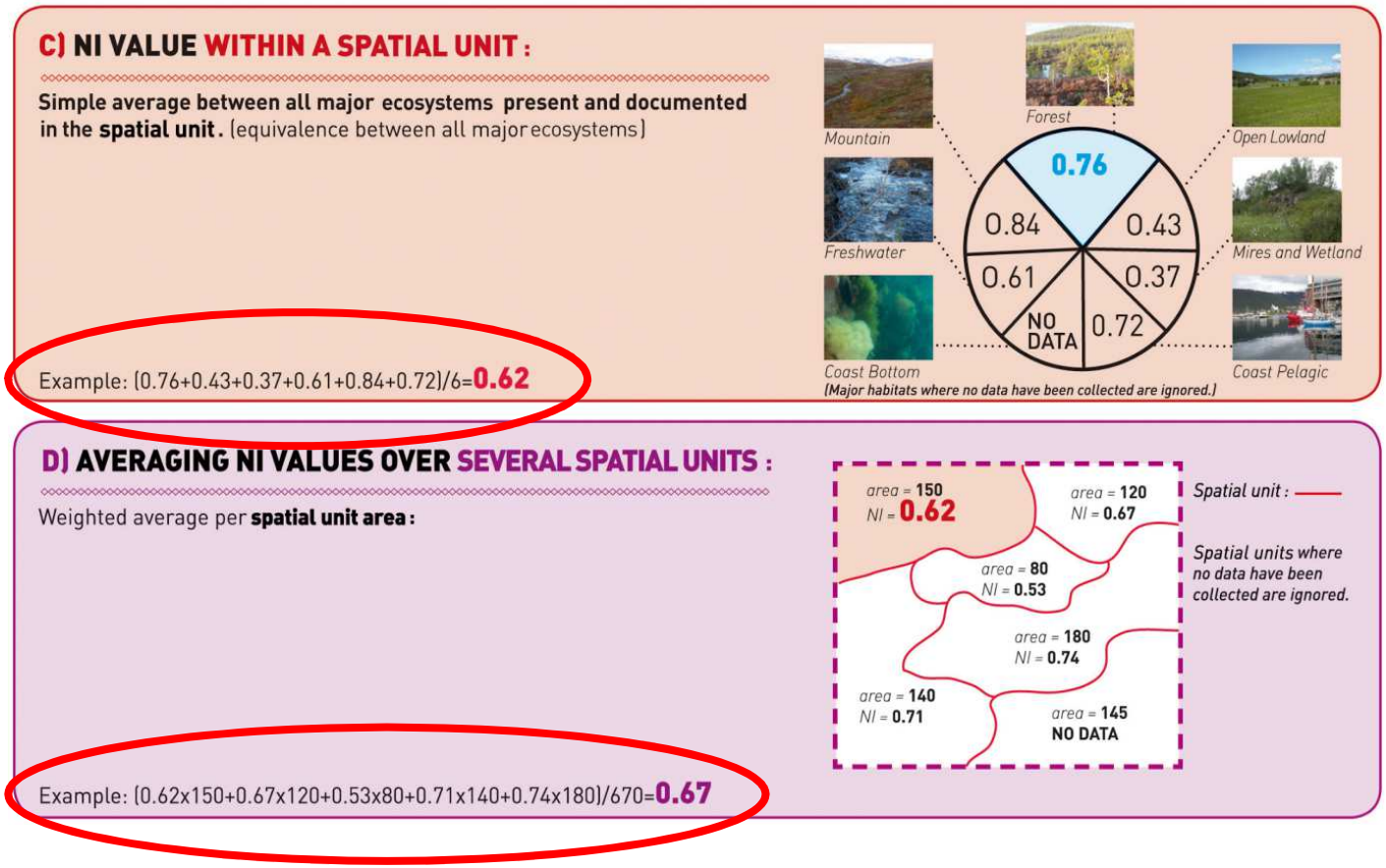
Example 1: Norway's Nature Index

- **Construct** an index for a species group based on relative measures of key species in an ecosystem.
- **Combine** several indexes for ecosystem area



Example 1: Norway's Nature Index

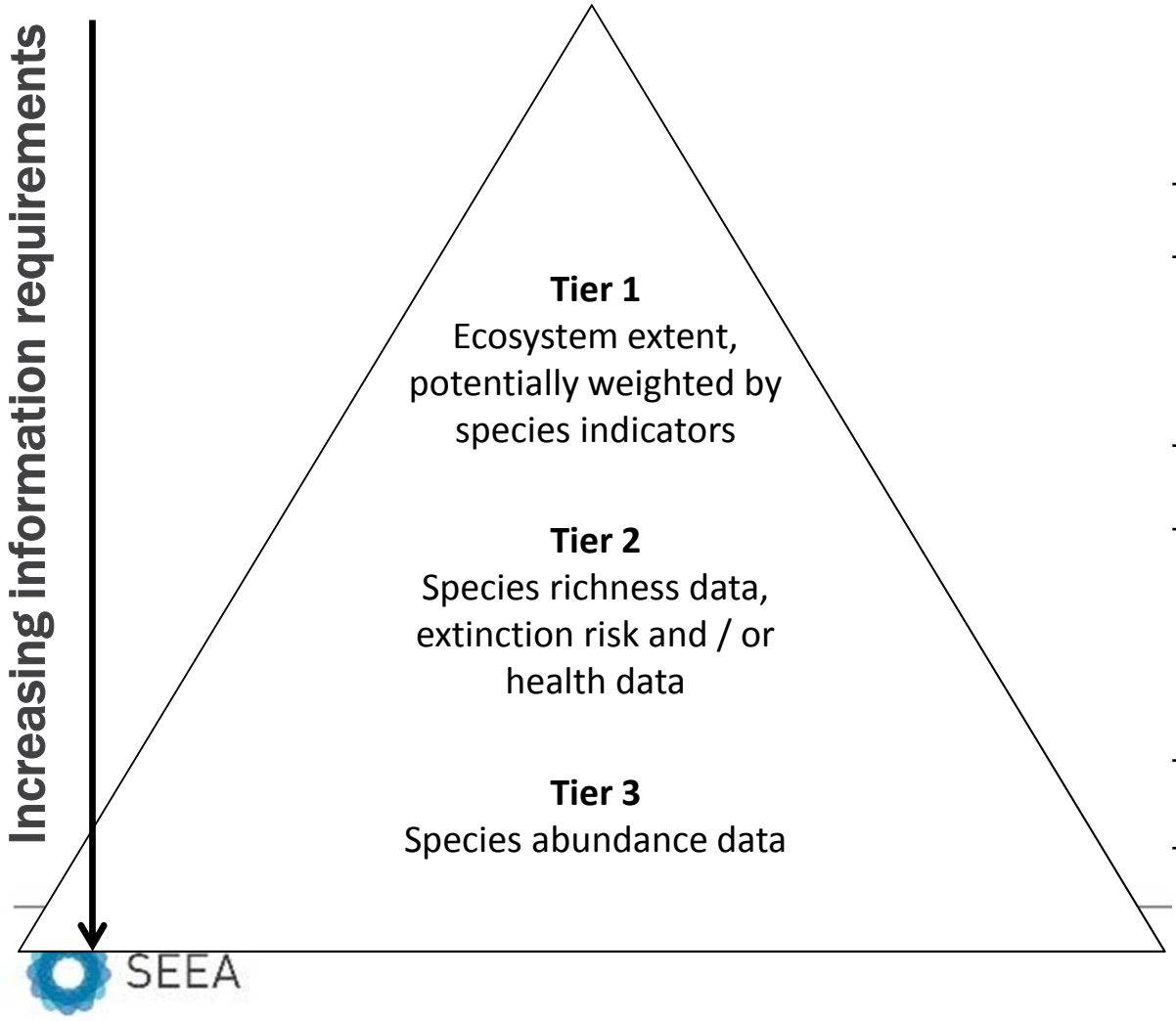
- **Aggregate across all ecosystems** in a spatial area
- **Aggregate across all spatial areas**



Example 2: IUCN National Red List

- Information relevant to species' extinction risk is considered from published and grey literature, museum records and specimen databases. Specifically relating to:
  - Species distribution
  - Population trend information
  - Habitat, ecology and life history information
  - Threats to the species
  - Conservation measures currently in place
- Supported by national workshops that rely on local species experts to provide validation.
- Implemented in many countries: Ecuador, Finland, Norway, Spain, Sri Lanka, Thailand etc.

Example 3: montane coniferous forest



Examples of information recorded for a montane coniferous forest ecosystem asset (EA)
Tier 1:
Montane coniferous forest EA extent, weighted by an input condition indicator (e.g. deadwood).
Tier 2:
Species richness of montane coniferous forest EA. Supplemented with information on species Red List status.
Tier 3:
Species abundance monitoring data for montane coniferous forest EA.

SEEA

Approach by tiers – tier 1

- 'Tier 1' approach, using indicator weighted habitat area
- Example based on Norwegian Nature Index approach

	Habitat Area	**Bird Population (x)**	**Species Richness (y)**	**Butterfly population (z)**	**Headline Indicator (HI)**	**Stock**
Indicator Weight		*0.25*	*0.50*	*0.25*	*HI = 0.25x + 0.50y + 0.25z)*	*Stock = HI * Area*
Open (2000)	5.0	0.90	0.80	0.70	0.8000	4.000
Additions	1.0	0.00	0.10	0.15	0.0875	0.525
Reductions	0.0	0.10	0.05	0.05	0.0625	0.375
Close (2010)	6.0	0.80	0.85	0.80	0.8250	4.950
Net Change	+1.0	-0.10	+0.05	+0.10	+0.0250	+0.950
Reference	N/A	Level in 1970	Level in 1970	Level in 1970	N/A	N/A

Approach by tiers – tier 2

- 'Tier 2' approach, based on species **richness** and status
- Example from an Australian terrestrial area for year 2000 (Bond et al., 2011)

	Introduced species	Native species				
		Unprotected	Protected	Rare and endangered	*Total native species*	Total species
Animals						
Vertebrates						
-Mammals	15	2	112	20	114	129
-Birds	10	0	458	33	458	468
-Reptiles	2	0	202	26	202	204
-Amphibians	1	0	51	9	51	52
-Bony fish	4	56	0	0	56	60
-Cartilaginous fish	NA	NA	NA	NA	NA	NA
-Insects	0	11	2	0	13	13
Subtotal	*32*	*69*	*825*	*88*	*894*	*926*
Plants	**376**	5	3239	91	3244	6320
Subtotal	*376*	*5*	*3239*	*91*	*3244*	*6320*
Fungi	**0**	0	68	0	68	68
Subtotal	*0*	*0*	*68*	*0*	*68*	*68*
Protista	**0**	0	148	0	148	148
Subtotal	*0*	*0*	*148*	*0*	*148*	*148*
TOTAL	**408**	**74**	**4280**	**179**	**4354**	**4762**

SEEA

Approach by tiers – tier 3

- Example 'Tier 3' approach, based on species abundance.

	Animals				Plants	Headline Indicator (HI)
	Mammals	Birds	Reptiles	Invertebrates		
Weight	u	v	x	y	z	
Open (2000)	1.00	1.00	1.00	1.00	1.00	
Additions	0.05	0.00	0.00	0.15	0.10	
Reductions	0.10	0.15	0.05	0.05	0.05	
Close (2010)	0.95	0.85	0.95	1.10	1.10	
Net Change	-0.05	-0.15	-0.05	+0.10	+0.05	
Reference	Level in 2000	Level in 2000	Level in 2000	Level in 2000	Level in 2000	

Concepts group exercise

- In groups of 3-5: (30 min)
  1. Develop a key policy question for biodiversity accounting
  2. Describe what information will be required to answer this question
  3. Describe an appropriate spatial scale to collect this data and how often it will need to be updated.
  4. List specific data sources which already exist that can be used
  5. Suggest some processes to plug any data gaps
  6. List resources required to mobilise data for biodiversity accounting
  7. Report your results

Concepts group exercise - discussion

- Closing discussion (15m)
- Group reports
  - Key policy question
  - Description of data required
  - Possible sources of data
  - Protocols to plug gaps
  - Broad description of resources required
- Discussion
  - Data sources suggested?
  - Issues with the ways of plugging data gaps suggested?
  - Anything else important?

Other related training materials

- Secretariat for the Convention on Biological Diversity (SCBD)
  - > Quick Start Package (QSP) (Weber, 2014)
    - Available online at www.ecosystemaccounting.net
    - Includes free GIS software and tutorials
  - > National Biodiversity Strategies and Action Plans
    - Training modules at www.cbd.int/nbsap/training/
- World Bank WAVES: http://www.wavespartnership.org/en
- SEEA EEA Technical Recommendations (forthcoming): https://seea.un.org/ecosystem-accounting
- Statistics Canada:
  - > Measuring Ecosystem Goods and Services Teacher's Kit

References

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Acknowledgements

These materials have been developed in partnership with various organizations including the United Nations Statistics Division, UN Environment, the Convention on Biological Diversity, supported by the Norwegian Ministry of Foreign Affairs, and the European Union.

United Nations UNEP Convention on Biological Diversity NORWEGIAN MINISTRY OF FOREIGN AFFAIRS