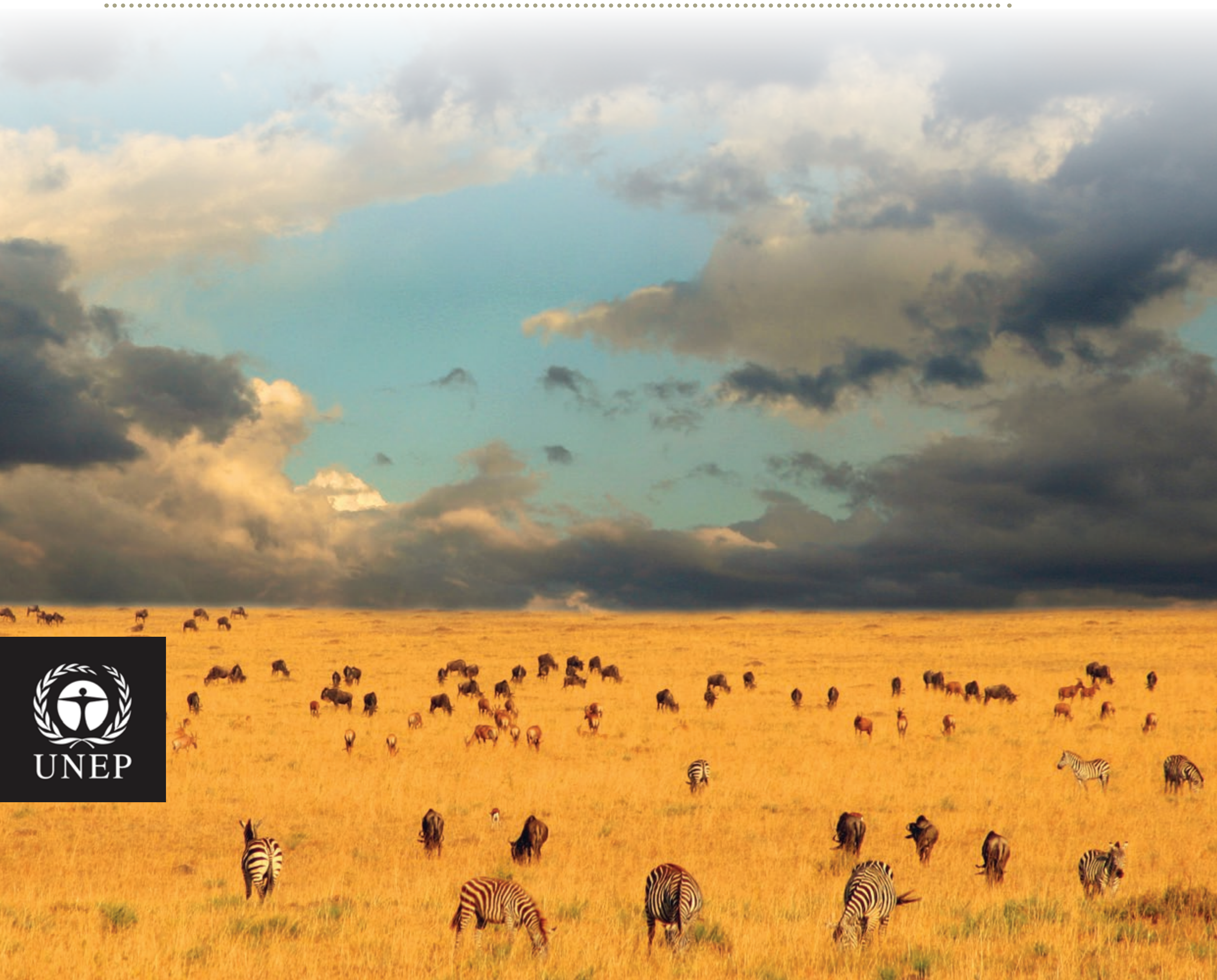
EXPLORING APPROACHES FOR CONSTRUCTING SPECIES ACCOUNTS IN THE CONTEXT OF THE SEEA-EEA



UNEP

Coordinating lead authors

Steven King, Claire Brown, Mike Harfoot and Lucy Wilson

Contributing authors

Katie Bolt (RSPB), Neil Brummitt (Natural History Museum), Stuart Butchart (Birdlife International), Bridget Emmett (Centre for Ecology and Hydrology), Julian Chow (UNSD), Amanda Driver (SANBI), Mark Eigenraam (IDEEA Group), Simon Ferrier (CSIRO), Per Arild Garnåsjordet (Statistics Norway/NINA), Hedley Grantham (Wildlife Conservation Society), Lars Hein (Wageningen University, NL), Craig Hilton-Taylor (IUCN), Emil Ivanov (University of Nottingham), Daniel Juhn (Conservation International), Georgina Mace (University College London), Ronald Kaggwa (Uganda National Planning Authority), Trond Larsen (Conservation International), Francis Ogwal (Uganda National Environmental Management Authority), and Jan-Erik Petersen (European Environment Agency).

This work was coordinated by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). The step-by-step approach for constructing Species Accounts that is presented in this document is informed by a three-day workshop held at UNEP-WCMC's offices in Cambridge in February 2016. The work has been funded by the Norwegian Ministry of Foreign Affairs and the Swedish International Development Cooperation (SIDA).

Acknowledgements

We gratefully acknowledge the input and support from Alessandra Alfieri and Ivo Havinga (UNSD), Rocky Harris (DEFRA), Carl Obst (IDEEA Group), Stig Gustaf Johansson (the World Bank), Michael Vardon (ANU, World Bank), Ken Joseph Bagstad (USGS, World Bank), Hilary Allison, Arnout van Soesbergen and James Vause (UNEP-WCMC), Thomas Brooks and Caroline Pollock (IUCN), Lisa Waselikowski and Markus Erhard (European Environment Agency), Iulie Aslaksen (Statistics Norway), and Olav Skarpaas Signe Nybø, Erik Framstad and Baard Pedersen (The Norwegian Institute for Nature Research).

For providing the case study material for Wales, we would like to thank the CEH team (Bridget Emmett, Lindsay Maskell, Simon Smart, Gavin Siriwardena and Bronwen Williams). For providing the Peru case study material, we would like to thank Daniel Juhn, Trond Larsen and Hedley Grantham (Conservation International); Simon Ferrier (CSIRO Australia); Roger Loyola and Araceli Urriola (Ministerio del Ambiente, MINAM); Jose Luis Robles Franco, Judith Samaniego and Eliana Quispe (INEI); Fernando Grandez Veintimilla and Yzia Encomenderos (Económico del Gobierno Regional de San Martín, GRDE); and Mario Rios, William Velasquez, Silvia Reategui and Richard Bartra (Autoridad Regional Ambiental, ARA).

Citation

UNEP-WCMC (2016) Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA.

Copy edited by Helen Walsh (www.lonelycottage.co.uk)

Layout: Ralph Design Ltd. (www.ralphdesign.co.uk)

Front cover image © Lorimer Images / shutterstock.com

ISBN: 978-92-807-3582-6
DEP/2017/CA

UNEP WCMC

UNEP World Conservation Monitoring Centre (UNEP-WCMC)
219 Huntingdon Road,
Cambridge CB3 0DL, UK
Tel: +44 1223 277314
www.unep-wcmc.org

Contents

LIST OF FIGURES, TABLES AND BOXES

Figures

Tables

Boxes

Summary

***Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA* proposes an initial step-by-step process for developing spatial accounts of species status. Such 'Species Accounts' can be constructed as standalone accounts, or as part of the wider System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) process. It provides a framework for developing a minimum set of Species Accounts and mobilising the data they contain into summary statistics that reflect species diversity, fit with identified needs and are appropriate for end users. To this end, early and consistent engagement and communication with a diverse range of stakeholders is central to constructing Species Accounts that are relevant, credible and legitimate. Developing an effective stakeholder engagement and communication strategy, and establishing an appropriate governance structure that can inform each step of the process, is critical. It is intended that this document be used by those interested in the research and development of Species Accounts, such as environmental and biodiversity agencies, institutes and other organisations.**

The eleven steps to developing Species Accounts as outlined in this guide are:

1) **Define uses and users**. The key policy questions and analytical uses for the accounts are determined. This provides the foundation upon which the accounts are constructed in order to ensure they satisfy user needs.

2) **Select species of special concern and scope data**. Species relevant to the needs identified in Step 1 are selected and the availability of data for these species is scoped.

3) **Decide the approach and type of Species Accounts**. A series of sub-steps are completed in order to identify the most appropriate approach for constructing selected Species Accounts.

4) **Decide the Reporting Units, frequency and summary statistics**. The spatial scales and reporting units for the Species Accounts are determined. Additionally, the frequency of data compilation and procedures for generating meaningful summary statistics (composite indicators/indices) from the data are established.

5) **Collate and prepare data**. The data scoped in Step 2 is collated and prepared in a format suitable for populating Species Accounts.

6) **Populate Species Accounts**. The data collated and prepared in Step 5 is inputted into the set of Species Accounts and summary statistics (composite indicators/indices) are calculated.

7) **Identify and fill gaps in the Species Accounts**. The Species Accounts are reviewed and any gaps in the data identified. Where data gaps exist, options for addressing these are assessed and implemented where necessary.

8) **Organise and aggregate Species Accounts**. Procedures for presenting multiple Species Accounts for different ecosystems within Reporting Units and aggregating species information to larger scales are reviewed and implemented where necessary.

9) **Analyse and integrate Species Accounts**. The information contained in the Species Accounts is analysed in the context of the key analytical uses and policy questions identified in Step 1.

10) **Communicate and use**. A strategy for communicating the findings of the Species Accounts to key stakeholders and wider audiences is developed.

11) **Review and refine**. The Species Accounts are reviewed and intervention options for refinement and improvement identified.

While these steps are presented in a sequential fashion, choices made in the early stages of the process will have implications for options available later on. Therefore, this document should be read thoroughly in advance and a sequence of likely actions determined in order to inform the construction of Species Accounts on a case-by-case basis. Throughout, the suitability of the different methods proposed under each step should be reviewed in light of the intended uses of the Species Accounts, resources available and the most appropriate scale for their construction.

This document is intended to be an initial step towards developing guidelines for constructing Species Accounts that can be implemented in all the world's countries. As such, it is part of a process that will develop over time and through experimentation. We hope that the approach presented here will be tested by national agencies, research institutes and other organisations to determine its applicability in different situations. With such a new approach, any initial Species Accounts will be experimental, so it is important to record experiences, and identify and implement improvements in the accounts over time. These experiences will help to improve future approaches to species accounting based on the lessons learnt. Feedback from users of this document will be gratefully received.

Résumé

Le guide d'examen des stratégies de recensement des espèces dans le cadre de la Comptabilité expérimentale des écosystèmes du SCEE *(Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA)* propose un processus progressif de recensement géographique des espèces par statut. Les recensements d'espèces peuvent être réalisés de façon indépendante ou s'inscrire dans le processus de Comptabilité expérimentale des écosystèmes du Système de comptabilité économique et environnementale (SCEE), qui fournit un cadre à la réalisation d'un ensemble minimal de recensements d'espèces et l'élaboration, à partir des données recueillies, de statistiques sommaires adaptées aux utilisateurs finaux qui reflètent la biodiversité et répondent aux besoins identifiés. La mobilisation précoce et durable d'un large éventail de parties prenantes, ainsi que la mise en place d'une bonne stratégie de communication avec elles, sont indispensables pour garantir la pertinence, la crédibilité et la légitimité des recensements d'espèces. Il est par conséquent essentiel de mettre au point une stratégie efficace en ce sens et d'établir une structure de gouvernance appropriée sous-tendant chaque étape du processus. Le présent document est destiné à l'usage des agences de protection de la biodiversité ou de l'environnement et de tout autre institut ou organisme s'intéressant à la recherche et au développement de recensements d'espèces.

Le respect de la stratégie présentée dans ce document donnera principalement lieu à des « recensements d'espèces préoccupantes ». Les données peuvent être collectées par le biais de l'observation directe des différentes espèces (par le comptage des populations notamment) ou de l'observation des espèces dans leur milieu, qui reposent chacune sur des méthodes de modélisation différentes. Suivant le rôle que doivent remplir ces recensements, les espèces préoccupantes peuvent être classées en fonction de leur thème de conservation, de l'état de leur écosystème, ou des services écosystémiques qu'elles fournissent. Nous recommandons d'organiser les recensements d'espèces préoccupantes par type d'écosystème et à une échelle spatiale adaptée aux décisions qu'ils doivent venir étayer. Le présent document fournit également des informations sur la réalisation de recensements d'espèces figurant sur la liste rouge, et de recensements sur l'étendue des sites importants pour les espèces.

Les sept étapes de la réalisation de recensements d'espèces présentées dans ce guide sont les suivantes :

1) **Définition des usages et des utilisateurs.** Les principales questions stratégiques et analyses que doivent alimenter les recensements sont déterminées. Elles constituent la base à partir de laquelle les recensements seront établis de façon à satisfaire les besoins des utilisateurs.

2) **Sélection des espèces préoccupantes et analyse des données.** Les espèces répondant aux critères définis lors de l'étape 1 sont sélectionnées et l'étendue des données disponibles sur ces espèces est évaluée.

3) **Choix de la stratégie et du type de recensement à mettre en œuvre.** Une série de sous-étapes permet d'identifier la stratégie la plus appropriée au recensement des espèces sélectionnées.

4) **Définition des unités de rapport, de la fréquence et des statistiques sommaires.** Les échelles spatiales et les unités de rapport des recensements sont établies, de même que la fréquence d'élaboration des données et les procédures à respecter pour mettre au point des indicateurs ou indices composites pertinents à partir des données.

5) **Assemblage et préparation des données.** Les données analysées lors de l'étape 2 sont assemblées et mises en forme pour le recensement.

6) **Recensement.** Les recensements d'espèces sont effectués et les statistiques sommaires (indicateurs/indices composites) établies à partir des données rassemblées et préparées lors de l'étape 5.

7) **Identification et compensation des lacunes du recensement.** Les recensements d'espèces sont contrôlés et toutes les lacunes sont identifiées. En cas de lacune, les solutions envisageables sont évaluées et mises en œuvre si nécessaire.

8) **Présentation et agrégation des recensements.** Les méthodes de présentation de plusieurs recensements pour différents écosystèmes au sein d'unités de rapport données et les stratégies d'agrégation des informations sur les espèces sont évaluées et mises en œuvre si nécessaire.

9) **Analyse et intégration des recensements.** Les informations contenues dans le recensement sont examinées à la lumière des principales analyses et questions stratégiques identifiées lors de l'étape 1.

10) **Communication et utilisation.** Une stratégie de communication des résultats des recensements auprès des principales parties prenantes et du grand public est mise au point.

11) **Évaluation et améliorations.** Les recensements sont évalués et les améliorations possibles identifiées.

Ces différentes étapes sont présentées ici par ordre chronologique, mais les choix effectués au début du processus auront des conséquences sur les options disponibles lors des étapes suivantes. Il est donc préférable de lire au préalable le guide dans son intégralité et de définir une suite d'actions probables de manière à réaliser des recensements d'espèces spécifiques à chaque cas. Tout au long du processus, la pertinence des différentes méthodes proposées pour chaque étape doit être évaluée à la lumière des utilisations prévues, des ressources disponibles et de l'échelle la plus appropriée pour le recensement.

Le présent document constitue un premier pas vers l'élaboration de directives pour la réalisation de recensements d'espèces dans le monde entier. Il s'inscrit ainsi dans un processus qui se développera au fil du temps et des expériences. Nous espérons que la stratégie présentée ici sera mise à l'essai par des agences nationales, des instituts de recherche et d'autres organismes de façon à vérifier son applicabilité dans divers contextes. Le caractère nouveau de cette stratégie signifie que tout recensement d'espèces réalisé revêtira, dans un premier temps, un caractère expérimental. C'est pourquoi il importe de garder des traces de ces expériences, d'identifier les améliorations possibles et de les mettre en œuvre au fur et à mesure. Elles permettront de perfectionner les recensements à venir sur la base des enseignements tirés. Les retours de la part d'utilisateurs au sujet de ce document sont vivement encouragés.

Resumen

El documento *Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA* (Exploración de los enfoques para contabilizar las especies en el contexto del Módulo Experimental de Contabilidad de los Ecosistemas del Sistema de Contabilidad Ambiental y Económica [SCAE]) propone un proceso inicial paso a paso para la preparación de inventarios espaciales del estado de las especies. Esas «cuentas de especies» pueden elaborarse de manera independiente o como parte del proceso más amplio del Módulo Experimental de Contabilidad de los Ecosistemas del SCAE. Proporciona un marco para la realización de un conjunto mínimo de cuentas de especies y el uso de los datos que estas contienen en estadísticas resumidas que reflejen la diversidad de las especies, se adapten a las necesidades identificadas y sean apropiadas para los usuarios finales. Con este fin, la comunicación y el compromiso tempranos y continuos con una amplia variedad de partes interesadas resulta fundamental para contar con inventarios pertinentes, creíbles y legítimos. El desarrollo de una estrategia eficaz de colaboración y comunicación con las partes interesadas resulta de vital importancia, así como el establecimiento de una estructura de gobernanza apropiada que conforme cada paso del proceso. Este documento se dirige a quienes estén interesados en la investigación y el desarrollo de cuentas de especies, como los organismos, centros y otras organizaciones ambientales y de biodiversidad.

Los productos principales que derivan de la adopción del enfoque descrito en este documento son las «Cuentas de especies de preocupación especial». Entre las opciones para la obtención de datos se incluyen las observaciones directas de las especies (por ejemplo, los censos de población) y las observaciones basadas en los hábitats, que emplean diferentes métodos de elaboración de modelos. Dependiendo de la función prevista de estas cuentas, las especies de preocupación especial pueden organizarse en función de su conservación, el estado de su ecosistema o los servicios proporcionados por este. Se recomienda elaborar las cuentas de especies de preocupación especial por tipo de ecosistema, a una escala espacial acorde con las decisiones que se tomarán a partir de la contabilización. Este documento también proporciona información sobre la formulación de «cuentas en la lista roja» y «cuentas de la extensión de los lugares importantes para las especies».

Los 11 pasos para la elaboración de cuentas de especies que se presentan en esta guía son los siguientes, a saber:

1) **Definir los usos y los usuarios**. Se determinan las cuestiones clave en materia de políticas y se determinan los usos analíticos de las cuentas. Esto proporciona la base sobre la cual se elaboran las cuentas a fin de que satisfagan las necesidades de los usuarios.

2) **Seleccionar las especies de preocupación y el alcance de los datos.** Se seleccionan las especies correspondientes a las demandas identificadas en el paso 1 y se analiza la disponibilidad de datos para estas especies.

3) **Decidir el enfoque y el tipo de las cuentas de especies.** Se completan una serie de subpasos dirigidos a identificar el criterio más adecuado para elaborar las cuentas de las especies seleccionadas.

4) **Determinar las unidades de información, la frecuencia y las estadísticas resumidas.** Se determinan las escalas espaciales y las unidades de información para las cuentas de especies. Asimismo, se establecen la frecuencia de recopilación de los datos y los procedimientos para la generación de indicadores compuestos significativos o índices de los datos.

5) **Recopilar y preparar los datos**. Se recopilan y preparan los datos analizados en el paso 2 en un formato adecuado para completar las cuentas de las especies.

6) **Completar las cuentas de especies.** Los datos recopilados y preparados en el paso 5 se introducen en el conjunto de cuentas de especies y se calculan las estadísticas resumidas (indicadores o índices compuestos).

7) **Identificar y subsanar las lagunas en las cuentas de especies.** Se revisan las cuentas de especies y se determinan las posibles carencias de datos. Si existieran lagunas, se evalúan y aplican las opciones para subsanarlas en caso necesario.

8) **Organizar y agregar cuentas de especies.** Si fuera necesario, se examinan y aplican procedimientos para presentar múltiples cuentas de especies de los diferentes ecosistemas incluidos en las unidades de información y agregar la información sobre las especies a escalas mayores.

9) **Analizar e integrar las cuentas de especies.** Se analiza la información contenida en las cuentas de especies en el contexto de los principales usos analíticos y las cuestiones relativas a las políticas establecidos en el paso 1.

10) **Comunicar y utilizar los resultados.** Se desarrolla una estrategia para divulgar las constataciones de las cuentas de especies a las principales partes interesadas y a públicos más amplios.

11) **Revisar y refinar las cuentas.** Se revisan las cuentas de especies y se identifican las opciones para refinarlas y mejorarlas.

Aunque estos pasos se presentan de manera secuencial, las opciones elegidas en las primeras etapas del proceso tendrán consecuencias para las opciones disponibles más adelante. Por tanto, debe leerse la guía con detenimiento y antelación y determinarse la secuencia de acciones probables a fin de conformar la elaboración de las cuentas de especies caso por caso. En todo momento debe examinarse la idoneidad de los diferentes métodos propuestos en cada paso a la luz de los usos previstos de las cuentas de especies, los recursos disponibles y la escala más adecuada para su elaboración.

Este documento pretende ser un primer paso hacia el desarrollo de directrices para la elaboración de cuentas de especies aplicables en todos los países del mundo. Como tal, es parte de un proceso que se desarrollará con el tiempo y a través de la experimentación. Esperamos que los organismos nacionales, los centros de investigación y otras organizaciones pongan a prueba el enfoque que aquí se presenta a fin de determinar su aplicabilidad en diferentes situaciones. Según este nuevo planteamiento, las cuentas de especies iniciales se considerarán experimentales, por lo que resulta importante que se registren las experiencias y se determinen, con el tiempo, las posibles mejoras y se apliquen a las cuentas. Estas experiencias contribuirán a mejorar los enfoques futuros de la contabilidad de las especies a partir de las lecciones aprendidas. Se agradecen las opiniones de los usuarios acerca de este documento.

Резюме

В документе «*Изучение подходов к формированию Счетов учета видов в контексте СЭЭУ-ЭЭС*» предлагается первоначальный поэтапный процесс разработки пространственных счетов учета текущего состояния видов. Такие «Счета учета видов» можно выстраивать как обособленные счета учета или как составную часть более широкого процесса формирования Системы эколого-экономического учета – экспериментальных экосистемных счетов (СЭЭУ-ЭЭС). Это обеспечивает рамочные основы для разработки минимального набора Счетов учета видов и сведения воедино содержащейся в них информации в виде обобщенных статистических данных, отражающих разнообразие видов, отвечающих выявленным потребностям и соответствующих требованиям конечных пользователей. В этой связи ключевое место в формировании Счетов учета видов и обеспечении их актуальности, достоверности и легитимности занимает последовательное вовлечение в работу широкого спектра заинтересованных сторон и информационное взаимодействие с ними уже на раннем этапе. Критически важной является разработка эффективной стратегии привлечения заинтересованных сторон и информационного взаимодействия с ними, а также учреждение надлежащей структуры общего руководства, которые могут наполнить каждый этап данного процесса конкретным содержанием. Настоящий документ предназначен для использования лицами, заинтересованными в проведении научных исследований и разработке Счетов учета видов, таких как учреждения, институты и другие организации по охране окружающей среды и биоразнообразия.

В результате реализации подхода, в общих чертах обрисованного в настоящем документе, основными выходными данными станут «Счета учета видов особой природоохранной значимости». Альтернативные варианты получения входных данных включают непосредственные наблюдения за видами (такие как переписи популяций) и наблюдения по ареалам обитания с использованием различных методов моделирования. В зависимости от предполагаемого применения этих счетов, информация по видам особой природоохранной значимости может быть структурирована по таким темам, как сохранение природы, состояние экосистем и предоставление экосистемных услуг. Мы рекомендуем, чтобы Счета учета видов особой природоохранной значимости формировались по типам экосистем в пространственном масштабе, соответствующем решениям, информационное наполнение которых они призваны обеспечить. Настоящий документ также содержит информацию о формировании вспомогательных «Счетов учета текущего состояния Красного списка» и «Счетов учета протяженности важных мест обитания видов».

Как в общих чертах обрисовано в настоящем руководстве, процесс разработки Счетов учета видов включает следующие одиннадцать этапов:

1) **Определение видов использования и пользователей**. Определяются ключевые вопросы политики и виды использования счетов для целей анализа. Это закладывает фундамент для формирования счетов таким образом, чтобы они гарантированно удовлетворяли потребности пользователей.

2) **Отбор видов природоохранной значимости и определение сферы охвата данными**. Производится отбор видов, значимых с точки зрения потребностей, которые были выявлены на этапе 1, и оценка сферы охвата этих видов имеющимися в наличии данными.

3) **Принятие решения о подходе к формированию и типе Счетов учета видов**. С целью определения наиболее подходящего способа построения Счетов учета видов по результатам проведенного отбора выполняется ряд подэтапов.

4) **Принятие решения об органах, представляющих отчетность, периодичности сбора и обобщения статистических данных**. Определяются пространственные масштабы сбора информации и органы, представляющие отчетность по Счетам учета видов. В дополнение к этому устанавливаются периодичность компилирования данных и процедуры генерирования значимых сводных показателей или индексов на основе имеющихся данных.

5) **Упорядочение и подготовка данных**. Производится упорядочение и подготовка данных по сферам охвата, определенным на этапе 2, в формате, пригодном для наполнения баз данных по Счетам учета видов.

6) **Наполнение баз данных по Счетам учета видов**. Упорядоченные и подготовленные на этапе 5 данные вводятся в базу данных по Счетам учета видов, после чего производится расчет обобщенных статистических данных (сводных показателей / индексов).

7) **Выявление и заполнение пробелов в Счетах учета видов**. Производится рассмотрение Счетов учета видов и выявляются пробелы в данных. При наличии пробелов в данных производятся оценка возможных вариантов решения вопроса и их реализация в случае необходимости.

8) **Систематизация и агрегирование данных по Счетам учета видо**в. Производится оценка процедур представления данных по множеству Счетов учета видов для различных экосистем в рамках органов, представляющих отчетность, а также агрегирования информации по видам в более крупных масштабах, и их реализация в случае необходимости.

9) **Анализ и интеграция Счетов учета видов**. Информация, содержащаяся в Счетах учета видов, анализируется в контексте ключевых видов их использования для целей анализа и вопросов политики, определенных на этапе 1.

10) **Информационное взаимодействие и использование.** Разрабатывается стратегия доведения выводов по Счетам учета видов до сведения ключевых заинтересованных сторон и более широкой аудитории.

11) **Обзор и доработка.** Производится рассмотрение Счетов учета видов и определяются возможные меры по их доработке и совершенствованию.

Указанные этапы представлены в последовательном порядке, однако решения, принятые на ранних этапах процесса, будут влиять на возможные варианты действий на более поздних стадиях. По этой причине следует тщательно изучить данное руководство до начала работы и определить последовательность вероятных действий с тем, чтобы формировать содержательную часть Счетов учета видов в зависимости от конкретных обстоятельств. На протяжении всего процесса пригодность различных методов, предлагаемых для каждого этапа, следует рассматривать в свете предполагаемого использования Счетов учета видов, наличных ресурсов и наиболее подходящего масштаба их построения.

Настоящий документ призван стать первым шагом на пути к разработке руководящих принципов формирования Счетов учета видов, которые могли бы быть реализованы во всех странах мира. Таким образом, он представляет собой составную часть процесса, который будет развиваться с течением времени в ходе экспериментальной отработки. Мы надеемся, что подход, представленный в настоящем документе, будет апробирован национальными учреждениями, научно-исследовательскими институтами и другими организациями с целью определения степени его применимости в различных ситуациях. При использовании этого нового подхода любые первоначальные Счета учета видов будут носить экспериментальный характер, и по этой причине важно регистрировать опыт практической работы, а также постепенно выявлять и реализовывать возможности совершенствования этих счетов. Такой опыт практической работы будет способствовать улучшению будущих подходов к ведению Счетов учета видов на основе извлеченных уроков. Отзывы и комментарии пользователей настоящего документа будут приняты с благодарностью.

10

8) **نظِّم حسابات الأنواع وجمعها.** تتم مراجعة إجراءات تقديم عدة حسابات للأنواع في إطار النظم الإيكولوجية المختلفة داخل وحدات التقارير وتجميع المعلومات عن الأنواع إلى نطاقات أوسع، وتنفيذ هذه الإجراءات حيثما كان ذلك ضرورياً.

9) **حلّل حسابات الأنواع وادمجها.** يتم تحليل المعلومات الواردة في حسابات الأنواع في سياق الاستخدامات التحليلية الرئيسية والمسائل ذات الصلة بالسياسات المحددة في الخطوة 1.

10) **التواصل والاستخدام.** تُوضع استراتيجية لإبلاغ أصحاب المصلحة الرئيسيين والجمهور الأوسع بنتائج حسابات الأنواع.

11) **المراجعة والتحسين.** تتم مراجعة حسابات الأنواع وتحديد خيارات التدخل للصقل والتحسين.

وفي حين تُعرض هذه الخطوات على نحو متتابع، فإن الخيارات التي تُتخذ في المراحل المبكرة من العملية تكون لها آثار على الخيارات المتاحة لاحقاً. ولذلك، ينبغي قراءة الدليل بصورة جيدةً مسبقاً وتحديد سلسلة من الإجراءات المحتملة لتوجيه عملية بناء حسابات الأنواع على أساس كل حالة على حدة. وعموماً، ينبغي إعادة النظر في مدى ملاءمة الأساليب المختلفة المقترحة في إطار كل خطوة في ضوء الاستخدامات المقصودة من حسابات الأنواع والموارد المتاحة والنطاق الأنسب لبنائها.

وتهدف هذه الوثيقة إلى أن تكون خطوة أولى نحو وضع المبادئ التوجيهية لبناء حسابات الأنواع التي يمكن تنفيذها في جميع دول العالم. و هي تشكّل على هذا النحو، جزءًا من عملية من شأنها أن تتطور مع مرور الوقت ومن خلال التجريب. ونأمل أن يخضع النهج المقدم هنا للاختبار من قبل الوكالات الوطنية ومعاهد البحوث والمنظمات الأخرى لتحديد إمكانية تطبيقه في حالات مختلفة. وفي ظل هذا النهج الجديد، فإن أي حسابات أولية للأنواع ستكون تجريبية، لذلك من المهم أن يتم تسجيل الخبرات، وتحديد التحسينات في الحسابات وتنفيذها مع مرور الوقت. وستسهم هذه التجارب في تحسين النُهُج المستقبلية إزاء حسابات الأنواع بناء على الدروس المستفادة. ونرحب بالآراء والتعليقات من مستخدمي هذه الوثيقة.

ملخص

استكشاف النُهُج لإنشاء حسابات لأنواع النباتات والحيوانات في سياق المحاسبة التجريبية للنظم الإيكولوجية التابعة لنظام المحاسبة البيئية الاقتصادية Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA هي دراسة تقترح عملية أولية تدريجية لتطوير حسابات مكانية لأوضاع أنواع النباتات والحيوانات. ويمكن بناء "حسابات أنواع النباتات والحيوانات" هذه إما كحسابات مستقلة أو كجزء من عملية أوسع للمحاسبة التجريبية للنظم الإيكولوجية التابعة لنظام المحاسبة البيئية والاقتصادية. وهي توفر إطاراً لتطوير مجموعة تمثل الحد الأدنى من حسابات الأنواع وتعبئة البيانات التي تحويها ثم تحويلها إلى إحصاءات موجزة تعكس تنوّع الأنواع، وتتناسب مع الاحتياجات المحددة وتلائم المستخدمين النهائيين. وتحقيقاً لهذه الغاية، فلابد من الإشراك والتواصل المبكرين والمستمرّين مع طائفة متنوعة من أصحاب المصلحة، إذ أن ذلك أمر أساسي لبناء حسابات للأنواع تمتاز بكونها ذات صلة ومصداقية وشرعية. كما أن وضع استراتيجية فعّالة لإشراك أصحاب المصلحة والتواصل معهم، وإنشاء بنية مناسبة للحكم بحيث تثري كل خطوة من خطوات العملية بالمعلومات لهو أمر بالغ الأهمية. والغرض من هذه الوثيقة هو أن يتم استخدامها من قبل المهتمين بالبحث والتطوير في مجال حسابات الأنواع، مثل وكالات البيئة والتنوع البيولوجي والمعاهد والمنظمات الأخرى.

ومخرجات المحاسبة الرئيسية الناجمة عن اتباع النهج الوارد في هذه الوثيقة هي "حسابات للأنواع التي تثير قلقاً خاصاً". وتشمل خيارات الحصول على البيانات المدخلة، كلاً من الملاحظات المباشرة للأنواع (كالتعدادات) وعمليات الرصد المعتمدة على الموائل التي تستخدم أساليب نمذجة مختلفة. واعتماداً على التطبيق المقصود من هذه الحسابات، يمكن تنظيم الأنواع التي تثير قلقاً خاصاً تحت موضوعات كالحفظ وحالة النظام البيئي وتقديم خدمات النظم الإيكولوجية. ونحن نوصي بإنشاء حسابات للأنواع التي تثير قلقاً خاصاً حسب نوع النظام البيئي في النطاق المكاني ذي الصلة بالقرارات التي تستقي معلوماتها من الحسابات. وتوفر هذه الوثيقة أيضاً معلومات عن إنشاء حسابات تكميلية مثل "حسابات حالة القائمة الحمراء" و "حسابات مدى الأماكن الهامة للأنواع."

والخطوات الإحدى عشرة لتطوير حسابات للأنواع على النحو المبين في هذا الدليل هي:

1) **حدّد الاستخدامات والمستخدمين.** يتم تحديد المسائل الرئيسية المتعلقة بالسياسات والاستخدامات التحليلية للحسابات. ويشكّل ذلك، الأساس الذي تقوم عليه نظم المحاسبة من أجل ضمان تلبيتها لاحتياجات المستخدمين.

2) **حدّد الأنواع التي تستدعي القلق وارسم نطاق البيانات.** يتم اختيار الأنواع ذات الصلة بالمطالب المحددة في الخطوة 1 مع تحديد نطاق توافر البيانات لهذه الأنواع.

3) **قرّر نهج حسابات الأنواع ونوعها.** يجري إتمام سلسلة من الخطوات الفرعية من أجل تحديد النهج الأكثر ملاءمة لبناء حسابات محددة للأنواع.

4) **قرّر وحدات الإبلاغ والوتيرة وإحصاءات الموجز.** يتم تحديد المقاييس المكانية ووحدات التقارير لحسابات الأنواع. وبالإضافة إلى ذلك، يجري تحديد وتيرة تجميع البيانات وإجراءات استنباط مؤشرات مركبة ذات مغزى أو مؤشرات من البيانات.

5) **جمّع البيانات وأعدّها.** يجري تجميع البيانات التي تم الحصول عليها في الخطوة 2 وإعدادها في شكل مناسب لتعبئة حسابات الأنواع.

6) **قم بتعبئة حسابات الأنواع.** يجري إدخال البيانات التي تم تجميعها وإعدادها في الخطوة 5، في مجموعة حسابات الأنواع، ويتم احتساب الإحصاءات الموجزة (المؤشرات المركبة).

7) **حدّد الثغرات في حسابات الأنواع وسدّها.** تتم مراجعة حسابات الأنواع وتحديد أي ثغرات في البيانات. ويتم تقييم الخيارات المتاحة، حيثما وُجدت ثغرات في البيانات، لمعالجة هذه الثغرات وتنفيذها حيثما كان ذلك ضرورياً.

摘要

探索在SEEA-EEA语境下建立物种账户的方法为建立物种状况空间账户提出了一个初步的分步过程。这种“物种账户”可作为独立账户建立，也可作为更广泛的环境经济核算-实验性生态系统核算(SEEA-EEA) 过程的一部分建立。它提供了用于开发一套最小的物种账户，并动员它们纳入汇总统计中的反映物种多样性的数据的框架，此框架符合确定的需求，而且适合最终用户使用。为此，及早与不同利益相关方展开始终如一的合作与沟通对于建立相关的、可信的和合法的物种账户具有核心作用。制定有效的利益相关方的参与和沟通策略，并建立能为过程的每一步骤提供依据的适当治理结构至关重要。本指南的目标读者为对物种账户的研究和开发感兴趣的单位，如环境和生物多样性机构、研究机构和其他组织。

根据本指南所列方法得到的主要核算输出是“特别关注物种账户”。获取输入数据的选项包括直接观察物种（如种群普查），及采用了不同建模方法的基于栖息地的观察。按照此类账户的预期应用，特别关注物种可被包含在保护、生态系统状况和生态系统服务交付等主题下。我们建议特别关注物种账户应按照生态系统类型、以与账户将为之提供依据的决定相关的空间规模建立。本指南还提供了关于制定补充性的“红色名单状态账户”和“物种重要场所范围账户”的信息。

本指南列出的建立物种账户的十一个步骤是：

1) **定义用途和用户。**确定账户的主要政策问题和分析用途。这提供了建立账户的基础，以确保账户满足用户需求。

2) **选择关注的物种和范围数据。**选择与步骤1确定的需求有关的物种，并审视这些物种的数据的可用性。

3) **决定物种账户的方法和类型。**完成一系列子步骤以确定建立选定的物种账户的最合适的方法。

4) **确定报告单位、频率和汇总统计。**确定物种账户的空间规模和报告单位。此外，还要确定数据汇编的频率和生成来自数据的有意义的综合指标或指数的程序。

5) **整理和准备数据。**整理和准备步骤2审视的数据，使其格式适合填充物种账户。

6) **填充物种账户。**在步骤5中整理和准备的数据被录入物种账户集，并计算汇总统计（综合指标/指数）。

7) **确定并填补物种账户中的缺口。**审查物种账户，并查明任何数据缺口。在存在数据缺口的情况下，评估解决这些缺口的选项，并在必要时实施选项。

8) **组织和汇总物种账户。**审查在报告单位内展示不同生态系统的多个物种账户，以及汇总生态系统信息使之规模更大的程序，并在必要时执行程序。

9) **分析和整合物种账户。**在步骤1中建立的关键分析用途和政策问题的背景下，分析物种账户所包含的信息。

10) **传播和使用。**制定将物种账户的研究结果传达给主要利益相关方和更广泛受众的策略。

11) **审查和完善。**对物种账户进行审查，确定优化和改进的干预选项。

虽然这些步骤是按顺序提出的，但在此过程的早期阶段所作的选择将对后来的可用选项产生影响。因此，应提前充分阅读本指南，确定可能采取的行动的顺序，以便根据具体情况为物种账户的建设提供依据。自始至终，每一步骤下提出的不同方法的适用性应按照物种账户的预期用途、可用的资源和建设它们的最合适的规模进行审查。

期望本指南成为制定建设可在全世界所有国家执行的物种账户的指导方针的第一步。因此，它是一个过程的一部分，此过程将随着时间的推移和不断的实验得到发展。我们希望国家机关、研究机构和其他组织测试在这里介绍的方法，以确保它在不同情况下的适用性。有了这种新方法，任何初始物种账户都将是实验性的，因此重要的是记录经验，并随着时间的推移确定和实施改进。这些经验将有助于在所获得的经验教训基础上改进未来的方法。欢迎本指南的用户提供反馈。

Glossary

Aichi Biodiversity Targets: A set of 20 targets for biodiversity to be achieved by 2020 by parties to the Convention on Biological Diversity (CBD).

Alpha diversity: The biodiversity of an individual location or the within-community diversity.

Basic Spatial Units (BSU): The underlying spatial infrastructure for organising information contained within ecosystem accounts based on a grid of appropriate cell size (also known as a 'grid cell' in geo-information disciplines and a 'grain' in landscape ecology).

Beta diversity: The complementarity of two measures of alpha diversity.

Biological diversity (Biodiversity): 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.

Community: Assemblages of plant and animal populations that live in a particular area or habitat and interact to form a system with its own emergent properties.

Ecosystem asset: An ecosystem, represented by its characteristics and spatial area.

Ecosystem condition: The condition of an ecosystem based on measurements of various characteristics at a given point in time (SEEA-EEA TR, 2015).

Ecosystem diversity: The variety of ecosystems in a given place (WWF, n.d).

Ecosystem extent: The size of an ecosystem asset in terms of spatial area (SEEA-EEA, 2014).

Ecosystem resilience: The ability of an ecosystem to tolerate shocks and disturbance but still maintain the same level of functioning (Mori et al., 2013).

Ecosystem services: Benefits people obtain from ecosystems. These include provisioning services, such as food and water; regulating services, such as regulation of floods, drought, land degradation and disease; supporting services, such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, religious and other non-material benefits (MA, 2005a).

Ecosystem Unit: The conceptual spatial unit for accounting for ecosystems, defined on the basis of a contiguous arrangement of BSUs of a common ecosystem type (SEEA-EEA, 2014).

Endangered species: A species that has been classified by IUCN as facing a high risk of extinction in the wild.

Endemic species: A species that is only found in a given range or location in the world.

Gamma diversity: The collective biodiversity across a landscape (a combination of alpha and beta diversity).

Genetic diversity: The variation in the amount of genetic information within, and among, individuals of a population, species assemblage, or community (UN, 1992).

Index: A specific type of indicator that comprises a number of measures combined in a particular way to increase their sensitivity, reliability or ease of communication (Brown et al., 2014).

Indicator: A measure that communicates something of interest and is specific to a purpose and/or audience (Brown et al., 2014).

IUCN Red List of Threatened Species: A global approach for evaluating the conservation status of plant and animal species.

Measure (or measurement): The actual measurement of a state, quantity or process derived from observations or monitoring, e.g. species counts, biomass or area of habitat (Brown et al., 2014).

Metric: A set of measurements or data collected and used to underpin a specific indicator (Brown et al., 2014).

Modifiable Areal Unit Problem (MAUP): Where the same base data can tell a different story depending on the boundary used for aggregation (Bond et al., 2013).

Natural Capital: The stocks of Earth's natural assets and resources, including soil, water, air and biodiversity.

Predicted distributions: Areas where a species is likely to be present as modelled from the suitability of environmental conditions (Rondinini et al., 2006).

Proxy: A measurement that can be used to represent the value of a different measure in a calculation.

Reporting Unit: A geographical aggregation for reporting species or ecosystem information.

System of Environmental-Economic Accounting – Central Framework (SEEA-CF): An internationally agreed, multipurpose, statistical framework for understanding the interactions between the environment and the economy.

System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA): An experimental, multipurpose, statistical framework that aims to reinforce and quantify the importance of the relationship between people and their environment.

System of National Accounts (SNA): An internationally agreed standard for compiling national statistics on economic activity.

Species abundance: The total number of individuals of a taxon or taxa in an area, population or community (or, where counts are not feasible, other measures, such as biomass and percentage cover, may be used) (MA, 2005c).

Species diversity: Diversity at the species level, often combining aspects of species richness, their relative abundance, and their dissimilarity (MA, 2005b).

Species population: The summation of all the organisms of the same species or species group that live in a particular geographical area and have the capability of interbreeding.

Species richness: The number of a species within a given sample, community or area (usually from a particular taxa, e.g. plant species richness) (MA, 2005c).

Sustainable Development Goals (SDGs): A set of goals adopted by countries to end poverty, protect the planet, and ensure prosperity for all.

Taxon (plural taxa): A taxonomic category or group, such as phylum, order, family, genus or species.

Threatened species: Any species vulnerable to endangerment in the near future. Comprises the IUCN Red List categories of 'Vulnerable Species', 'Endangered Species' and 'Critically Endangered Species'.

Purpose, scope and structure of *Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA*

This document on constructing Species Accounts has been prepared in the context of the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA, 2014). The SEEA-EEA is a multipurpose statistical framework that aims to reinforce and quantify the importance of the relationship between people and their environment. It is designed to allow the integration of information on ecosystem extent, condition and services with information on economic and other human activity (SEEA-EEA TR, 2015). In this context, species and other aspects of biodiversity are key features of ecosystem condition and play an essential role in maintaining and delivering ecosystem services, such as food, climate regulation and aesthetics (MA, 2005a). Species Accounts can contribute to the thematic accounting of biodiversity within the SEEA-EEA framework. This provides an opportunity to integrate information on species and biodiversity with information on economic activity.

Due to an increasing number of high-level policy commitments, such as the Aichi Biodiversity Targets and the United Nation's Sustainable Development Goals, there is a need for robust statistics on biodiversity. These statistics must be underpinned by monitoring systems that are accurate, comprehensive and tracked continuously over time to be able to measure progress at the national level. Tools like the SEEA-EEA framework help countries to take biodiversity into consideration within their economic activities. They also provide a mechanism to help monitor progress and prioritise activities to meet policy commitments. Developing Species Accounts alongside the SEEA-EEA framework enables the measurement of progress towards biodiversity policy commitments and, potentially, identifies the economic drivers that influence such progress. Therefore, species accounting can deliver multiple benefits, not only for informing sustainable development and economic planning, but also for biodiversity conservation.

Building on a UNEP-WCMC (2015) report on the current state of knowledge on biodiversity accounting, this document proposes an initial step-by-step approach to help those concerned with the process of planning and constructing Species Accounts at national or sub-national levels. As a next step in the process, this approach will be tested to determine its applicability in different situations. These experiences will help to improve future approaches to species accounting based on the lessons learnt. Feedback from users of this guide will be gratefully received.

The target audience for this document includes specialist agencies, research institutes and other organisations interested in the implementation of species accounting at national or sub-national levels. In order to implement the approaches set out in this document, a multidisciplinary team is needed. Such a team may include:

- Ecologists to steer the construction of ecologically meaningful accounts and to collect relevant data.
- Modellers to generate spatial distributions of biodiversity data.
- Geographical Information System (GIS) experts to process data in the spatial format required for the SEEA-EEA.
- Statisticians and data analysts to assist in the construction of Species Accounts and to link information to other accounts in the SEEA-EEA.
- Economists to identify the links between species-level biodiversity, the economy and human well-being.
- Planners to ensure the relevance of summary statistics to end users, and to coordinate the implementation, support and use of Species Accounts.

Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA has three chapters:

- **Chapter 1** provides an introduction to biodiversity and species and ecosystem accounting. It identifies how species accounting information can be linked to wider accounts within the SEEA-EEA framework, introduces the spatial units employed within SEEA-EEA, and discusses the challenges to undertaking species accounting.
- **Chapter 2** presents the approach to constructing Species Accounts as an eleven-step process based around four phases: Planning; Implementation; Communication and use; and Review and refinement (Figure A). Where possible, real life examples from countries are captured under each step.
- **Chapter 3** offers conclusions and recommendations for future research.

Two examples of Species Accounts for Wales and Peru are set out in Appendices A and B.

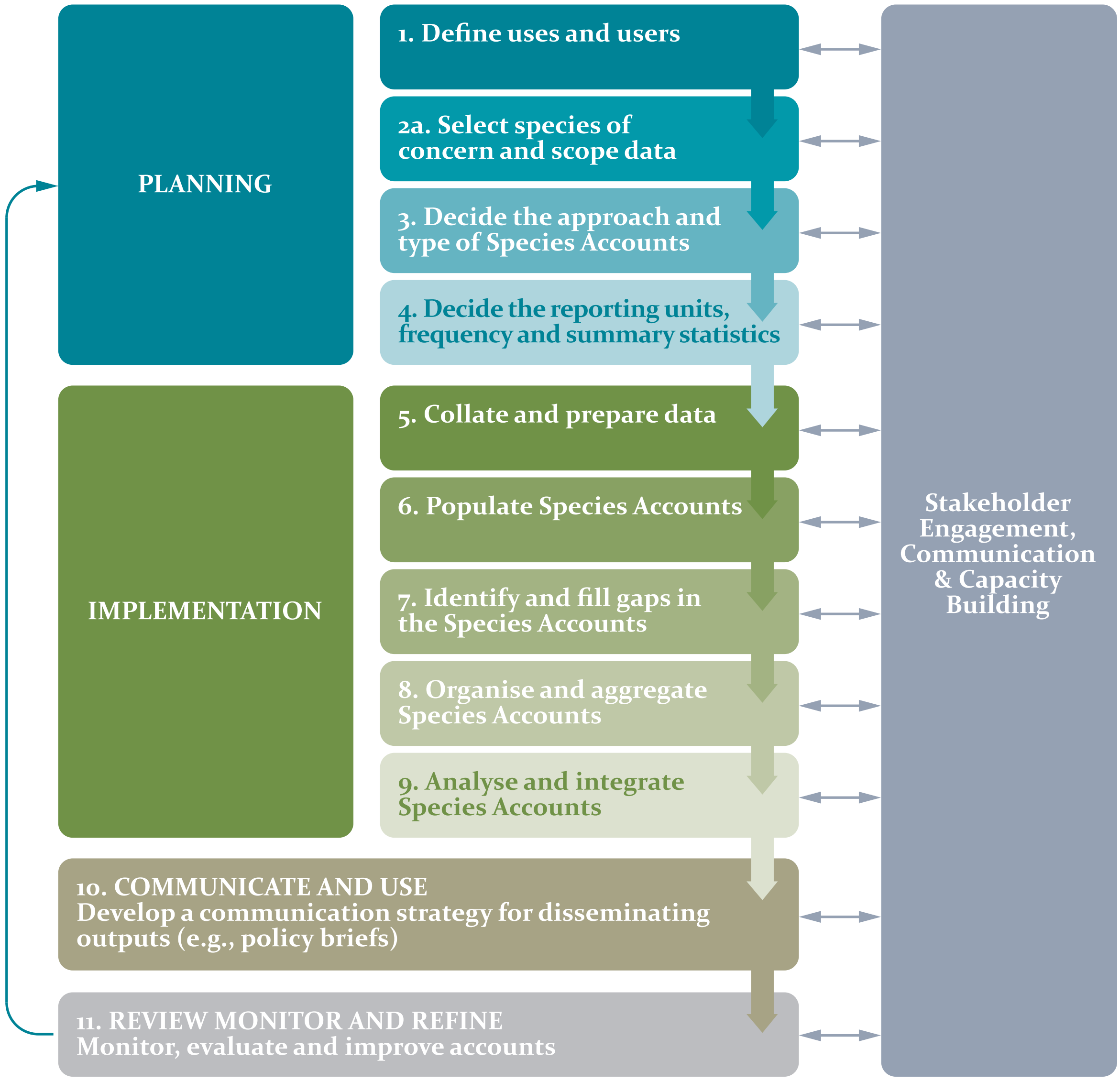


Figure A: Step-by-step approach for constructing Species Accounts

1. Introduction

1.1 WHAT IS BIODIVERSITY?

The definition of biodiversity used here, and elsewhere within the SEEA-EEA (2014) framework, is that adopted by the Convention on Biological Diversity (CBD, 1992):

"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" (Figure 1.1.).

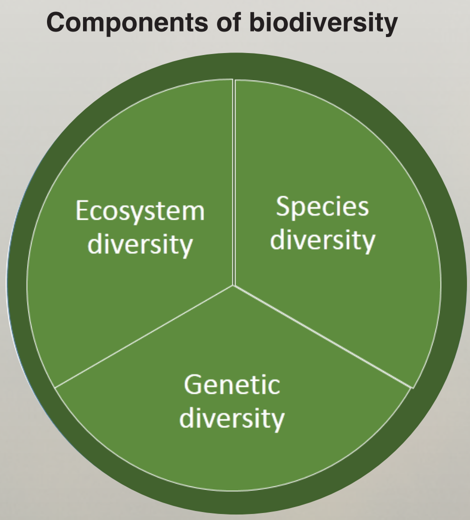


Figure 1.1: The three components of biodiversity (UNEP-WCMC, 2015).

In Figure 1.1., 'ecosystem diversity' represents the variety of ecosystems in a given place (WWF, n.d); 'species diversity' represents diversity at the species level, often combining aspects of species richness, their relative abundance and their dissimilarity (MA, 2005b); and 'genetic diversity' represents the variation in the amount of genetic information within, and among, individuals of a population, a species, an assemblage or a community (UN, 1992).

This document focuses on constructing biophysical accounts of species status. These accounts can be constructed holistically or under themes of species relevant to conservation, ecosystem condition and functioning and ecosystem services concerns. The document also offers suggestions for summarising the information organised in Species Accounts as an indicator or index to communicate species diversity or the overall status of species assemblages. For information on constructing accounts of the extent and diversity of different ecosystems, please see the SEEA-EEA Technical Recommendations (SEEA-EEA TR, 2015). In addition, Driver et al. (2015) provides an example for constructing ecosystem extent accounts in KwaZulu-Natal, South Africa. Genetic diversity is not considered in this document, but work should be undertaken to integrate this in the future.

1.2 WHY ACCOUNT FOR SPECIES?

Biodiversity is an important part of a country's 'natural capital stock'. As a component of biodiversity, species form the biotic elements of ecosystems and have an important role in how ecosystems function and deliver ecosystem services that support economic activity and human well-being. It is generally agreed that maintaining a diverse assemblage of species is key to sustaining healthy ecosystem functioning (Balvanera et al., 2006; Tilman et al., 2006; Cardinale et al., 2012). The Millennium Ecosystem Assessment (MA, 2005a) terms this maintenance of ecosystem functions and processes as 'supporting ecosystem services'. Identifying the relationship between species-level biodiversity and ecosystem service delivery remains an area requiring further research (Harrison et al., 2014). However, adopting a precautionary approach to species-level biodiversity will help to maintain the ability of ecosystems to function effectively and to deliver multiple ecosystem services into the future.

The ability of ecosystems to tolerate shocks and disturbance while maintaining the same level of functioning is often referred to as 'ecosystem resilience' (Mori et al., 2013). Maintaining diverse assemblages of species is also important to ecosystem resilience. Different species may contribute to particular ecosystem functions in similar ways, but respond to disturbances differently (Elmqvist et al., 2003). In this way, they may be substituted for one another. This is termed 'functional redundancy'.

Specific species also contribute directly to economic activity and well-being. For instance, some species are important for providing food or medicines used by local communities and commercial activities. Other species may contribute to well-being due to their charismatic and iconic nature. They are valued on the basis of aesthetics, characteristics and behaviour, or because of the cultural status given to them (Mace et al., 2012; Kellert, 1997; Martín-López et al., 2007). Such species may support important nature tourism opportunities and associated revenue streams.

Therefore, national accounting systems should include information on species contributing to ecosystem functioning and the delivery of ecosystem services. Integrating such information into accounting systems serves to highlight the condition of ecosystems and their capacity to deliver the ecosystem services that underpin sustainable economic growth and human well-being. The integration of Species Accounts with the broader SEEA-EEA also provides information on the economic drivers of change and economic levers required to influence change. This can inform decision-making and actions regarding sustainable development and help to achieve conservation targets. Indeed, Species Accounts may support the following analytical uses:

- Comparing current trends in species status with information on economic activities and other drivers of species loss.
- Exploring trends by organising the information required to support trend analysis (for instance, via interpolation or forecasting).
- Organising information on species for aggregation and communication across all scales.
- Communicating the relationships between species, ecosystems and the supply of ecosystem services.
- Providing objective statistics to report on policies related to species and ecosystems.
- Exploring future trade-offs by organising the information required to support scenario modelling.
- Informing cost-benefit or ecological return on investment analyses.
- Supporting expert judgement on species status and trends by organising available information on the observations of species.

1.3 WHAT IS THE SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING – EXPERIMENTAL ECOSYSTEM ACCOUNTING (SEEA-EEA) FRAMEWORK?

In 2012, the United Nations Statistical Commission adopted the System of Environmental-Economic Accounting – Central Framework (SEEA-CF, 2014) as the international statistical standard for environmental-economic accounting. This multipurpose, statistical framework is used to describe the interaction between the economy and the environment; the stocks of environmental assets and the flows of the products and services they provide; the inputs environmental assets receive; and expenditure on environmental protection and resource management.

Ecosystems are specifically considered within the complementary System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA, 2014) framework (Figure 1.2). Within the SEEA-EEA, ecosystems are spatially explicit units ('assets') that are characterised on the basis of their type, extent and a range of condition characteristics (including species assemblages) relevant to their capacity to deliver ecosystem services. The data on ecosystem extent and condition are organised within a set of supporting accounts, which are developed from biophysical measures, such as ecosystem area and species abundance. The accounting model proposes that changes in the stock of the ecosystem asset is measured via changes in the biophysical measures of extent and condition. Ecosystem assets also produce a flow of ecosystem services over time, which contribute to the production of benefits and, ultimately, well-being. Data on ecosystem services is organised within the physical and monetary ecosystem services supply and use accounts. These accounts record the flow of ecosystem services from ecosystems to economic users occurring within an accounting period (typically a year), in physical and monetary units respectively (SEEA-EEA TR, 2015). Figure 1.2 also recognises the importance of supporting ecosystem services (termed 'inter-' and 'intra-ecosystem flows') to ecosystem functioning (termed 'ecosystem processes') due to their role in transferring energy and nutrients both within and between ecosystem assets.

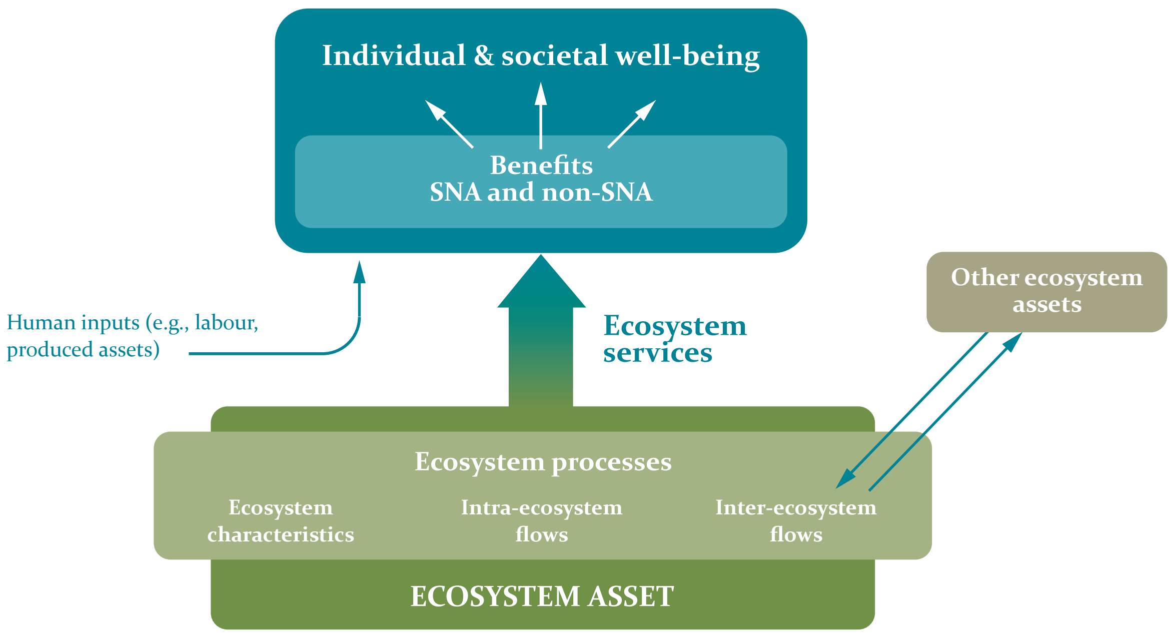


Figure 1.2: SEEA-EEA Accounting Model (SEEA TR, 2015)

The SEEA-EEA provides a framework for coherent coverage of information relating to ecosystem assets and ecosystem services. Yet, from an analytical perspective, it is challenging to focus on a whole system or holistic approach that considers the interactions between all accounts within the framework. More commonly, our views of managing ecosystems, and our policy responses, are framed using themes that concern specific aspects of the economic-environment relationship. Four main themes that are identified within SEEA-EEA are land, water, carbon and biodiversity (SEEA-EEA, 2014). Figure 1.3 illustrates how such thematic accounts are used to organise information that feeds into supporting accounts of ecosystem extent, condition, and services supply and use. Thematic accounts may also be used in their own right to address policy questions of interest.

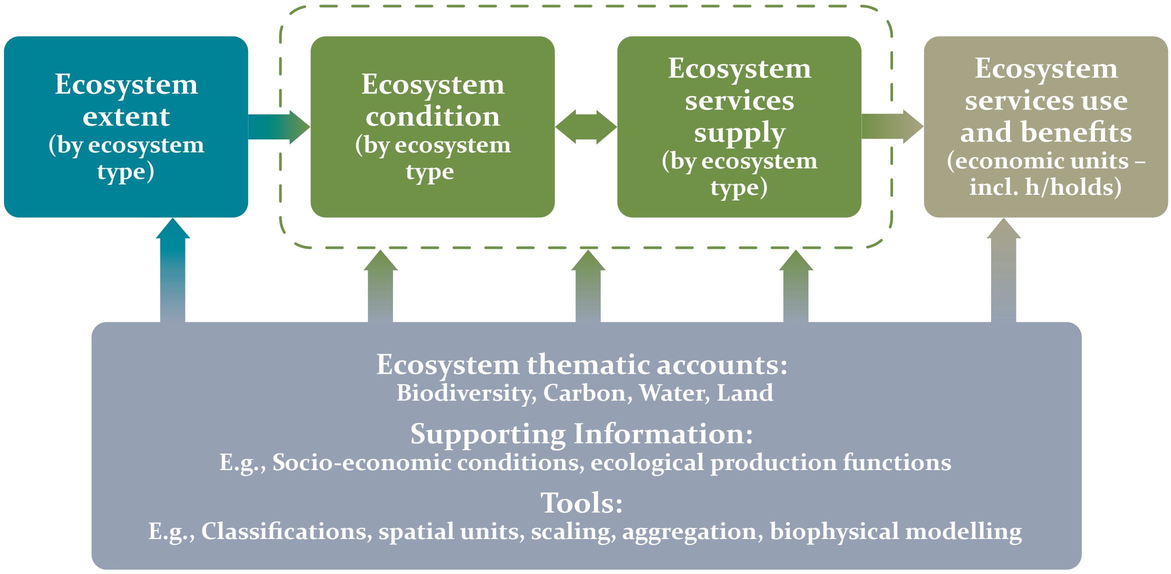


Figure 1.3: Relationship between thematic accounts and other SEEA-EEA accounts (Chow, 2016)

1.4 HOW CAN SPECIES INFORMATION BE CAPTURED IN THE SEEA-EEA?

This document focuses on generating spatial thematic accounts of species status and habitat-based observations relevant to species abundance: called 'Species Accounts'. These accounts can be employed to reveal changes in the status and abundance of species that are of conservation concern, important for ecosystem condition and functioning, or important in the delivery of ecosystem services. Integrating species information into accounting structures allows linkages to be made with ecosystem extent, condition, service provision and the wider economy. Thus, changes in species can be understood in the context of changes in, for example, ecosystem extent or flows of ecosystem services recorded in a wider set of ecosystem based accounts. This provides a basis for communicating a coherent overall picture of the environment and ecosystems to decision-makers.

Figure 1.4 sets out the linkages between Species Accounts, Ecosystem Asset Accounts (Ecosystem Extent Accounts and Ecosystem Condition Accounts), Ecosystem Service Accounts and the economy. Information from spatial accounts for different species or species groups can inform accounts of both ecosystem extent and condition (Figure 1.4, arrow A). For Ecosystem Extent Accounts, data on species composition could be used to delineate ecosystem assets on the basis of species assemblages. For instance, spatial information on the distributions of discrete communities (assemblages of plant and animal populations that live in a particular area and interact to form a system with its own emergent properties) could be used to delineate ecosystem assets; indeed, Eigenraam et al. (2016) suggest an approach based on vegetation classes. For Ecosystem Condition Accounts, relevant Species Accounts contain information on species that play an important role in ecosystem functioning or are suitable proxies for well-functioning ecosystems (European Union, 2014). For example, good quality marshland will contain certain assemblages of wading birds and grasses whose presence reveal the ecosystem to be in good condition. These data can then be aggregated in a summary statistic (a composite indicator or index) in order to inform accounts of ecosystem condition.

Some species directly contribute to economic activity and human well-being. For example, species provide food, medicine and opportunities for nature viewing (which can support ecotourism). However, as these contributions reflect ecosystem services, they should be captured in Ecosystem Service Accounts (Figure 1.4, arrows B1 and B2). This helps to avoid the double counting of species benefits. Certain ecosystem services, such as regulating services, may also have an established link to individual species or species groups (Figure 1.4, arrow C). For instance, insect-pollinated crops, such as fruits and vegetables, will depend on insect pollination services (Klien et al., 2007). The value of this service can be significant; Gallai et al. (2009) estimate the worldwide value of pollination services provided by insects to agriculture in 2005 at €153 billion/year. Similarly, soil formation services will depend on the stock of microorganisms present. In these contexts, species abundance could be considered a proxy for the services provision.

The link from the economy to Ecosystem Asset Accounts (Extent and Condition Accounts) (Figure 1.4, arrow D) represents the integration of wider statistics relevant to economic agents (such as land ownership, land use and productivity) with statistics on ecosystems and their characteristics. These agents may be described as small businesses operating at single locations (a hotel, for example), enterprise with multiple facilities (a chain of hotels), or aggregated together within industries (accommodation). The management practices of these agents can impact on ecosystems, both positively and negatively. If ecosystems experience impacts, such as changes in extent and condition, it can change the delivery of ecosystem services (Figure 1.4, arrow E). Such changes may, in turn, affect the economy and our well-being (Figure 1.4, arrow F). Finally, the impacts of economic activity on species and the delivery of ecosystem services should be captured within the overall accounting framework (Figure 1.4, G1 and G2). For example, when the level of ecosystem service use is unsustainable, these impacts may manifest as overharvesting or species exploitation. Accordingly, Species Accounts can help to identify the economic drivers of species loss.

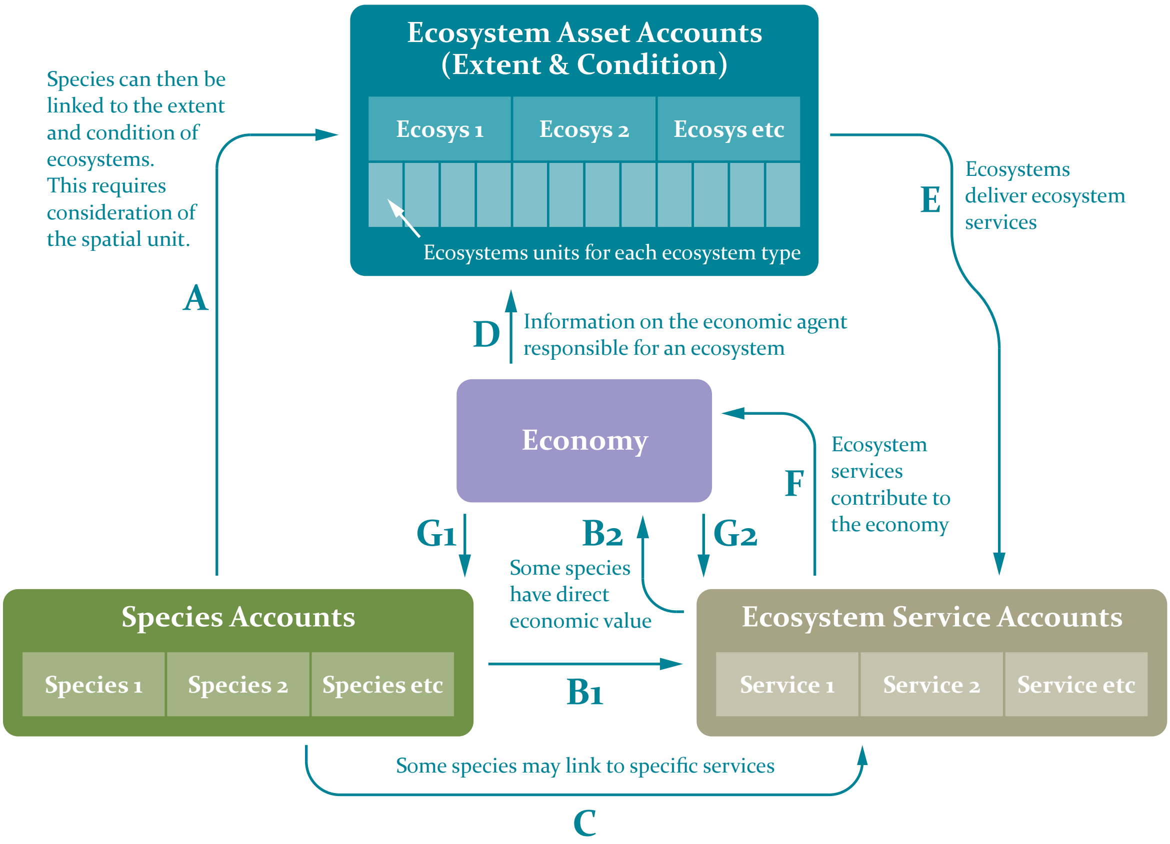


Figure 1.4: Linkages between Species Accounts, Ecosystem Asset Accounts (Ecosystem Extent and Condition Accounts), Ecosystem Service Accounts and the economy

1.5 WHAT ARE THE APPROPRIATE SPATIAL UNITS FOR SPECIES ACCOUNTS IN THE SEEA-EEA?

Within the SEEA-EEA, spatial areas are the basic focus for measurements (SEEA-EEA, 2014). This approach (Figure 1.5) consists of three interrelated spatial units:

- Basic Spatial Units (BSUs)
- Ecosystem Units
- Geographical Aggregations

BSUs provide the underlying spatial infrastructure for organising the majority of the information contained within ecosystem accounts. The recommended approach to identifying BSUs is to construct a grid of appropriate cell size (Figure 1.5) for an area of interest (Eigenraam 2012); this forms a spatial reference grid for ecosystem and species information. As a starting point, a 100 m grid reflects an appropriate level of spatial variability, while still being able to handle big data volumes (Schröter et al., 2015). However, grid size will depend on the geographical scope of the accounts. In this context, a BSU corresponds to a 'grid cell' in geo-information disciplines and a 'grain' in landscape ecology (SEEA-EEA TR, 2015).

The SEEA-EEA proposes the Ecosystem Unit as the conceptual spatial unit to represent an individual ecosystem asset. As shown in Figure 1.5, Ecosystem Units are defined on the basis of a contiguous arrangement of BSUs of a common ecosystem type. Approaches for delineating Ecosystem Units are discussed in the SEEA-EEA Technical Recommendations (2015). Ecosystem Units form the basis for statistics linking supply and use of ecosystem condition and extent to the supply and use of ecosystem services and economic agents.

Conceptually, it is possible to develop ecosystem accounts for each Ecosystem Unit. In most cases, however, larger scales will be more relevant for any policy analysis carried out. Within the SEEA-EEA, it is proposed that accounts will present information for Geographical Aggregations (Figure 1.5) in a manner that reflects the different types of ecosystems within them and is relevant to required analysis. In this document, such Geographical Aggregations are termed 'Reporting Units'. If two or more areas of the same ecosystem type occur within one Reporting Unit, aggregated data on species across all these Ecosystem Units may be reported, even if the areas are not physically connected. Scales for Reporting Units include countries, watersheds, administrative areas, or areas of particular interest, such as National Parks. Where an individual Ecosystem Unit crosses the boundary of a Reporting Unit (for example, when reporting for an administrative area), only the portion of the Ecosystem Unit retained in the Reporting Unit area should be considered in the account for that Reporting Unit.

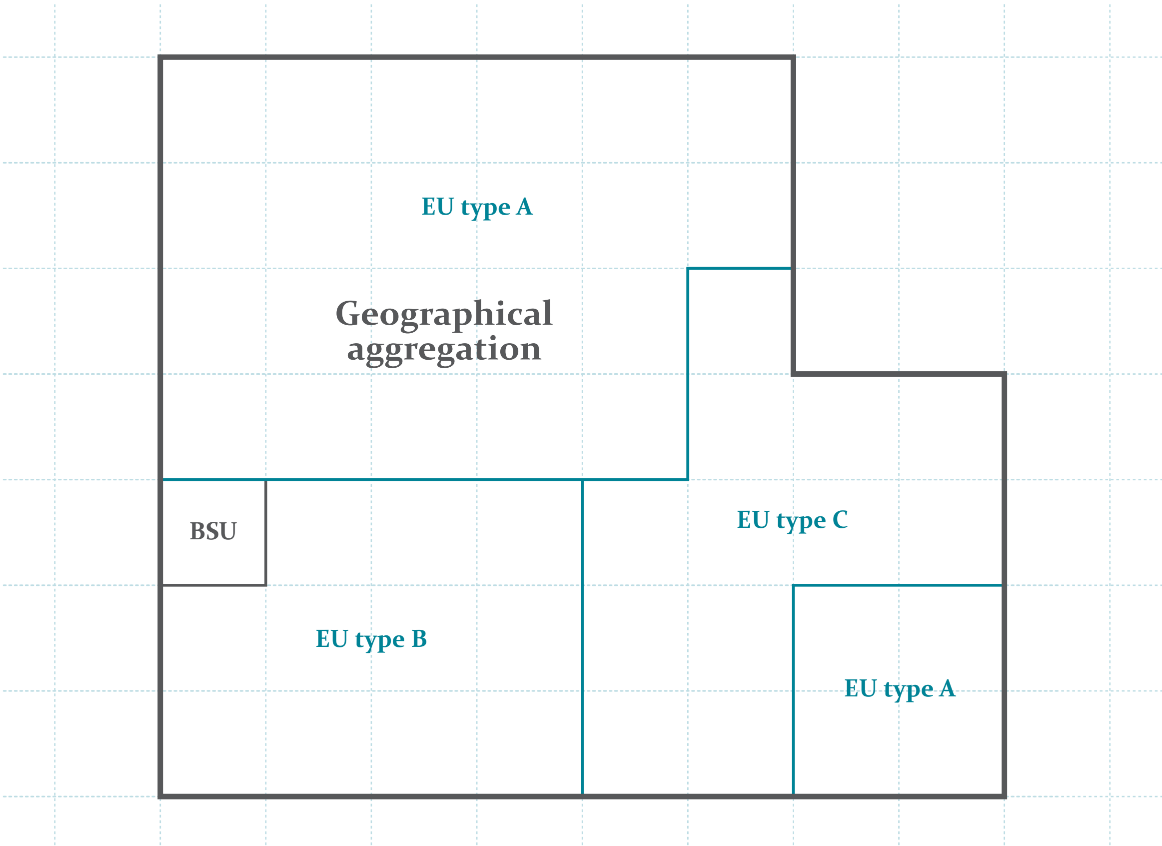


Figure 1.5: The relationship between spatial areas used for ecosystem accounting

The scale and spatial units chosen for organising information on species is one of the most important decisions to be made when constructing Species Accounts. As the SEEA-EEA is a multipurpose framework, Species Accounts can be constructed at all scales as standalone accounts. However, it is likely that most people will develop Species Accounts as part of the larger SEEA-EEA framework, for instance, in tandem with the development of ecosystem extent, condition and services accounts. In this case, there needs to be a consistent Reporting Unit in order to integrate the accounts. The scale of the Reporting Unit for Species Accounts should be decided on the basis of the policy questions they are intended to answer, and the data and resources that are available. This will also inform whether a 'bottom-up' or 'top-down' approach should be employed.

The bottom-up approach requires species information to be mapped or modelled at the BSU or Ecosystem Unit scale in manner that allows aggregation. While BSUs are a typical unit for assigning ecosystem information, species information may already exist at the Ecosystem Unit scale. For instance, where surveys have been completed for certain ecosystems (such as animal surveys within individual forests), they could be used to assign species information to particular Ecosystem Units.[1] Where data on species covers multiple Ecosystem Units, it may also be possible to disaggregate this to individual Ecosystem Units, although further data manipulation may be required if surveys only partially cover the Ecosystem Unit in question. Species Accounts may then be constructed by ecosystem type for any Reporting Unit desired by aggregating these component spatial units (as long as EUs are delineated in a manner that does not cross the Reporting Unit boundary; SEEA-EEA TR, 2015). Furthermore, organising Species Accounts at the BSU or Ecosystem Unit scale provides the capacity to 'drill-down' spatially, and thematically, and inform a wider range of analytical uses. This allows information on species to be linked to economic agents via 'cadastres' – administratively defined spatial units delineated on the basis of land ownership (SEEA-EEA TR, 2015). Cadastres are established in a number of countries and linking this information to Ecosystem Units facilitates a more detailed assessment of the implications of land management decisions and policy initiatives where land is under private ownership.

While the bottom-up approach represents the ideal scenario, it also provides a key measurement challenge for species accounting for two reasons. Firstly, it requires that species data is available at (or can be converted to) a spatial resolution consistent with BSUs or Ecosystem Units, while remaining meaningful at this scale for the species concerned and amenable to aggregation in an additive manner. Secondly, species may not map sensibly on to Ecosystem Units; for example, certain species are likely to use several Ecosystem Units during their life cycles.

The alternative, top-down approach constructs Species Accounts directly at the Reporting Unit scale, tackling the issue of species using several ecosystems during their life cycles. This approach is generally less resource intensive, but does not allow the user to drill-down spatially or link species information to cadastres. The ability to analyse detailed implications of policy options and management decisions will also reduce as the size of the Reporting Unit increases and the characterisations of ecosystems become increasingly coarse. Nonetheless, top-down approaches provide an entry point for incorporating species information into decision-making and a base for providing more detail over time.

Ideally, in the top-down approach, species information should be organised by ecosystem type within the Reporting Units. Where this is not possible, Species Accounts for Reporting Units will still provide useful macro information on species trends and stocks. Testing different scales and spatial units for Species Accounts (and ecosystem accounting generally) remains a key area for further research and experimentation. Feedback from users of this document will contribute to this process.

[1]It should be noted this will require a significant sampling effort and is likely to be limited to areas of particular interest, such as National Parks, or to countries where substantial biodiversity monitoring infrastructure is established.

1.6 WHAT DO SPECIES ACCOUNTS LOOK LIKE?

The SEEA-EEA takes the basic environmental asset account from the SEEA-CF as a starting point for considering the minimum set of data items necessary to inform an account for species (Table A). The data items in the account are represented by the species or species groups in each of the columns in Table A. The set of species or species groups selected must be ecologically meaningful and relevant to the needs of end users.

The Species Account provides an opening stock (Table A, Row 2) and ends with a closing stock (Table A, Row 5) for the species. These measures of stock may comprise various heterogeneous measures of species status, such as population abundance, biomass or hectares of suitable habitat. These measures must be relevant to the stated opening and closing years for the account (for example, 2005 and 2010 in Table A, respectively). Where available, observations for multiple years can also be accommodated in the accounting structure by specifying the opening period as 2003 to 2005, for example. However, it is important that the opening period and the closing period are equivalent to allow comparability. The changes between the opening and closing stock are recorded as additions or reductions (Table A, Rows 3 and 4, respectively). Ideally, the nature or causes of individual additions or reductions are recorded in separate rows of the account. The net change row (Table A, Row 6) then communicates changes in the stock over the accounting period. This could be over a year or some other relevant accounting period, but should remain consistent between different iterations of the accounts to allow comparability.

A reference condition is included to provide a point of comparison (Table A, Row 1). This must capture a consistent year or state for all species measures across all the columns in Table A. The opening and closing population, and the associated net change in species measures, are also expressed in relative terms with respect to the reference condition in the bottom half of Table A (Rows 7, 8 and 9, respectively). Where absolute measures are not available, Species Accounts can be constructed solely on the basis of such relative measures. The final row in Table A is the change as a percentage of the opening stock (Row 10). This reveals proportionate changes within different accounting periods.

Ideally, species measures recorded in the columns of the account should aggregate. However, this requires the adoption of a standardised measurement unit for all species. The heterogeneous nature of species data, and the variation in species assemblages between both ecosystems and locations, generally precludes this at present. As a pragmatic option, it is proposed that a composite indicator or index that aggregates relative species measures, and is anchored in a common reference condition across all columns in the accounting table, is determined (Table A, Final Column).

Table A: Hypothetical example Account of Species and Species Groups of Special Concern (2005-2010)

		Species or Species Group 1	Species or Species Group 2	Species or Species Group 3	Species or Species Group 4	Species or Species Group 5	
	Examples Species	Panda	Cuckoo	Tree sparrow	Orangutan	Vertebrates	Composite indicator
	Unit of measurement	No. of individuals	No. of individuals	Relative abundance based on population density	Hectares of suitable habitat	Proportion of original species complement	N/A
Row 1: Reference condition for a common year	Reference (1995)	2,000	100,000	Set to 1.0	1,000,000	85%	100%
Row 2: Abundance measure at start of accounting period	Opening (2005)	1,500	60,000	0.70	100,000	80%	N/A
Row 3 & 4: Additions and reductions should be stated if known	Additions	100	N/A	N/A	10,000	N/A	N/A
	Reductions	200	N/A	N/A	30,000	N/A	N/A
Row 5: Abundance measure at end of accounting period	Closing (2010)	1,400	65,000	0.50	80,000	70%	N/A
Row 6: Net change in abundance over accounting period	Net Change	-100	+5,000	-0.20	-20,000	-10%	N/A
Row 7: Relative abundance measure at start of accounting period	Opening (%of reference, 2005)	75%	60%	70%	10%	94%	TBC
Row 8: Relative abundance measure at end of accounting period	Closing (%of reference, 2010)	70%	65%	50%	8%	82%	TBC
Row 9: Net change in relative abundance over accounting period	Net change (%of reference)	-5%	+5%	-20%	-2%	-12%	TBC
Row 10: Change as a percentage of the opening relative abundance	Change (%of opening)	-6.7%	+8.3%	-29%	-20%	-13%	TBC

1.7 CHALLENGES TO IMPLEMENTING SPECIES ACCOUNTS

Practitioners embarking on establishing a species-related accounting system within their own countries have faced a number of challenges. Currently, there are a limited number of countries (including Peru, Australia, Norway, Scotland and the Netherlands) who have tried to implement accounts that capture information on species at some scale, and which can be used to guide others. A review of these experiences and the general state of species accounting identified a number of questions frequently faced by practitioners:

1) Where can I find the information and data I need for accounting?
2) Which measurements of species status do I capture in the accounts (e.g. species richness vs. species abundance)?
3) It is impossible to account for all the species in my country, so how do I prioritise which to include?
4) How should I develop species indicators for ecosystem condition?
5) How do I aggregate Species Accounts across different habitats/ecosystems?
6) At which scale should I organise my information on species and how do I integrate this in the wider SEEA-EEA accounts?
7) How do I aggregate my data from the local to national level within the accounting framework?
8) How do I determine a benchmark (reference) condition for species diversity?

(UNEP-WCMC, 2015; Vardon et al., 2015)

This document does not provide answers to all these questions, but it does set out a process to overcome the principal barriers to constructing meaningful, user-driven and operational Species Accounts in the context of the SEEA-EEA framework.

1.8 KEY MESSAGES

The key elements to consider when constructing Species Accounts in the context of SEEA-EEA are:

1) the classification of the landscape into different ecosystem types and spatial units;
2) the minimum set of species and associated data required to initiate the compilation of the accounts; and
3) the structure and design of composite indicators from the Species Accounts.

Guidance on element 1 is provided in the SEEA-EEA Technical Recommendations (SEEA-EEA TR, 2015). This document focuses on elements 2 and 3 in relation to Species Accounts.

2 Step-by-step approach

The approach presented in this document is designed to be flexible. It provides a framework for constructing user-driven spatially relevant Species Accounts in both data-rich (where direct observations of species are available) and data-limited (based on habitat-based methods for inferring species status) contexts. Two case studies for Wales and Peru are presented as appendices to demonstrate these different contexts, respectively. It is recommended these accounts focus on species of special concern, organised either holistically or under the following themes:

1) Accounts for Species of Special Concern
    a. Species of conservation concern
    b. Species important for ecosystem condition and functioning
    c. Species important for ecosystem service delivery

The Accounts for Species of Special Concern may also be supplemented with the following accounts:

2) Accounts of Red List Status

3) Accounts of the Extent of Important Places for Species

In all cases, Species Accounts should initially be constructed using existing data compiled under existing reporting systems. This document outlines eleven steps for constructing Species Accounts (Figure 2.1). These steps have been designed to guide the user through the process and are grouped under four phases:

1) Planning

2) Implementation

3) Communication and use

4) Review and refinement

While the steps are set out in a linear format, they need not be implemented as such. The construction of Species Accounts is an iterative process. As a decision is made during one step, a previous step may need to be revisited and adjustments made accordingly. In addition, the decisions made in earlier steps may also have implications for the choices available in subsequent steps. As such, the document should be read thoroughly in advance and a sequence of likely actions determined in order to inform the construction of Species Accounts on a case-by-case basis. The suitability of the different methods proposed should then be assessed, along with the most appropriate scale for constructing accounts in light of the intended uses, and the data and resources available.

Each step begins with a series of expected outcomes on completion, which can be achieved by following the actions described. To aid navigation and understanding, case studies are provided throughout the steps, in addition to those in the appendices.

Stakeholder engagement and the identification of potential users are important features of constructing policy relevant accounts throughout the process (Figure 2.1). Thus, it is important to maintain communication with these groups throughout the process in order to ensure the construction of Species Accounts that are relevant, credible and legitimate.

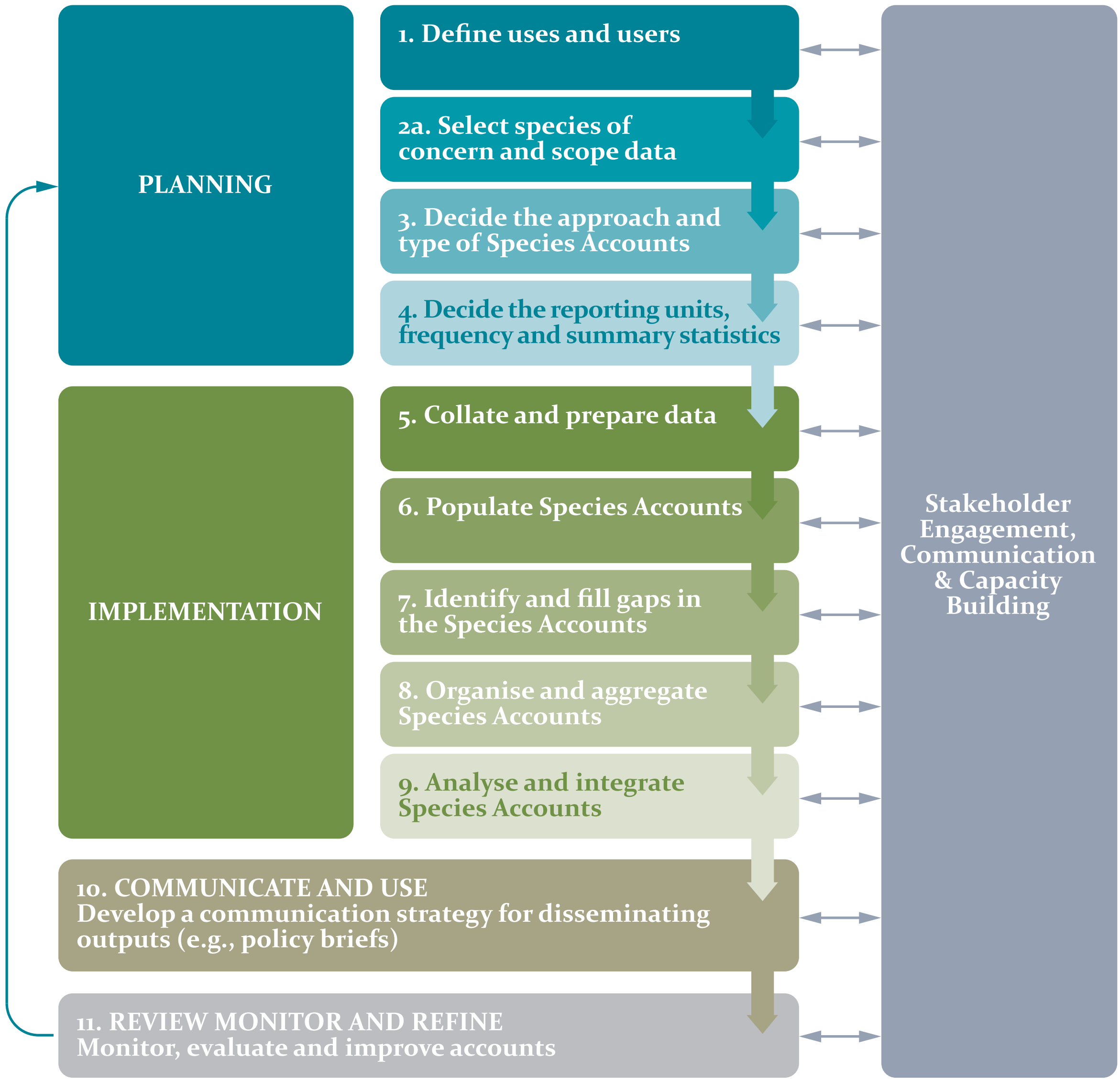


Figure 2.1: Step-by-step approach for constructing Species Accounts

2.1 PLANNING

The Planning phase for constructing Species Accounts comprises four steps:

Step 1. *Define uses and users*. The key policy questions and analytical uses for the accounts are determined. This requires the identification of potential users of the accounts and relevant stakeholders, and the establishment of a suitable governance structure to help steer the whole process. It provides the foundation upon which the accounts are constructed in order to ensure they satisfy user needs.

Step 2. *Select species of special concern and scope data.* Species relevant to the needs identified in Step 1 are selected and the availability of data for these species is scoped.

Step 3. *Decide the approach and type of Species Accounts.* A series of actions are completed in order to identify the most appropriate approach for constructing selected Species Accounts.

Step 4. *Decide the Reporting Units, frequency and summary statistics*. The spatial scales and Reporting Units for the Species Accounts are determined. Additionally, the frequency of data compilation and procedures for generating meaningful composite indicators or indices from the data are established.

2.1.1 Step 1: Define uses and users

2.1.1.1 Rationale

The purpose of Step 1 is to identify and agree upon the policy relevant questions and key analytical uses for constructing Species Accounts. This should not be conducted in isolation from existing policies and commitments, but rather as a complementary activity to improve the evidence base and inform decision-making. At this early stage, multi-stakeholder engagement is fundamental to ensuring the relevance, credibility and legitimacy of the accounting process and outputs. This should be supported by a clear governance structure to help guide the accounting process. This will be crucial to securing buy-in and further engagement from the wider community (Brown et al., 2016). Delivering accounting outputs that are robust, legitimate and policy relevant will also be essential if they are to be maintained and embedded into reporting processes over the long-term.

Specific outputs at the end of Step 1:

- A summary of a desk-based assessment of 'policy entry points' for information collated via Species Accounts.
- A list of key stakeholders.
- A record of stakeholder engagement undertaken, including establishment of governance structure.
- A set of key analytical uses or questions for Species Accounts that have been agreed by relevant stakeholders.
- A communication strategy for keeping stakeholders engaged in the species accounting process.

2.1.1.2 Actions

By explicitly considering the role of species in the supply of ecosystem services, Species Accounts provide an overarching thematic framework to help understand the contribution of species to human well-being and the economy. Additionally, species and species diversity is considered by many to be intrinsically valuable in its own right, reflecting the moral argument for conservation (Turner et al., 2003). The focus of this document is on constructing Species Accounts that will contain information relevant to both of these conservation goals. Furthermore, Species Accounts provide opportunities for the harmonisation of national-level species data alongside other reporting mechanisms, such as the Convention on Biological Diversity (CBD) and Sustainable Development Goals (SDGs).

2.1.1.2.1 Action A: Complete a desk-based assessment

Species Accounts are part of a broader information system (including basic data, interpretation and analysis) that aids decision-making across several stages of the policy cycle (Figure 2.2). Species Accounts can identify issues, such as worrying trends. They can help to formulate policy and target policy responses to such trends or, for example, to particular areas or ecosystems. They can allow different policy responses to be assessed, whether through simple forecasting based on past trajectories, or by using more sophisticated modelling (Vardon et al., 2016). Indeed, how policies are implemented can also be evaluated using Species Accounts, such as measuring the sustainable use of environmental resources. Collectively, these uses all represent different 'policy entry points' for Species Accounts. In addition, Species Accounts benefit the public sector by providing regular and consistent information to decision-makers, avoiding the need for commissioning individual studies to collect and analyse data for policy implications (Vardon et al., 2016).

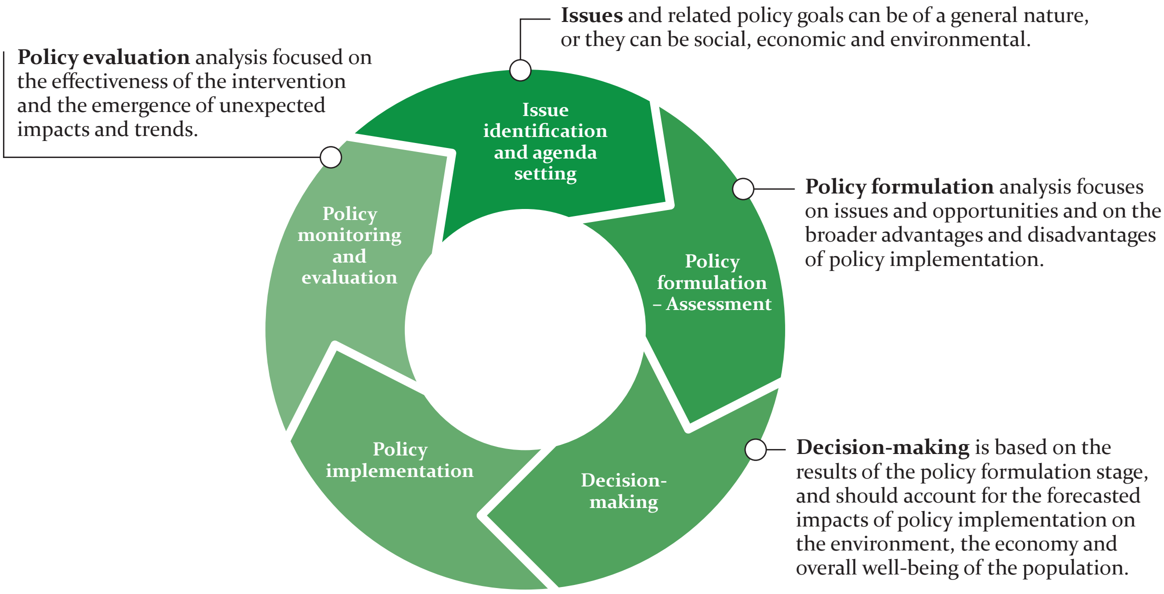


Figure 2.2: Overview of the policy cycle (UNEP, 2014)

The first part of Step 1 recommends that you undertake a desk-based study of the range of relevant policy entry points for Species Accounts within existing relevant national (and/or sub-national) policies, plans and commitments. This will help you to identify the policy relevant analytical uses for Species Accounts (for instance, supporting trade-off analysis), or the questions that Species Accounts should be designed to answer (for instance, where and how do trends in species threaten the delivery of ecosystem services?).

Documents that may include relevant policy goals and objectives include:

- Long-term development strategies
- National 'vision' documents
- National development plans
- Economic development plans
- Green economy/green growth strategies
- National environment policies
- Climate change policies
- National Biodiversity Strategies and Action Plans
- Local/sub-national development plans
- Tourism policies
- Wildlife policies
- National forest plans
- Fisheries policies
- Water policies
- Land-use plans
- Agricultural plans
- Environmental impact legislation
- Endangered species legislation
- Regional (e.g. European Union [EU]) policies relevant to species, biodiversity and associated impact drivers
- National adoption of SDGs
- Health and well-being policies

By the end of the desk-based study, you should have a better understanding of where outputs from Species Accounts can inform the policy cycle and commitments made within international, national or sub-national strategies, plans and polices. At this point, it is recommended that you construct a list of the analytical uses and policy questions that data organised by your Species Accounts can inform.

2.1.1.2.2 Action B: Identify and engage with stakeholders and users

The second part of Step 1 is to identify and engage with of a wide range of stakeholders and users in order to reach agreement on the key analytical uses or policy questions that your Species Accounts will inform. This reflects the principle of 'decision-centred design' (Vardon et al., 2016), where accounts, and the reports derived from them, are designed to provide the most relevant information in the most useable format to decision-makers. Your desk-based assessment (Action A) will help you to identify a number of stakeholders relevant to the public decision-making context. While this policy focus reflects government uses, the design of your Species Accounts should also aim to maximise their usefulness for other actors, such as those in industry, non-governmental organisations (NGOs) and the general public (Vardon et al., 2016).

Activities to identify and map stakeholders include: brainstorming; mind mapping; developing generic stakeholder lists; and reviewing previous and/or similar projects with stakeholder consultation. Once you have identified your stakeholders, you can then look for ways to engage them in the development and use of your Species Accounts (Box 2.1).

Box 2.1: Forms of stakeholder engagement

The following methods of stakeholder engagement can be selected and combined as required, depending on the accounting context. Stakeholders can be:

- consulted on the needs for Species Accounts;
- consulted on key questions framing Species Accounts;
- given information on progress, findings and opportunities to participate;
- asked to contribute knowledge to the construction of Species Accounts;
- asked to contribute contextual information about ecological or social systems;
- consulted on the condition and trends of species-level biodiversity, ecosystem services and human well-being;
- asked to attend workshops on species accounting;
- asked to participate in the accounting process as students, interns or fellows;
- asked to participate in governance;
- a formal end user of the accounts;
- asked to participate in the peer review of Species Accounts; and
- a partner in the dissemination of accounts and associated findings.

Adapted from Ash et al. (2010)

Once you have identified the relevant stakeholders, you will need to engage them in an appropriate format (for example, email, web forum, workshop, or an existing platform or mechanism). This will allow stakeholders to actively participate in the process of discussing and establishing the user requirements for Species Accounts (i.e. determining the analytical uses and policy questions the accounts are needed for). Examples of the different potential uses of Species Accounts by different stakeholder groups are presented in Table 2.1.

Table 2.1: Examples of the potential uses of Species Accounts by different stakeholder groups

Stakeholder groups/users	Analytical uses
Policymakers (split into different interest groups)	• How do you monitor species-level biodiversity and ecosystem service delivery? • How do you evaluate trade-offs between species and species-level biodiversity and planning? • How do you understand the trade-offs between species and ecosystem services? • How are species hotspots located in relation to infrastructure, urban development and important ecosystem services?
Forest and national park managers	• What are appropriate investment levels for blue/green infrastructure?
Environmental ministries	• What is happening to species-level biodiversity at national and sub-national levels? • How do you report on conservation goals (including endangered species)? • How do you evaluate different land use options? • How can you inform 'No Net Loss', environmental compensation and offset programmes (Pindilli & Casey, 2015)?
Ministries of state	• How do you manage key migratory species whose habitat needs extend into other nations (including the development, implementation and enforcement of international treaties and multinational management plans; Semmens et al., 2011)?
Sectoral policymakers/ economic actors	• How much should you invest in biodiversity and species for natural solutions (e.g. reduced pesticides)? • What is happening to locally produced ecosystem services?
Tourism ministries	• How much should you invest in species important for tourism (e.g. games species, iconic species and charismatic species)? • What are the returns on investment in species and species-level biodiversity?
Policymakers/decision-makers without a vested interest in biodiversity	• How can you communicate the economic arguments for investment in species and species-level biodiversity? • How can you provide information on the aspects of species and species-level biodiversity that are important to ecosystem condition and services? • How can you track progress towards SDGs?
On-the-ground decision-makers and managers	• How can you mobilise information on species to assist in day-to-day decision-making in relation to key policy and conservation goals? • How can you develop a common framework to regularly document information on species and ecosystems (e.g. location and trends)?
Finance ministry	• What is happening to the species asset base and what are the implications for future benefits associated with these trends? • What are the economically rational levels of investment in ecosystems vs. other investment opportunities?

Stakeholder groups/users	Analytical uses
Agricultural and fisheries ministries	• How can you reveal external impacts of land conversions? • What are the best investment choices for land use in order to maintain species and species-level biodiversity? • How can you inform sustainable fisheries management for commercial, artisanal, recreational/tourism-based fisheries? • What levels of investment are needed to achieve desired conservation status? • What are the best investment choices in coastal management related to species conservation, coastal green infrastructure and climate adaptation? • How can you evaluate and track trends in natural pest control and pollination and the impacts of agricultural intensification, climate-smart agriculture, and other interventions on biodiversity?
Researchers and analysts (e.g. ecologists, environmental and social scientists, and environmental economists	• What are the causal links between a range of environmental drivers of change (e.g. land use, climate change and pollution) on species trends? • What are the social and economic drivers of change in species status?
NGOs	• What are the trends in species and species-level biodiversity (including endangered species)? • What are the returns on investment in conservation? • How can you make the case for increased investment in biodiversity?

To effectively engage with stakeholders, it is important to provide the results of the desk-based study well in advance of any discussions. In addition, you may need to build understanding among stakeholders of what Species Accounts are and how they can be used, helping them to manage their expectations of the outputs of the accounts, as well as to recognise potential policy uses. A key output from initial stakeholder engagement will be a prioritised and agreed list of key analytical uses or policy questions for constructing Species Accounts; Box 2.2 shows an example of the stakeholder engagement process as undertaken in Uganda.

Box 2.2: Feasibility study for species accounting in Uganda (UNEP-WCMC, 2016)

A desk-based study was undertaken in order to identify policy entry points for species and ecosystem accounting in Uganda. The documents reviewed during the assessment included: Uganda Vision 2040; Second National Development Plan (NDPII, 2015/16-2019/20); Post 2015 Sustainable Development Goals (SDGs); Uganda Green Growth Development Strategy (UGGDS); National Biodiversity Strategy and Action Plan (NBSAP, 2015-2025); Uganda National Climate Change Policy; National Environment Management Policy (NEMP, 1994); United Nations Development Assistance Framework for Uganda (2016-2020); Tourism Policy (2014); National Agriculture Policy (2013); Uganda Forest Sector Policy (2001); National Forestry Plan (2011/12-2021/2022); and Uganda Wildlife Policy (2014).

Following the review, stakeholder mapping was undertaken by the National Planning Authority and key stakeholders in ministries, government authorities, NGOs and academia were identified. Stakeholders were then visited and presented with the motivations, methods and entry points for species and ecosystem accounting identified in the desk study. The needs of stakeholders for biodiversity accounting outputs were also discussed and captured during these meetings.

A stakeholder workshop was convened to review user demands for species and ecosystem accounting outputs and to establish a set of common policy questions the accounts could help to answer. Stakeholders were split into four mixed groups to discuss these themes and develop a set of priority policy questions. Some common questions (i.e. proposed by more than one group) that emerged from this exercise included:

1. How do we increase awareness and appreciation of biodiversity as an asset among policymakers and the public in Uganda?
2. How can we make a case for increased budget allocation for key sectors rich in biodiversity in Uganda (e.g. tourism, wildlife, forestry, agriculture)?
3. How to inform the ongoing debate on gazettement and degazettement of Protected Areas in Uganda?
4. What is the extent of ecosystem degradation and areas where biodiversity trends threaten the delivery of ecosystem services in Uganda?

A report was issued to all stakeholders shortly after the workshop to present findings.

At this stage of the stakeholder engagement process, you should also seek to establish a governance structure for the process of constructing Species Accounts. One way to organise this is to convene an advisory group of different stakeholders and users who can contribute to discussions and decision-making during the different steps of constructing the Species Accounts. Establishing an effective, ongoing relationship with this group is essential if the accounts are to be used to inform decision-making in practice (Vardon et al., 2016). This group will be fundamental in giving immediacy to the production of Species Accounts and steering the design of accounting outputs to meet the needs of end users. When establishing the governance structure, consider who you should include (ideally fewer than 20, so it remains manageable), when to meet, how decisions should be made, and responsibilities for reporting different aspects of the accounting process to the wider community of stakeholders; Ash et al. (2010) provide a more detailed discussion of these considerations.

In terms of wider stakeholder engagement, it is also important at this stage to gain agreement between institutions about the sign off and release of accounting data at the end of compilation process.

2.1.1.2.3 Action C: Develop a stakeholder communication strategy

A communication strategy to retain the interest of all stakeholders is fundamental in ensuring the accounting process and its outputs are seen as relevant, credible and legitimate (Ash et al., 2010). Regular communication with key stakeholders will also help to ensure that, as the accounting process evolves, it will continue to be relevant to the needs of end users. ONS (2015) suggest strategies for communication when developing Natural Capital Accounts that are relevant in the context of Species Accounts:

- Workshops
- Websites and other social media
- Introductory, non-technical guides
- Newsletters
- Summaries of outcomes from advisory group meetings
- Press releases and other formal media engagement

2.1.1.3 Expertise and capacity

To complete Step 1, you will need:

- The expertise of the policy and institutional landscape in order to ensure that the key policy entry points and stakeholders are identified.
- Capacity for communicating species accounting, its uses and its development to stakeholders.
- Capacity for stakeholder engagement (e.g. workshop facilitation) in order to ensure optimal stakeholder engagement.

2.1.2 Step 2: Select species of special concern and scope data

2.1.2.1 Rationale

The purpose of Step 2 is to prioritise a set of species or species groups for the accounts and to review the availability of data for these species. These species or groups will form the main data items (i.e. the columns with associated measurements) in your accounts. As it will not be possible to account for all species, a subset of species relevant to the analytical uses of the Species Accounts should be selected.

Specific outputs at the end of Step 2:

- A list of species or species groups of special concern for inclusion in Species Accounts that are relevant to the policy and/or decision-making context.
- A metadatabase relevant to the analytical uses and policy questions determined in Step 1.

2.1.2.2 Actions

At the planning stage, you will need to determine the key species and measurements to be captured. This includes selecting species of special concern for inclusion in the accounts and deciding which data to collate on them. Reflecting on the intended uses (e.g. trend analysis, policy options, scenario analysis) and audiences (e.g. policymakers, decision-makers, public) of the Species Accounts will help to guide your selection of the species or species groups, and will help you to scope what information should be recorded in the accounts.

2.1.2.2.1 Action A: Select species or species groups of special concern

The selection of species or species groups for inclusion in your accounts should be informed by the user needs you identified in Step 1. As such, you may need to consider a number of different uses for the accounts and take this into consideration when selecting specific species or groups to be included. For instance, conservationists may be particularly interested in the abundance of rare and threatened species and the important cultural services they provide. Other stakeholders may be more concerned with the role of species in maintaining ecosystem

condition (i.e. maintaining the functions and processes that deliver a range of regulating and supporting services). Finally, some users may be interested in species that provide provisioning services such as fish for consumption or plants for medicine.

While rare species may be the focus of some conservation efforts, common species and especially species groups are more responsible for maintaining the condition of ecosystems and functionality of communities, and are likely to be significant contributors to a wide range ecosystem services (Mace et al., 2005). However, some individual species – referred to as 'surrogates' – are considered better proxies of species diversity and ecosystem condition than others (Caro, 2010).

The provision of multiple ecosystem functions (referred to as 'ecosystem multifunctionality') is increasingly thought to be linked to the diversity of species within the ecosystem (known as 'alpha diversity'), rather than the presence of individual species (Maestre et al., 2012; Wagg et al., 2014). Therefore, it is recommended that you select species which cover several taxonomic groups; for instance, considering a mammal and an amphibian will generally provide a better indication of species diversity than selecting two mammals (UNEP-WCMC, 2015). The status of species of special concern is also likely to be linked to the rest of the ecological community, for example through trophic interactions or other indirect feedbacks of ecosystem functioning.

Other relevant factors in choosing species will be the scale at which your Species Accounts are constructed. If the accounts are intended to cover large tracts of land, for example, it is likely that a larger number of species or species groups will need to be included in order to satisfy user needs. This is also likely to be the case when a diverse range of ecosystems exists within the landscape. Throughout, you will also need to bear in mind the resources that are available. In the initial phase, it may be appropriate to focus efforts on a limited number of key species or species groups and expand this in subsequent iterations of the accounts.

Species groups

Instead of solely focusing on individual species, it may be useful for you to construct Species Accounts using information on species groups. Information for species groups may be directly available as surveys will often record all species in a group (e.g. all birds, butterflies or plants). Alternatively, species groups could be constructed by aggregating information on individual members of the group. This type of information will be particularly useful for stakeholders that are interested in biological diversity or the functions and services that rely on species diversity within a whole group, rather than on individual species per se. When choosing your species groups, it is useful to allow for comparability.

Taxonomic and phylogenetic groups

The SEEA-EEA (2014) provides a preliminary account of species based on taxonomic groups. Constructing accounts of taxonomic groups may be an approach you wish to consider when broad trends in species diversity are of concern. For instance, the account presented in the SEEA-EEA considers a mix of different kingdom (plants) and animal classes (e.g. mammals). Other taxonomic groups could include phylum (e.g. chordate), order (e.g. carnivora), family (e.g. canidae) and genus (e.g. Canis).

You could also organise species in phylogenetic groups, based on the relationships between the species and a common ancestor (Baum, 2008). The advantage of using phylogenetic groups is that it provides more detailed evolutionary information on community composition of groups than taxonomic classifications (Swenson, 2009). This will allow you to consider an evolutionary perspective within your accounts (Faith, 2008), thus allowing representation of different evolutionary histories of conservation interest (Mace et al., 2003). This could, for example, be used to implicitly group species on the basis of inherited features of interest being likely to persist (Faith, 1992), and would provide information on how these features are trending. This may be useful for outcomes such as maintaining wild crop relatives or other commercially important species. Phylogenetic diversity has also been shown to be significant in explaining ecosystem functioning, specifically with respect to plant biomass production in communities (Cadotte et al., 2008).

Functional groups
Species may be grouped according to shared attributes or traits which govern their effects on one or several ecosystem functions (Lavorel et al., 2007). There is a body of evidence that suggests functional diversity is closely linked to local ecosystem functioning (Hooper et al., 2005, Diaz et al., 2007, DeVictor et al., 2010). Accordingly, functional groups can provide a link between species and ecosystem processes, structures and resilience (Sundstrom et al., 2012).

Functional species groups could be selected for biomass production, pollination, nitrogen fixation, seed dispersal, predation of other organisms, decomposing biomass, soil mixing, modifying water flows, and facilitating ecosystem succession, reorganisation and colonisation (Elmqvist et al., 2010). The benefits arising from these functional groups should not be constrained to the economic or human well-being perspective, but should also consider inter- and intra- ecosystem services (i.e. supporting services) that support other species (Vardon et al., 2015).

Categorising species into different functional groups is typically achieved by identifying similarities in a set of attributes or traits important to the function of interest (Petchey & Gaston, 2006). The general approach is to obtain information on the morphological, physiological and ecological traits of species and estimate how similar they are in the values of those traits (e.g. nitrogen fixing ability, size, etc.). A classification system is then constructed that captures similarities between species (Petchey and Gaston, 2006).

When organising functional species groups, they should reflect the ecosystem functions and services of interest (Petchey and Gaston, 2006). If you are interested in ecosystem condition, for instance, you may wish to organise species in a broad range of functional groups as the loss of an important functional group may significantly impact on ecosystem functioning (Jackson et al., 2001). Monitoring functional diversity, or, more specifically, functional redundancy, will also be important in understanding the resilience of ecosystems. If disturbance causes a species to go extinct in a system that contains species with similar functional roles, it is likely that the survival of a similar species, unaffected by the disturbance, will allow the ecosystem to continue to function (Elmqvist et al., 2003). Alternatively, if you are interested in specific ecosystem services, you may organise species into functional groups that are relevant to these services, such as pollinators, primary producers or nitrogen fixers.

Other groups
Other groupings may be relevant to the uses you have in mind for your Species Accounts, including: a community of species coexisting at a given place; a group of specialists versus a group of generalist species; endemic versus invasive species; or species grouped on the basis of trophic relationships (e.g. autotrophs, heterotrophs, etc.). Given the complexities of selecting species groups, this must be undertaken in close consultation with ecological and taxonomic specialists, and in consideration of the data available. This will ensure that groups are sufficiently represented by species data and that the species are grouped in an ecologically meaningful way, pertinent to the key analytical uses and policy questions determined in Step 1.

Factors in selecting individual species and species groups
It is not possible to capture all species within your Species Accounts, so you should select species or species groups on the basis of factors relevant to the key analytical uses and policy questions determined in Step 1. A non-exhaustive list of such factors and example species or species groups is provided here, arranged under the themes of conservation, ecosystem condition and functioning, and ecosystem services.

Conservation

- *Threatened species* are those at high risk of extinction. The IUCN Red List classifies the risk of a species becoming extinct into several categories: Extinct, Critically Endangered, Endangered, Vulnerable, Near Threatened, and of Least Concern. This is based on changes in the distribution and/or abundance of a species. You could select an individual Red List species, such as Critically Endangered Black Rhino or the Gharial, for your Species Accounts, or you could group species of interest using their Red List classification (i.e. you could consider a number of Critically Endangered species as a species group).
- *Endemic and/or restricted range species* are species indigenous and restricted to a certain geographic area, such as a country or ecosystem type. It is often assumed that, when there are no other areas in which these species are found, they might be more vulnerable to extinction than species found in multiple locations.
- *Migratory and/or congregatory species* are those that move a relatively far distance, usually on a seasonal basis (migratory), or come together in significant numbers in one spot, often to breed or feed (congregatory). Migratory species are often congregatory ones, as well. Locations where these species occur are very important as their degradation can affect large numbers of individuals. Special management concerns also emerge from managing migratory species that cross international borders and multiple ecosystem types at different parts of their annual cycle (Semmens et al., 2011).
- *Phylogenetically unique or distinct species* are those that have an ancestral lineage that is shared with few other species. Such species often contribute more to regional, national and global genetic and morphological diversity than other species, so may be a conservation priority.

Ecosystem condition (including ecosystem functioning)

- *Keystone species* have a disproportionate effect on the ecosystem relative to their abundance (Mills et al., 1993; Paine, 1995). As such, they affect the types and abundance of many other species in a community. The identification and management of these species can be important in conservation (Fleishman et al., 2000). You may wish to include individual keystone species, such as elephants or wolves, within your Species Accounts (Power et al., 1996), or concentrate on groups of species, such as dung beetles (Nichols et al., 2008).

- *Umbrella and proxy species* are those species that are used as surrogates to represent the distribution or abundance patterns of other species. Umbrella species are defined as such because their requirements include those of many other species as a result of sharing the same habitat; indeed, their status can serve as a proxy for the status of multiple species (e.g. the jaguar in South America). Although single species have been used as umbrella species, a multi-species approach may be more effective (Roberge and Angelstam, 2004). For example, Watson (2001) used the hooded robin and yellow robin together to effectively indicate protection of woodland birds in south-east Australian temperate woodlands.

- *Other species or groups important for ecosystem functioning* might include trophic groups or those species and groups with specific roles in ecosystem functioning, such as nitrogen fixing plants, decomposers, herbivores and predators.

Ecosystem services

- *Charismatic species* are ones with widespread popular appeal, such as lions, tigers and bears. They are often large and visible creatures, and may be termed 'charismatic megafauna'. These species may have high cultural and non-use values to people, and may include species that serve as national symbols or are internationally recognised.

- *Species that deliver direct use benefits* (Pascual et al., 2010) are important in providing a range of ecosystem services that directly contribute to economic activity and well-being. They include species for consumption, species important for recreation, culturally important species (e.g. sacred plants and animals), and socially important species (e.g. medicinal plants).

- *Species that provide indirect use benefits* include species and species groups important for regulating services, such as pollination, water purification, carbon sequestration, hazard protection, pest control and soil formation. For example, bats provide pollination and seed dispersal services (Kunz et al., 2011), and birds provide insect pest control, seed dispersal and nutrient cycling services (Wenny et al., 2011).

Figure 2.3 illustrates how different species or species groups could be used in different Species Accounts for different purposes. Many species or species groups may be relevant to conservation, ecosystem condition and functioning, and ecosystem service delivery. Where this is the case, the same species may be recorded in different Species Accounts under these different themes, but may only be recorded in any individual account once. The final selection of species for inclusion in the accounts should be justified on the basis of ecological principles or other criteria relevant to the analytical uses and policy questions determined in Step 1. Box 2.3 provides a case study that demonstrates how species were selected for inclusion in a set of Species Accounts for Wales.

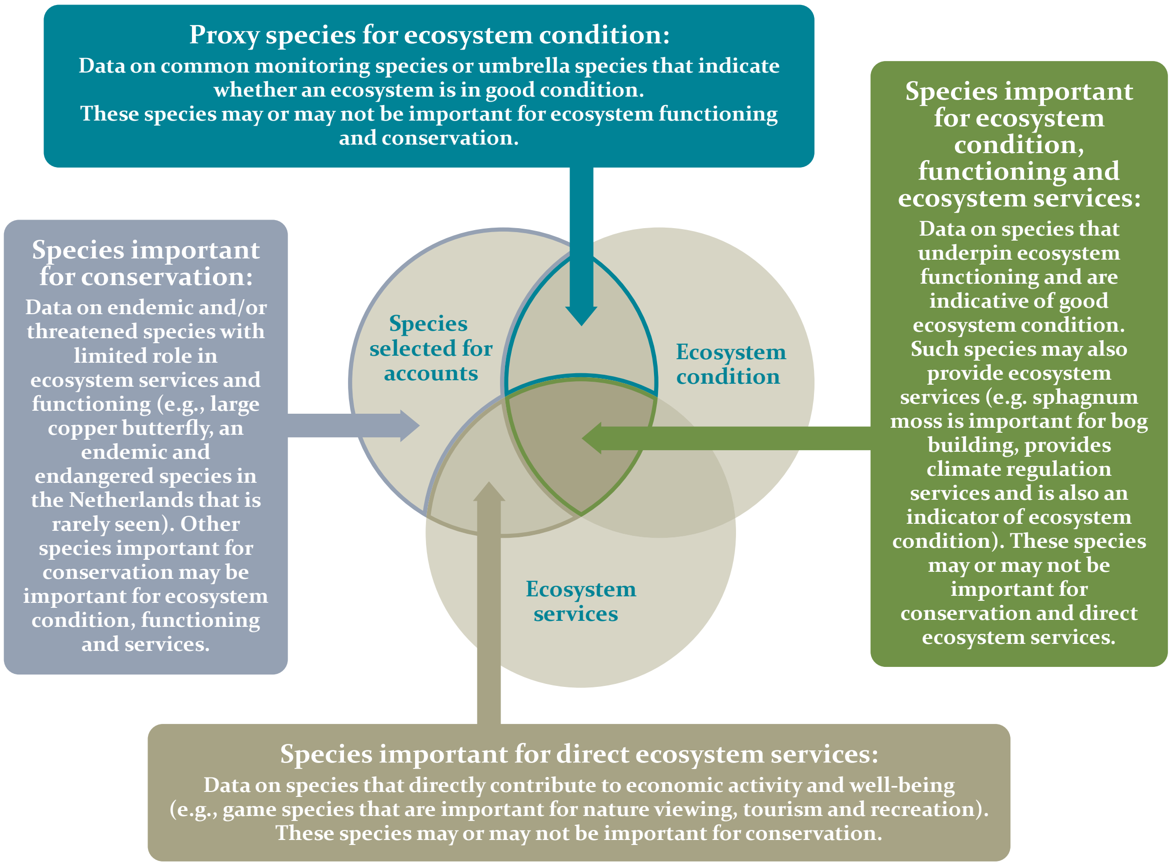


Figure 2.3: Diagram illustrating how species selected for Species Accounts can also provide information on conservation, ecosystem condition and functioning and ecosystem services

Box 2.3: Evaluating the potential for the development and use of Species Accounts in Wales*

The potential value of developing Species Accounts to track changes in terrestrial species important for conservation, ecosystem function and condition has been evaluated for Wales in order to inform future State of Natural Resources Reports. Wales is an example of a data-rich country; major investment since 2012 has helped to develop a national, integrated monitoring programme for tracking change in terrestrial natural resources and the impact of payments to land managers for environmental outcomes. This project is called the Glastir Monitoring and Evaluation Programme (GMEP; Emmett at al., 2015, www.gmep.wales) and augments an array of independent volunteer-based monitoring programmes. The full case study for Wales is presented in Appendix A. It is built upon work undertaken in 2015 with the GMEP stakeholder group to develop a range of biodiversity and other ecosystem indicators for national-scale reporting. Species selected for inclusion in the accounts were ones previously prioritised by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006 as those of principal importance for the conservation of biological diversity in Wales (557 in total). This list is much broader than the IUCN Red List, which is already reported on through other pathways.

The policy priorities for Wales clearly require the consideration of species beyond those important for conservation alone to ensure tracking of species important for ecosystem resilience and condition (and the resulting benefits) are also monitored. Woodland is presented as a test case, with species data selected including plant, bird and soil metrics relevant for the assessment of woodland condition and five functions/services for which direct species relationships could be identified (and for which data were available): pollination, dispersal, wildlife tourism, flood mitigation and soil functional resilience.

Unfortunately, time constraints did not allow further consultation and refinement of the trial Species Accounts, but the work was informed by the many discussions currently ongoing in Wales to develop objective and transparent indicators to track the progress of new policy initiatives.

**The case study for species accounting in Wales provides an initial attempt at exploring the methodology to help inform other organisations and countries as to the issues identified during the process of following this step-by-step approach. No resulting values or approaches should be seen as approved or ready to be cited in any capacity.*

2.1.2.2.2 Action B: Review data for selected species

Once you have selected species or species groups of special concern, you will need to review and assess existing sources of data relevant to your selections (useful data sources are presented in ‘Resources and tools’ at the end of this Step). This assessment should be based on a consideration of the spatial resolution and accuracy required, consistency of data across time and sampling locations, and temporal update frequency and temporal aspect (how long the time series is). Initially, this should comprise existing monitoring, recording or modelling efforts.

Taxonomic, geographical, sampling or other biases in species data may be partially addressed through additional, targeted data mobilisation of non-digitised records from natural history collections. This may add significant time and financial commitments, however, and those records may not always be held within the country of interest. If it can be done, it will facilitate powerful species distribution modelling techniques that may help fill remaining gaps in species datasets.

Box 2.4 presents a review of data available for informing Species Accounts in Wales (case study introduced in Box 2.3).

Box 2.4: Review of data availability for Species Accounts in Wales.*

In order to inform the Species Accounts for Wales (Box 2.3), the availability and quality of data were assessed. The structured survey co-located approach within the Glastir Monitoring and Evaluation Programme (GMEP) was considered to provide a high-quality source of data, which builds on well-established statistical approaches published in the peer-reviewed literature: transparency and accessibility of methodology with low bias and high precision but low temporal resolution. Data from the British Trust for Ornithology (BTO)/Joint Nature Conservation Committee (JNCC)/Royal Society for the Protection of Birds (RSPB) Breeding Bird Survey were also considered of high quality, with methodologies established in the peer-reviewed literature and with low precision in actual abundance data, but high temporal resolution. Inclusion of data from other sources, such as an array of volunteer taxa-specific monitoring schemes, should be explored in the future.

**The case study for species accounting in Wales provides an initial attempt at exploring the methodology to help inform other organisations and countries as to the issues identified during the process of following this step-by-step approach. No resulting values or approaches should be seen as approved or ready to be cited in any capacity.*

2.1.2.2.3 Action C: Review habitat data

Some species (or groups of species) may suffer from a limited number of observations. However, it may be possible to link their potential presence to suitable habitat/biodiversity areas where such preferences are known. Time series maps of these habitat or ecosystem types reveal whether their extent is increasing, stable or declining over time. These maps can reveal which changes in land cover or use are impacting species' habitat requirements and form the basis for constructing Species Accounts using a habitat-based methods.

Many regions and countries have moved towards establishing maps of land cover, habitats and ecosystems and updating these periodically to reveal changes in the extent of different ecosystems and habitats. You may find such maps useful if you are employing a habitat-based method to compiling Species Accounts; they may be available from:

- Departments of land and surveys
- National environment ministries
- National planning authorities
- Statistical offices
- Universities

Remote sensing and modelling can also be employed to upscale existing datasets in order to estimate spatial data on species in non-sampled areas (Strategy 2, Step 3). In some cases, these types of habitat-based methods may already be underway and be generating distributions or other measures of species and species communities under national programmes. Such data may also be useful for informing your Species Accounts.

2.1.2.2.4 Action D: Record relevant data sources in a metadatabase

During the review process, you should capture key information about each dataset in a metadatabase, such as contact details of the institute who generated the data, how regularly the data are updated, the spatial resolution of the data, the consistency of the data across time and sampling locations and the temporal aspect (how long the time series is) of the data. At this stage, it is also important to gain agreement with relevant institutions about the release of data to inform your Species Accounts.

2.1.2.3 Resources and tools

A number of sources of data exist that can contribute to populating Species Accounts. Depending on the country, these sources include species point observations and information on species' distributions and abundance. In order to inform Species Accounts, this data must exist at the spatial resolution required, provide a time series of observations, and be consist across both space and time.

In some cases there may be conflicting assessments of species due to differences in criteria, assessment times, methods of dealing with scale effects, and other reasons. When reviewing different data sources, it is important to consider the uses of the accounts and select the best quality data for such purposes. Throughout, you should bear in mind that the concept of quality is multidimensional. Statistics Canada (2009) defines the dimensions of quality as: relevance (how well the information meets users' needs); accuracy (how well the information represents the phenomena that is being measured); timeliness (how quickly information for a given period can be generated); accessibility (how easily information can be obtained and used); interpretability (how well supported the information is, with details on methods of collection, concepts and indications of accuracy); and coherence (how easily it can be integrated with other information). Inevitably, there will be trade-offs across these dimensions that you will need to consider.

National datasets

Start by considering existing national and, if relevant, sub-national biodiversity monitoring schemes to determine possible sources of species information and data. Examples include butterflies (e.g. Israel's Butterflies Monitoring Scheme; Pe'er, 2015), birds (e.g. New Zealand's Garden Bird Survey, which is a nationwide citizen science project; Spurr, 2012), and bats (e.g. the North American Bat Monitoring Programme; USGS, 2015). It is important to note that such data on species and habitats will normally be collected on a very detailed level, based on mapping and sampling strategies.

Species distribution maps and the distribution of species richness and endemism are often contained within other data sources, such as:

- The IUCN Red List of Threatened Species (also a source of range data for species)
- National and Regional Red List assessments (also a source for threatened species)
- Other national or sub-national listing processes (these may use IUCN or other criteria)
- The national Global Biodiversity Information Facility (GBIF) node for members of the GBIF (a dedicated institution that coordinates and manages biodiversity data in a country; GBIF Secretariat, n.d.)
- NatureServe (holds data on plants, animals and ecosystems in the USA, Canada and countries in Latin America)
- Other literature and publications (search engines such as Web of Science for scientific journals, etc.)
- Regional species-mapping initiatives (e.g. European Flora Atlas)

The Integrated Biodiversity Assessment Tool (IBAT) provides a common portal for accessing some of the datasets mentioned above (IBAT, n.d.).

Regional reporting obligations, such as those for the EU Habitats and Birds Directives, can be further sources of data. Other possible sources of relevant data include those that come from reporting on the progress of implementing international biodiversity conventions and agreements; for example:

- *Trends in the status of threatened species:* Parties to the Ramsar Convention are asked to report on species of fauna in Ramsar sites that are of particular concern (e.g. unique, rare, endangered or biogeographically important).
- *Species abundance:* Several conventions and agreements ask Parties to report on populations of species, for example: Appendix I Species under the Convention on Migratory Species; and of the main populations of fauna under the Protocol Concerning Specially Protected Areas and Wildlife (SPAW Protocol) annexes.

Supranational datasets

Supranational datasets of species point observations can be found at:

- Global Biodiversity Information Facility (GBIF)
- Genbank – the National Center for Biotechnology Information (NCBI)'s online repository of gene sequences for species (data is based on voucher specimens for which a geographic reference may or may not exist).

Examples of data sources concerning species distributions and, in some cases species, abundance at supranational scales:

- The IUCN Red List of Threatened Species (including data held by Red List Partners like NatureServe, BirdLife International, Royal Botanic Gardens Kew, etc.) (www.iucnredlist.org/)
- Map of Life (www.mol.org/)
- Aquamaps for the marine biome (www.aquamaps.org/)
- Sea Around Us from the University of British Columbia (updated annually) (www.seaaroundus.org/)
- Global map of Shannon's Index of Biodiversity from Ocean Data Viewer (http://data.unep-wcmc.org/datasets/15)
- Living Planet Index (updated annually) (www.livingplanetindex.org/)
- Peer-reviewed literature and associated online databases (e.g. PREDICTS database)

A number of additional datasets exist that can provide useful information on ecologically important places that support species, including:

- Key Biodiversity Areas (KBAs) – sites contributing significantly to the global persistence of biodiversity (IUCN, 2016b); A Global Standard for the Identification of Key Biodiversity Areas was endorsed by the IUCN Council in April 2016 (IUCN, 2016b).
- IUCN Red Lists for ecosystems (Bland et al., 2016).
- Alliance for Zero Extinction (AZE) sites – a joint initiative of 75 biodiversity conservation organisations from around the world. Identifies sites that are the last remaining refuges of one or more Endangered or Critically Endangered species as assessed on the IUCN Red List (http://www.zeroextinction.org/).
- Important Bird and Biodiversity Areas (IBAs) – KBAs that have been identified using data on birds. They are sites of global avian conservation significance for threatened, restricted range, biome-restricted and/or congregatory species. More than 13,000 IBAs have been identified to date in terrestrial, freshwater and marine ecosystems worldwide (www.birdlife.org/datazone/site/search).
- Biodiversity hotspots identified by Conservation International (www.conservation.org/How/Pages/Hotspots.aspx).
- Last of the Wild Places identified by the Wildlife Conservation Society (www.wcs.org/our-work/places).

- World Database on Protected Areas (www.protectedplanet.net/).
- World Heritage Sites (http://whc.unesco.org/en/list/).
- Region-specific priority setting exercises (often conducted by various organisations, institutions or governments, and already available for many countries).
- WWF Ecoregion profiles (http://wwf.panda.org/about_our_earth/ecoregions/)

2.1.2.4 Expertise and capacity

To complete Step 2, you will need:

- Expertise from biologists and ecologists to inform species selection and grouping.
- Expertise from biologists and ecologists to assess relevant and available datasets relative to the policy and decision-making contexts identified in Step 1.
- Experience in coordinating data mobilisation from several institutions.

2.1.3 Step 3: Decide the approach and type of Species Accounts

2.1.3.1 Rationale

The purpose of Step 3 is to establish an approach for constructing Species Accounts for the spatial areas you wish to report on (the Reporting Units). Depending on their intended uses, Accounts of Species of Special Concern may be organised under conservation, ecosystem condition and functioning, and/or ecosystem service delivery themes. Supplementary Accounts of Red List Status and Accounts of the Extent of Important Places for Species are also proposed.

The need for these different types of Species Accounts will vary across decision-making domains and the associated interests of key stakeholders, as determined in Step 1. In particular, Species Accounts should provide the necessary information to support key analytical uses, such as forecasting or interpolating trends; scenario analysis (particularly land-use impacts using habitat-based methods); comparing species status with information on economic activities and other drivers of species loss; providing objective statistics for policy formulation and assessment; communicating aggregated trends; revealing returns on investment; or supporting expert assessment.

Specific outputs at the end of Step 3:

- An agreement on the set of accounting tables relevant to the analytical uses and policy questions established in Step 1.
- An agreement on data acquisition procedures for your set of accounts.
- A list of 4 reference conditions identified for your set of accounts.

2.1.3.2 Actions

Step 3 provides a series of actions to help you to identify a suitable strategy for constructing your Species Accounts. During each sub-step, you will need to consider the following:

- Which accounts should you construct?
- Which species of special concern will be included in your accounts?
- What strategy should you use?
- What data should you use?
- How will the accounts be used?

2.1.3.2.1 Action A: Confirm data acquisition procedure for Accounts of Species of Special Concern

The Accounts of Species of Special Concern are intended to provide a common framework to support multiple uses in policy. In Step 2, you will have selected a set of species or species groups for which Accounts of Species of Special Concern will be developed, for example:

- Species of conservation concern
- Species important for ecosystem condition and/or functioning
- Species important for ecosystem service delivery

In consideration of the above, you may wish to construct separate accounts for conservation, ecosystem condition and functioning, and/or ecosystem service delivery concerns. This should be steered by the intended and potential use of such accounts.

There are two main strategies for acquiring data for constructing Accounts of Species of Special Concern:

Strategy 1: Direct observations of change in the state of a species

Strategy 2: Habitat-based methods to estimate changes in the state of a species

When deciding on which strategy to use, it is important to consider the end uses. If the goal is to organise detailed information on species in particular places, using direct observations of species may be the most suitable strategy (if the data exists). On the other hand, if comprehensive coverage of both space and ecosystems is required, using habitat-based methods may be a more useful strategy, particularly if data and resources are limited. In many applications, a mix of strategies may be necessary in order to meet the needs of multiple stakeholders and users.

The decision will also be dependent on the species you select and the availability of data, as scoped in Step 2. Given this interdependence, the final selection of an appropriate strategy for data acquisition is likely to require iteration between Steps 2 and 3. It is recommended that you convene an expert group to capture appropriate knowledge and expertise when making this decision.

Strategy 1: Direct observations

Ideally, Species Accounts should be based on spatially explicit direct observations of the species concerned. There are several types of direct and regular observations of species abundance that you could use as a basis for Species Accounts, for instance:

a) Direct observation of the number of individuals (total counts) of a species: This is likely to be limited to highly charismatic, socially important, observable or threatened species, such as elephant population surveys (Great Elephant Census, n.d.) (unit of measurement: number of individuals).

b) Direct population estimates for a species or group of species: These estimates are based on counting a sub-sample of a population and extrapolating this to the entire population. Since surveying the entirety of a species' population is often unfeasible, methods for estimating population size include:

i. Using transects, point counts or other sampling techniques to estimate the population density across part of a species' range, then extrapolating this to show the total species abundance for the total area that the species occupies (unit of measurement: number of individuals or relative abundance;[2] Buckland et al., 2005).

ii. Using mark-recapture methods (unit of measurement: number of individuals or relative abundance; Pollock et al., 1991).

iii. Using information on the amount of a species that has been harvested and the effort expended to acquire it. For example, if the biomass of a catch of sardines is known, along with the fishing hours required to catch it, these variables (along with other environmental factors) can be used to model the overall population (unit of measurement: tonnes of biomass or number of individuals). Such methods have been developed primarily for fisheries stock assessment (Maunder and Punt, 2004).

iv. Using information from fisheries stock assessments on the abundance of different age classes within a species' population (i.e. the age structure of the population) to calculate the relative abundances of each age class and, subsequently, the whole population (unit of measurement: number of individuals; Haddon, 2010).

c) Indirect measurement using an indicator of abundance: An indicator of abundance, such as counts of nests or scat (faecal pellets), rather than a direct observation can be used to derive population estimates in a similar way to the approaches used in b) i (unit of measurement: relative abundance; Bonesi and Macdonald, 2004).

d) Direct observation of the area occupied by a species: The presence or absence (occupancy) of a species in different spatial units can be used as a proxy of abundance since a positive relationship has been observed between the extent of occupancy of a species and its abundance (unit of measurement: number of spatial units occupied; Gaston et al., 2000).

e) Estimates of cover: The abundance of a species can be based on an estimate of the cover/extent of a species, for example, the extent of heather or the extent of coral (unit of measurement: area, e.g. square kilometres or percentage canopy cover).

In many circumstances, there will be established monitoring systems in place for collecting direct observations on at least some species in certain areas (such as National Parks) that should inform the accounting process. Where large sample surveys (such as national surveys) exist, they may provide a comprehensive coverage of your area of interest at sufficient density to allow disaggregation to a more local scale. However, this is only likely to be feasible in countries where significant investments in species monitoring have been made. In order for such data to inform Species Accounts, it is likely that some degree of harmonisation and processing will be required (discussed in Step 5).

An example of how direct observations could be captured in a Species Account is provided in Table 2.2, which presents species data in both absolute and relative measures, and illustrates the different measurement units that could be used. The parenthesis adjacent to each species refers to the different direct observation method listed above. While a consistent measurement unit is preferred for accounting, this is likely to prove challenging for individual species. As such, heterogeneity in data may be imperfect, but combined with the use of relative measures, it will be sufficient to produce initial Species Accounts.

[2]Relative abundance reflects the abundance of a species relative to a baseline year. This is commonly used in bird surveys

Table 2.2: Hypothetical example Account of Species or Species Groups of Special Concern using direct observations (2005-2010)

		Species or Species Group 1	Species or Species Group 2	Species or Species Group 3	Species or Species Group 4	Species or Species Group 5	Species or Species Group 6	Composite indicator
	Examples Species	Panda (a)	Cuckoo (bi)	Tree sparrow (bii)	Tuna (biii)	Sardines (biv)	Heather plant (e)	
	Unit of measurement	No. of individuals	No. of individuals	Relative abundance based on population density	No. of individuals	Million tonnes of biomass	Area km^2	N/A
Reference abundance measure for a common year	Reference (1995)	2,000	100,000	Set to 1.0	20,000	2	600	100%
Abundance measure at start of accounting period	Opening (2005)	1,500	60,000	0.70	10,000	1	320	N/A
Additions and reductions should be stated if known	Additions	100	N/A	N/A	N/A	N/A	N/A	N/A
	Reductions	200	N/A	N/A	N/A	N/A	N/A	N/A
Abundance measure at end of accounting period	Closing (2010)	1,400	65,000	0.50	9,000	0.9	200	N/A
Net change in abundance over accounting period	Net Change	-100	+5,000	-0.20	-1,000	-0.1	-120	N/A
Relative abundance measure at start of accounting period	Opening (%of reference, 2005)	75%	60%	70%	50%	50%	53%	TBC
Relative abundance measure at end of accounting period	Closing (%of reference, 2010)	70%	65%	50%	45%	45%	33%	TBC
Net change in relative abundance over accounting period	Net change (%of reference)	-5%	+5%	-20%	-5%	-5%	-20%	TBC
Change as a percentage of the opening relative abundance	Change (%of opening)	-6.7%	+8.3%	-29%	-10%	-10%	38%	TBC

Strategy 2: Habitat-based methods

Where direct observations of species status are limited, this approach can be replaced or complemented by an alternative approach based on observations of changes in the spatial extent and configuration of habitat required by these species (Ferrier, 2011). This will particularly be the case for Reporting Units covering large areas, or for extensive study regions containing a large number of Reporting Units. This situation will also tend to be more pronounced in regions of the world for which insufficient resources are available to undertake physical surveys, particularly if these regions contain high-levels of species diversity and/or this diversity is poorly studied and described (e.g. tropical forest regions) (Pereira and Cooper, 2006).

Satellite-borne remote sensing is increasingly allowing changes in land cover and/or land use to be mapped cost-effectively at relatively fine spatial resolutions across large spatial extents (Hansen et al., 2013, Martinez and Mollicone, 2012). If classes of land cover or use provide a reasonable indication of the suitability or condition of habitat for particular species, or groups of species, then remotely mapped changes in the distribution of these classes can be used to infer changes in the distribution, and possibly abundance, of species (Souza et al., 2015).

To implement the habitat-based approach to deriving Species Accounts, remote land-cover/use change mapping needs to be combined with spatial information on the underlying pattern in the distribution of species level biodiversity. Even in the absence of human disturbance and habitat degradation any given species occurs within only a portion, and often a very small portion, of the total land area of the planet. This portion is determined by a combination of factors including climatic constraints, biotic interactions, and biogeographical barriers. Information on the spatial distribution of species level biodiversity is therefore a vital input to estimating the consequences of mapped changes in land cover or use for species. The same total amount of change in land cover or use can have very different implications for species level biodiversity depending on where this change occurs, relative to the distribution of species.

Information on the spatial pattern in the distribution of species level biodiversity can be derived in three different ways to inform habitat-based Species Accounts (see Figure 2.4). Your options for constructing Species Accounts using habitat-based approaches based on these distributions are summarised below:

- Using individual species distributions (units of measurement: Hectares of suitable habitat, condition weighted hectares of suitable habitat, proportion of suitable habitat remaining, probability of persistence)
- Using discrete community class distributions (units of measurement: Condition weighted hectares of community class, proportion of suitable habitat remaining, proportion of original species persisting)
- Using continuous community distributions (unit of measurement: Proportion of original species persisting)

Ultimately, the method you chose to construct your accounts will depend on the policy questions of interest, and the resources and data available. Whichever you choose, your data on remotely sensed changes in habitat condition and species-level biodiversity distributions must cover the entire area of the Reporting Unit(s) you are constructing the accounts for. This will allow you to construct Species Accounts for each Reporting Unit, either in aggregate or by aggregations of each ecosystem type within the Reporting Unit.

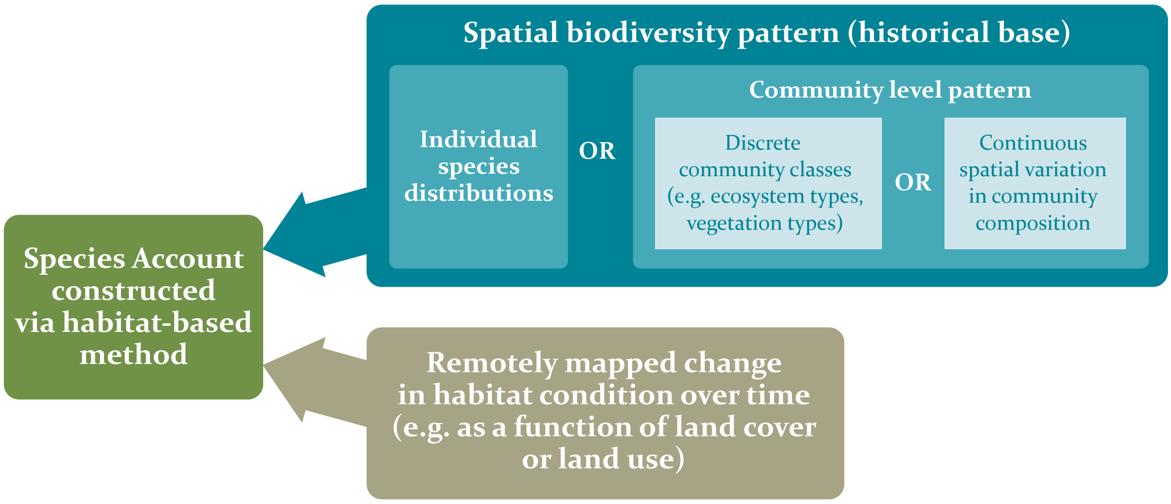


Figure 2.4: Major components of the habitat-based methods to deriving Species Accounts

Individual species distributions
For well-studied groups, such as birds and other vertebrates, digital range maps provide a coarse approximation of the distribution of individual species within that group (e.g., BirdLife, n.d.; IUCN, n.d.). You can often further refine these distributions through 'deductive modelling', in which expert knowledge is used to implement rules that exclude areas within the broad range of a given species expected to be unsuitable for that species – e.g. "species x occurs only above 500m elevation, and only in forest" to produce "extent of suitable habitat" maps (Corsi et al., 2000, Pearce et al., 2001, Beresford et al., 2011, Jetz et al., 2012).

Alternatively, distributions of individual species can be estimated using correlative Species Distribution Models (SDM). This involves using statistical or machine-learning techniques to fit an 'inductive model' relating point observations of presence, presence-absence or abundance of a given species to multiple mapped environmental variables, thereby allowing potential occurrence to be extrapolated across an entire study region of interest (Elith and Leathwick, 2009, Guisan et al., 2013).

If deductive or inductive modelling of a species distribution incorporates habitat attributes for which change can be detected through remote sensing, this opens the way for using such models to infer change in the distribution of species as a direct function of remotely observed change in habitat (Lung et al., 2012, Jetz et al., 2012). For example, a deductive model for a species includes a rule that it occurs "only in forest", then linking this model with remote sensing of change in the distribution of forest within the known range of this species would enable inference of change in the distribution and extent of suitable habitat for the species (Tracewski, et al., 2016). This approach can be applied to any number of species, provided that deductive rules for these species are specified in terms of classes of land cover, or land use, for which changes can be mapped remotely over time. Similarly, incorporation of land cover or use as environmental predictors in the fitting of correlative (inductive) SDMs can also enable change in the distribution and extent of suitable habitat for species to be predicted from remote land-cover/ and use mapping.

Even where land cover or use have not been explicitly incorporated into deductive or inductive modelling of species distributions, habitat-based modelling can still provide Species Accounts by combining remote sensing with best-available mapping of species' distributions (Barrows et al., 2008, Rios-Munoz and Navarro-Siguenza, 2009, Soberon and Peterson, 2009). This requires being able to map change in the overall condition (or 'intactness') of habitat collectively for a whole group of species, or for species-level biodiversity in general, rather than separately for each species. Such mapping of overall habitat condition is most commonly derived from remotely mapped land-use classes by assigning a condition score (for example, between 0 and 100) to each class. This score is based either on expert opinion, or on a prior meta-analysis of studies of land-use impacts on local species-level biodiversity (for example, the PREDICTS analysis of data for 27,000 species at more than 11,000 sites globally; Newbold et al., 2015).

The integration of spatial information on species' distributions with remotely sensed change in land cover or use is typically undertaken using a fine-scaled grid (i.e., a grid of BSUs) covering the study region of interest. For a given species, at a given point in time (e.g. a particular year), each cell in this grid (each BSU) is assigned a value indicating the suitability, or relative condition, of habitat for this species. These values can then be aggregated across all cells / BSUs within a Reporting Unit to derive a single measure of the state of this species within the Reporting Unit at this given point in time. The most basic way to aggregate this data is to simply sum the individual cell values. The sum of values at any point in time can then, optionally, be expressed in hectares of suitable habitat (or condition-weighted habitat), or as a proportion of suitable habitat remaining compared to a reference point in time (Barrows et al., 2008, Soberon and Peterson, 2009). For a given species, this method delivers an aggregated (cumulative) habitat suitability for each Reporting Unit. This basic method can be extended in many different ways including, for example: incorporating knowledge of habitat patch size requirements for particular species, by applying rules filtering out any cells of habitat within patches below a given size threshold; or linking mapped changes in the configuration of suitable habitat to process-based population or meta-population models capable of translating this configuration into an estimated likelihood of persistence for the species in question (Drielsma and Ferrier, 2009).

The process of acquiring data for Species Accounts using individual species distributions is shown in Figure 2.5. An example of how this data can be captured in a Species Account is provided in Table 2.3.

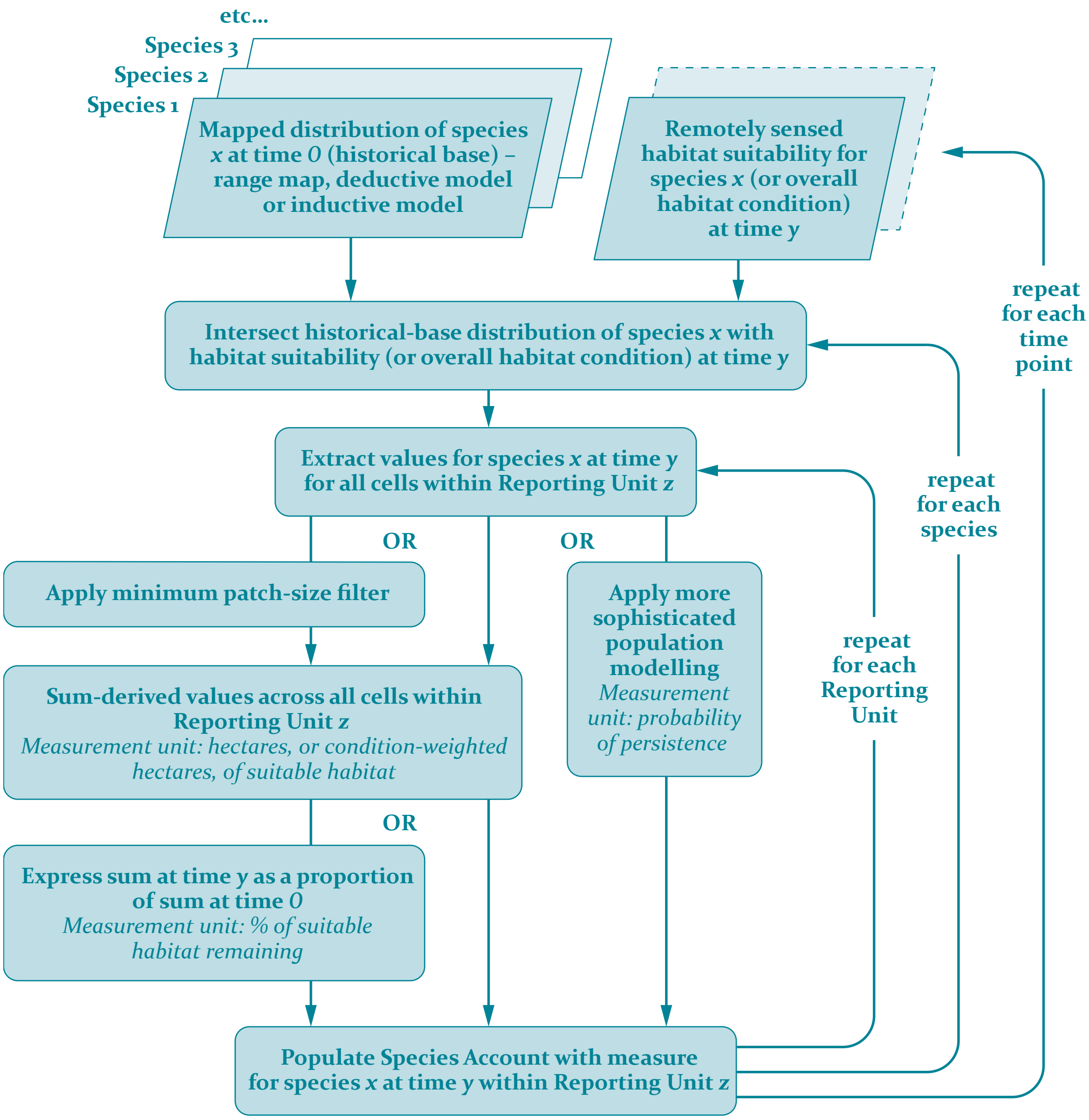


Figure 2.5: Data acquisition for Accounts of Species or Species Groups of Special Concern using habitat-based method with individual species distributions

Table 2.3: Hypothetical example Account of Species of Special Concern using habitat-based method with individual species distributions (2005-2010)

	Species 1	Species 2	Species 3
Example species / species group	Orang-utan	Sphagnum	Black rhino
Unit of measurement	Hectares of suitable habitat	Hectares of suitable habitat	Probability of persistence
Reference (minimal human disturbance)	1,000,000	5,000	1.0
Opening (2005)	100,000	2,000	0.95
Additions			
Reductions			
Closing (2010)	80,000	2,500	0.92
Net change	-20,000	+500	-0.03
Opening (% of reference, 2005)	10%	40%	95%
Closing (% of reference, 2010)	8%	50%	92%
Net change (% of reference)	-2%	+10%	-3%
Change (% of opening)	-20%	+25%	-3.2%

Discrete community class distributions
Community level approaches offer a means of estimating changes in the retention of species diversity within whole communities, without providing explicit information on the individual (named) species comprising this diversity. This is particular useful where the number of species in your biological group of interest is so high, and/or the average amount of information available for each of these species is so low, that species-level approaches become intractable (e.g. for arthropods or plants in tropical forests).

The discrete community level method can be implemented using a wide variety of mapped classification schemes (Ferrier et al., 2009). The only real constraints are that the classes within any employed classification are mapped across the entire region of interest (i.e., all Reporting Units), and that these classes provide a reasonable representation of major spatial patterns expected in the distribution of species-level biodiversity in the absence of habitat loss or degradation (i.e., the natural state before change). This second constraint is particularly important. If the effects of habitat degradation are incorporated into the classification itself (for example, an area of forest cleared for domestic grazing is mapped as grassland rather than its original state of forest), then the classification cannot be used for inferring the effects of remotely sensed change in habitat condition on species-level biodiversity.

Examples of mapped classes that could serve this purpose range from ecoregions at coarser spatial scales (Giam et al., 2011) through to mapping of the 'original' or 'natural' extent (prior to habitat transformation) of vegetation communities at finer scales (Keith et al., 2009). Recent advances in the global availability of fine-resolution abiotic environmental layers (e.g. for climate, terrain, soils) are also opening up new opportunities to derive environmental classes by integrating these layers – either by generating unique combinations of categories for each environmental variable (Sayre et al., 2014) or through automated numerical classification (Mackey et al., 2008).

Alternatively, if there is sufficient biological data (i.e. location records of multiple species) for the region of interest then various community-level modelling techniques can also be used to generate mapped environmental classes that best fit patterns observed in these data; for instance, maps of communities with similar species distributions, or maps of species groups with similar distributions (Ferrier and Guisan, 2006).

To generate habitat-based Species Accounts using any one of the mapped classifications introduced above, mapping needs to be integrated with remotely sensed change in habitat condition derived, for example, from land-use change mapping. To develop this for the Species Accounts condition scores should be allocated to land-use classes, which can be based either on expert opinion, or on some prior meta-analysis of land-use impacts on local species richness or abundance (Newbold et al., 2015, Souza et al., 2015). At a given point in time each fine-scaled grid cell in a mapped community class is assigned a habitat-condition score, then a measure of the state of that class within a particular Reporting Unit can be derived by simply summing the condition scores of all cells falling within both the community class and the Reporting Unit. This provides a sum of the hectares of suitable (condition weighted) habitat for the community class in the Reporting Unit. This observed sum can, again, be optionally expressed as a proportion of the sum obtained if all cells were in perfect condition (i.e. the effective proportion of habitat remaining in that community class for the Reporting Unit of interest, Scholes and Biggs, 2005; Pereira and Daily, 2006). This can then be linked to the communities of species that are associated with that class (e.g., woodland birds).

© Joe McDonald / shutterstock.com

The proportion of habitat remaining within a community class can be further used to predict the proportion of species originally associated with that class that are expected to persist if this proportion of habitat is retained over the longer term. This prediction is most commonly performed using some form of Species-Area Relationship (SAR; Pereira and Daily, 2006). An estimate of the proportion of species expected to persist across all community classes combined can potentially be derived by simply averaging the proportions of the individual classes (Proenca and Pereira, 2013). However, this assumes that all of the classes are equally rich in species, and that no species are shared between classes. If information is available on the relative species-richness of classes, and of the level of overlap in species composition between classes, then techniques exist for incorporating this directly into SAR-based predictions of the overall proportion of species retained in a Reporting Unit as a function of remotely sensed proportions of habitat retained in each class (Turak et al., 2011, Leathwick et al., 2010, Faith et al., 2008).

Accounting for the above, the discrete community class method can provide an aggregated (cumulative) condition score for each community class in each Reporting Unit. It can also be extended to predict the proportion of species originally present that are expected to persist.

Discrete community class distribution methods also reveal how species composition varies between locations in a Reporting Unit. As such, they provide information on 'beta diversity' (the complementarity of two measures of alpha diversity) (Ferrier et al., 2007). This can provide added value as conserving this aspect of species diversity is of importance to maintaining different ecosystem functions within the landscape of the Reporting Unit.

The process of acquiring data for Species Accounts using discrete community class distributions is shown in Figure 2.6. An example of how this data can be captured in a Species Account is provided in Table 2.4.

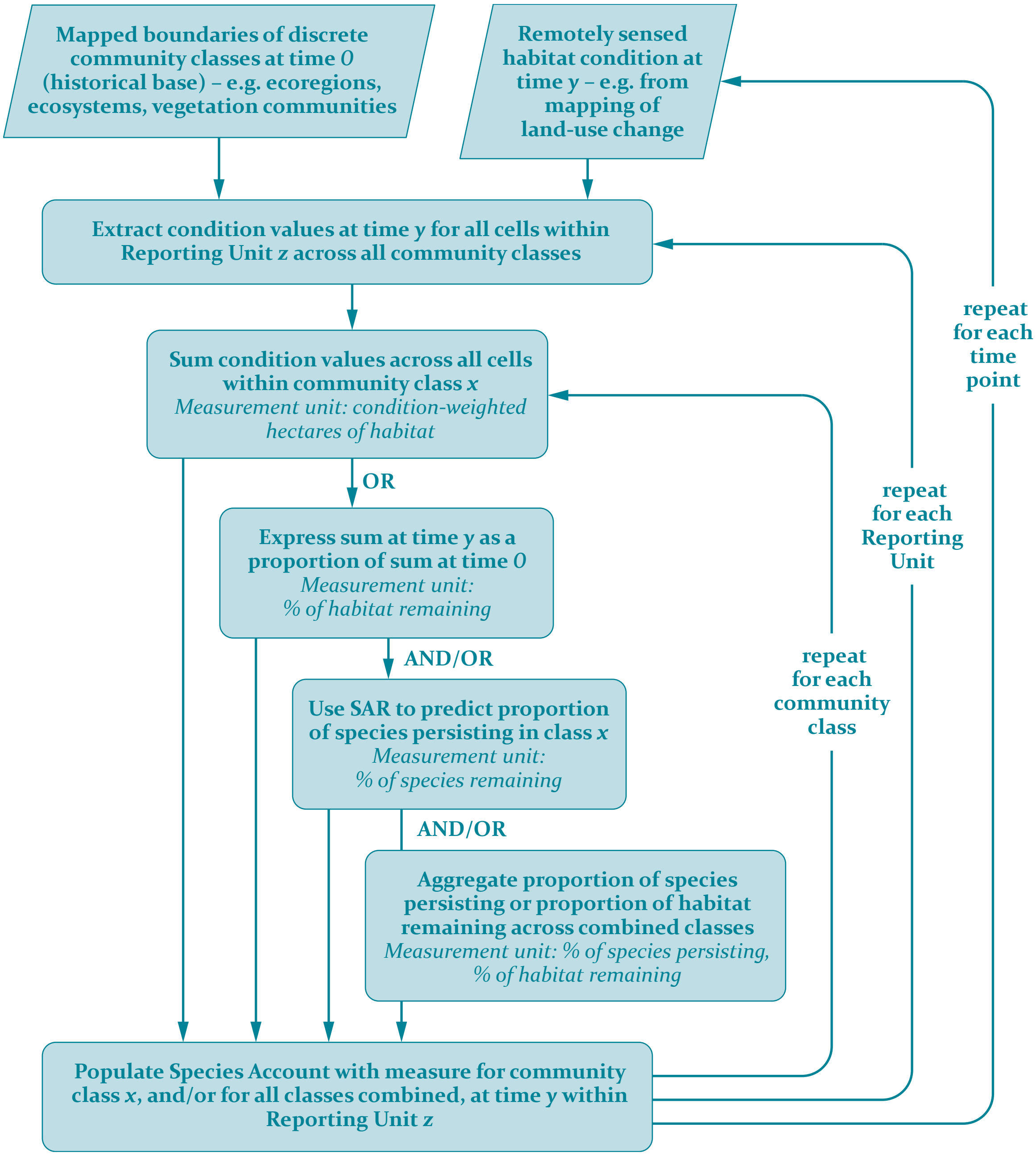


Figure 2.6: Data acquisition for Accounts of Species Groups of Special Concern using habitat-based method with discrete community class distributions

Table 2.4: Hypothetical example Account of Species Groups of Special Concern using habitat-based method with discrete community class distributions (2005-2010)

Example community class	Oak savanna	Mesic savanna	Dry oak forest	Aggregate savanna-forest
Unit of measurement	Proportion of habitat remaining	Proportion of habitat remaining	Proportion of habitat remaining	Proportion of original species complement
Reference (minimal human disturbance)	100%	100%	100%	100%
Opening (2005)	50%	95%	63%	75%
Additions	1%			
Reductions	6%			
Closing (2010)	45%	85%	42%	60%
Net change	-5%	-10%	-21%	-15%
Opening (% of reference, 2005)	50%	95%	63%	75%
Closing (% of reference, 2010)	45%	85%	42%	60%
Net change (% of reference)	-5%	-10%	-21%	-15%
Change (% of opening)	-10%	-10.5%	-33.33%	-20%

Continuous variation in community composition
In the discrete community class distribution method, each grid cell (BSU) in the region of interest is viewed as belonging to a discrete class of cells that are assumed to be equally similar to one another, and equally different from cells in other classes, in terms of the species they support. However, real-world patterns of spatial variation in species composition are often more complex than can be effectively represented by a discrete classification with hard boundaries between mapped classes. Continuous community level approaches attempt to address this reality by treating the composition of species occurring at each individual location as being unique, and the proportional overlap, or conversely distinctiveness, in composition between this location and any other as varying in a continuous manner (Ferrier et al., 2009).

One approach you can take to apply this continuous community level perspective to the derivation of habitat-based Species Accounts is to use generalised dissimilarity modelling (GDM) (Ferrier et al., 2007). GDM employs best-available occurrence records for all species in a given biological group (e.g. all plants, all reptiles) to fit a non-linear statistical model relating the dissimilarity in species mapped predictors (climate, terrain, soil, etc). Models fitted with GDM effectively weight and scale these environmental variables, thereby transforming multidimensional environmental space in such a way that distances within this transformed space match observed compositional dissimilarities in species communities as closely as possible.

You can use fitted GDM models to interpret remotely sensed change in the condition of habitat in various ways. One of the most straightforward solutions is to estimate the proportion, or effective proportion, of habitat remaining for each individual cell (BSU) within a region. This is calculated as a weighted average of habitat condition in all cells environmentally similar to the cell of interest, with each cell weighted by the level of similarity predicted by the GDM. From this an extension of the SAR-based method described under discrete community class distributions can then be employed to estimate the proportion of species retained relative to each cell. This can then be aggregated into an overall estimate of the proportion of species retained within any Reporting Unit of interest by factoring in GDM-predicted compositional dissimilarities between these cells (Ferrier et al., 2004, Allnutt et al., 2008). Step 6 presents a case study for populating Species Accounts in this way.

The process of acquiring data for Species Accounts using continuous variation in community composition is shown in Figure 2.7. An example of how this data can be captured in a Species Account is provided in Table 2.5.

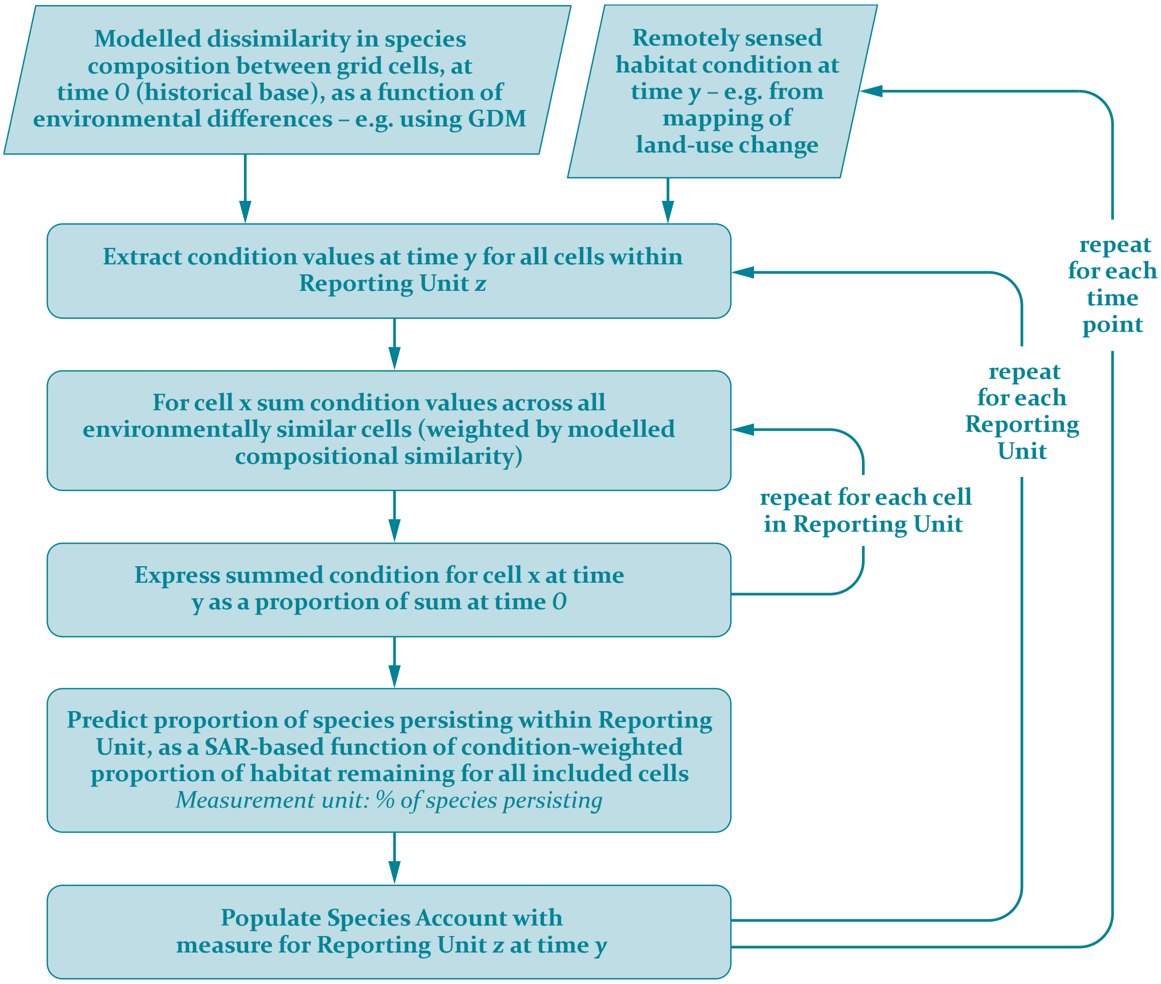


Figure 2.7: Data acquisition for Accounts of Species Groups of Special Concern using habitat-based method with continuous variation in community composition

Table 2.5: Hypothetical example Account of Species Groups of Special Concern using habitat-based method with continuous variation in community composition (2005-2010)

	Species Group 7	Species Group 8	Species Group 9
Example species / species group	Invertebrates	Vertebrates	Vascular plants
Unit of measurement	Proportion of original species complement	Proportion of original species complement	Proportion of original species complement
Reference (minimal human disturbance)	100%	100%	100%
Opening (2005) (% of reference)	95%	95%	95%
Closing (2010) (% of reference)	85%	85%	85%
Net change (% of reference)	-10%	-10%	-10%
Change (% of opening)	-10.5%	-10.5%	-10.5%

2.1.3.2.2 Action B: Confirm data acquisition procedure for Accounts of Red List Status

The IUCN Red List of Threatened Species is a checklist of taxa that have undergone an extinction risk assessment using IUCN criteria. The objective of the Red List is to inform conservation action by providing information on species' extinction risk, threats and actions. Guidelines for undertaking national Red List assessments are available; in fact, more than 100 countries have developed national Red Lists (National Red List, 2012). Guidelines on calculating a national Red List Index, which measures of the overall rate at which species move through IUCN Red List categories towards or away from extinction, are also available (Bubb et al., 2009).

You can construct Accounts of Red List Status using either global or national Red Lists. It should be noted, however, that global Red Lists are regularly updated and follow standardised IUCN criteria, whereas national Red Lists, although a more sensitive measure at the national scale, may not follow IUCN criteria and may not be updated regularly. Where national assessments are unavailable, the global or regional Red List can be disaggregated to allow accounting at the national level (Han et al., 2014, Rodrigues et al., 2014). National Red List Indices disaggregated from the global Red List Index will soon be available for all countries.

There will be many contexts where Accounts of Red List Status will be useful in assessing progress towards policy goals or identifying where resources are needed to combat biodiversity loss and safeguard species. Furthermore, the data available to construct these accounts will add context for your Accounts of Species of Special Concern, so it is recommended that you construct them at the start of the process. It should be appreciated, however, that Red List information is not amenable to spatial disaggregation beyond national or coarse sub-national levels.

2.1.3.2.3 Action C: Confirm data acquisition procedure for Accounts of the Extent of Important Places for Species

Accounts of the Extent of Important Places for Species provide a relatively simple accounting approach, where changes in the extent of ecologically important places for species are assumed to represent changes in the status of species. A number of potentially relevant designations are reviewed in Step 2, which you will need to consider if you wish to construct these types of accounts. These include specific sites that are important for species-level biodiversity, such as KBAs (e.g. Important Bird and Biodiversity Areas and Alliance for Zero Extinction sites) and National Parks. They also include broader landscape-scale designations, such as Wilderness Areas. The former will be more closely related to species of conservation concern.

2.1.3.2.4 Action D: Select reference condition

The reference condition is the abundance level or habitat-based measure against which the current direct observation or habitat-based measure is compared. A common reference point is required to allow comparison between different species or species groups on the basis of relative measures of abundance (i.e. the current abundance as a percentage of the reference). These relative measures are needed because it may not be possible to aggregate physical units for species, and such units do not provide a measure of the state of ecosystems (McDonald, 2011).

You have several options for selecting a reference condition for direct observations, including:

- Using abundance measures relevant to a common historical reference year for which data exists (e.g. the Living Planet Index uses 1970; Loh et al., 2005).
- Using an accrual approach based on abundance measures from the first year of accounting.
- Using scientifically derived or expertly judged targets, for example:
  - Favourable conservation status (e.g. under EU Birds and Habitats Directives)
  - Minimum sustainable populations (for breeding or to buffer population impacts from disease)
  - Maximum sustainable yield (e.g. for harvested fish)
  - A measure indicative of good ecosystem condition (e.g. good ecological status under the EU Water Framework Directive)
- Using abundance measures indicative of a state of minimal human disturbance (e.g. pre-colonisation estimates are often used in Australia). New observations in pristine area could also serve as a useful reference under this approach.

Using a state of 'minimal human disturbance' as a reference condition is recommended in the SEEA-EEA (2014), but care should be taken about the interpretation of this in highly modified systems. For example, much of Europe has been highly modified over long periods of time, so using a state of minimal human disturbance is unlikely to be meaningful in the context of current conditions.

When using historical reference years, you may also wish to align the reference condition with data from a policy-relevant year, as identified in Step 1. However, it is important that you keep the reference condition separate from socially aspirational or policy targets. This ensures that the accounts represent an empirical approach, grounded in ecologically sound arguments.

For habitat-based approaches, the underlying assumption of the three approaches presented for Strategy 2 is that they can describe the patterns of species level biodiversity in the absence of human disturbance. Therefore you will commonly see the undisturbed state used as the baseline for these approaches (Scholes and Biggs, 2005, Pereira and Daily, 2006). However, this does not preclude using a relative measure or an absolute measure (e.g., hectares of suitable habitat) for a more recent year as a reference condition.

2.1.3.2.5 Action E: Confirm the types of accounts you want to construct

Considering the interrelated factors of the species you have selected, and the data available for those species, you will need to decide on the methods or combination of methods you are going to use. In turn, this will help you to decide on the types of accounts you are going to construct; for instance, do you wish to construct separate accounts of species of conservation concern, species important for ecosystem condition and/or functioning, or species important for ecosystem service delivery?

Box 2.5 provides a case study from Wales, based mainly on direct observations (Strategy 1 as outlined in Step 3). Box 2.6 presents a case study from Peru, which employed habitat-based modelling (Strategy 2 as outlined in Step 3).

Box 2.5: Selecting the data collection strategy and reference conditions for Species Accounts in Wales

The strategy for data acquisition was based on data accessibility, spatial application for national accounts, and the quality and relevance of data to policy. As such, a direct observations strategy was primarily employed; this involved the use of:

- direct data from GMEP;
- a modified direct approach using published annual indices of abundance (Breeding Bird Survey [BBS]); and
- one example of the use of indirect habitat data, i.e. priority habitats extent.

The data in the Species Accounts all need to be referenced into the same year (or a common interval if a rolling average is to be used). The use of a rolling average is frequently justified on the basis high rates of temporal change related to sampling power and/or weather related dynamics unrelated to true population change. This caused a conflict as some condition and function/species data were available for the period 2005-2009, while other data were only available for the period 2013-2016. In some cases, there was only a single estimate within the time period, although it was thought to represent the range well.

Historical analysis of data available for the period 2005-2009 is possible, but identifying a common year or range of years across taxa and metrics requires further work. The final selection of an opening and reference year for consistency resulted in the loss of a rich set of historical trend data. This is concerning because it can provide important context as to whether rate of change is better or worse in response to changes in recent policy. As historical trends have been well-described elsewhere, however, it was considered more important, in this case, to use the well-structured, actual abundance data of GMEP to establish both an opening and reference year range of 2013-2016.

Box 2.6: Species Accounts constructed via habitat-based methods, San Martin, Peru (CI and CSIRO, 2016)

Peru is often considered to support the highest biodiversity on the planet. San Martín is a region of Peru characterised by a complex landscape that comprises biologically diverse natural ecosystems and areas of agricultural production. San Martin was selected as a pilot for ecosystem accounting as it is influenced by both the diversity of ecosystems and socio-economic issues, but also by the progressive green development policies promoted by the regional government in order to sustainably address current rapid development. Such policies include the promotion of biodiversity conservation and the protection of key ecosystems that supply economic production; fostering sustainable forestry, agriculture and tourism; and promoting adequate environmental management.

The main aim of this pilot was to develop an operational model of ecosystem accounting that can be used in other regions of Peru and, ultimately, be scaled up to the national level. The approach employed addresses gaps in the current SEEA-EEA framework by describing and implementing new methodologies. It accomplishes this by integrating spatially explicit measurements with information collected within national or sub-national administrative boundaries. These data are then used within a standardised monitoring approach to report on the values of biodiversity and natural capital in an accounting framework, and to inform land-use decisions, such as habitat restoration, land-use zoning and Protected Area expansion.

To capture general patterns of biodiversity distribution and change, a habitat-based modelling strategy was employed, the first method of which was Generalised Dissimilarity Modelling (GDM). This is a community-level modelling approach that allows differences in environmental conditions to be represented in terms of their effect on species composition for whole biological groups. It is then possible to compare the expected ecological similarity of any location with all other locations in the modelled environmental space. This enables the environmental uniqueness of a location, and its contribution to regional biodiversity, to be assessed. Using this approach, it is also possible to determine the impact of anthropogenic land degradation on the long-term persistence of biodiversity. In this study, GDM models were developed for vertebrates, vascular plants and invertebrates.

The second method used focused on threatened species and the areas where they live. Some species have high value from ecological, economic and/or social perspectives. Threatened species are often the focus of conservation because they are at risk of extinction the most. The approach taken measured habitat change within: 1) specific, predicted species distributions; and 2) places important for threatened species. There were two species for which data were available on their predicted distributions: the yellow-tailed woolly monkey and the San Martín titi monkey (known locally as Mono tocón). For important places, Key Biodiversity Areas (KBAs) were used; these are places of international importance for the conservation of biodiversity. KBAs are identified nationally using simple, standardised criteria, and based on their importance in maintaining species populations (Langhammer et al., 2007).

For both methods, the reference condition selected was that of minimal human disturbance (i.e. condition in a year prior to human impacts on the region).

2.1.3.3 Expertise and capacity

To complete Step 3, you will need:

- Ecologists and biologists to review the availability of direct observation data and their suitability for Species Accounts.
- Ecological modellers to review the potential for using habitat-based modelling to inform Species Accounts.
- Data analysts and Geographical Information System (GIS) experts to review the potential for mobilising data in the form required for spatial accounting of species.

2.1.4 Step 4: Decide the Reporting Units, frequency and summary statistics

2.1.4.1 Rationale

The purpose of Step 4 is to help you to decide how to report the species information you will generate via the strategies selected in Step 3. You will need to consider your reporting procedure in the context of the key analytical uses and policy questions established in Step 1.

Specific outputs at the end of Step 4:

- A suitable geographical aggregation for your Reporting Unit.
- An appropriate frequency for generating Species Accounts.
- A procedure for summarising species data as a composite indicator or index.

2.1.4.2 Actions

Step 4 presents a series of actions to help you to establish a useful reporting procedure for your Species Accounts that considers both the scale of your Reporting Units, and the frequency at which the accounts will be constructed. It also demonstrates how you can produce summary statistics for your Species Accounts. Ideally, the species' measures recorded in the columns of the accounts should aggregate. To make this possible, you will need to adopt a standardised measurement unit. For example, it does not make sense to compare estimates on the number of individuals of insect, plant and mammal species, or to combine results as a total number of individuals. Instead, measures of biomass may be compared, particularly if these species have trophic relations. However, the heterogeneous nature of species data, and the variation in species assemblages between both ecosystems and locations, is likely to preclude this form of comparison in most cases. Therefore, at this stage, a relative condition metric (i.e. composite indicator or index) is proposed as the most pragmatic approach to aggregating information on species. This also provides a means to capture a measure of species diversity using an appropriate estimation procedure.

2.1.4.2.1 Action A: Select geographical aggregations and Reporting Units

Ideally, ecosystem information for accounting will be organised in spatial units comprising BSUs or EUs that can be combined additively using a bottom-up approach (discussed in Section 1.5), thus avoiding the need for deciding on a specific Reporting Unit at this stage. This is particularly challenging for species data. It may be possible to downscale information on species status from distributions, and some habitat-based methods can potentially generate data on habitat suitability at this scale. However, most direct observation data will only be meaningful in informing spatial accounts at the scale at which it was collected, or its sampling strategy was designed for. In addition, many of the habitat-based methods discussed in Step 3 depend on fitting models at the spatial scale of interest. This reflects that it can be difficult to capture species status in an ecologically meaningful way at the very fine scale, so a top-down approach may often be the only feasible option (discussed in Section 1.5).

Once you have reflected on this, you will need to make a decision on the geographical Reporting Unit for your Species Accounts. At the most aggregated level, this may be the national scale. However, it is also likely to be informative to construct Species Accounts for sub-national aggregations. For example, the Reporting Unit could be:

1) The national scale (ideally by ecosystem type)

2) An ecologically defined spatial area, such as a watershed (ideally by ecosystem type)

3) A distinct spatial area, such as a National Park (ideally by ecosystem type)

4) An administrative area, such as a county (ideally by ecosystem type)

5) A given ecosystem with an individual management plan

The size and scale of the most appropriate Reporting Unit will depend on the specific uses you determined for the Species Accounts in Step 1. When deciding on your Reporting Unit, consider how the ability to analyse the detailed implications of policy options and management decisions will reduce as the size of the Reporting Unit increases and the resolution of species data and ecosystems becomes increasingly coarse. For example, abundance and presence of species will vary with scale. Larger Reporting Units will be more likely to capture information on multiple species and individuals, but they may not provide the resolution of data necessary to inform spatial decision-making. Generally, it will be most informative to construct Species Accounts by ecosystem type (e.g. forest) within Reporting Units. This may be challenging, however, if species use multiple ecosystem types.

2.1.4.2.2 Action B: Decide on the reporting frequency

National accounts are generally produced on an annual basis, at least; this is the aspirational reporting frequency proposed in the SEEA-EEA (2014). However, it may not be possible or necessary to produce Species Accounts every year. In general, the frequency with which you produce Species Accounts will depend on:

- The life cycles of the species you have selected[3]
- The economic importance of the species you have selected
- The resources you have available and the monitoring system you have in place
- Policy entry points and cycles relevant to the questions determined in Step 1
- The expected rate of change in the populations of the species you have selected
- Any potential new risk factors that emerge; for example, there may be lags between major disturbances (e.g. pollution incidents) and impacts on species (e.g. time for bioaccumulation)
- Other unexpected opportunities that emerge for reporting

You may decide to produce annual Species Accounts only for those species which are economically very important or are changing very rapidly. Alternatively, where measures or estimates for species abundance in interval years are missing, these values could be estimated (e.g. using log-linear interpolation; Loh et al., 2005; or Trends and Indices for Monitoring Data (TRIM) program; Pannekoek and van Strien, 1996). This would allow more accurate composite indicators to be developed that aggregate over multiple Reporting Units (e.g. the Nature Index of Norway) to be published annually even if not all of the species data is updated every year.

[3]Annually dynamic species populations, such as butterflies, may produce alarming results due to weather events in certain years. For these species, you may wish to use a moving average over a multi-year period to smooth out abundance measures when communicating results to decision-makers and other stakeholders.

Box 2.7 presents the selection of Reporting Units and reporting frequency for the case study in Wales. Box 2.8 presents the same for the case study in Peru.

Box 2.7: Reporting Unit and frequency chosen for Species Accounts in Wales

For the study in Wales, the Reporting Unit chosen was the national level as a sound evidence base is needed to support domestic legislation. Within this national unit, reporting by ecosystem type was considered the most practical to align with important data sources and to link to service accounts and other ecosystem assessments within Wales and the UK, such as GMEP (www.gmep.wales), Countryside Survey (www.countryside.org.uk) and the UK National Ecosystem Assessment (UK NEA, 2011). Species data was organised directly at this national level.

Ideally, the frequency of reporting on Species Accounts for Wales would be annual, but this is not practically possible for economic reasons. It may also be ecologically unreliable due to the temporal dynamics of many species. Instead, cycles of four to five years are considered to provide a good basis and be policy-relevant, for instance to the EU Rural Development Plan, which provides much of the economic support for payments to improve environmental outcomes and is highly relevant to the political cycle in Wales. In addition, GMEP was designed to provide a rolling four-year cycle of data collection, with reporting in year five against criteria. It, therefore, provides a good basis on which to track future progress in the Species Accounts. Further work is needed to align data from other important taxa-specific monitoring programmes to this reporting framework.

Box 2.8: Reporting Units used for habitat-based method for Species Accounts in San Martin, Peru (CI and CSIRO, 2016)

Eight types of ecosystem accounts were explored and measured for 2009, 2011 and 2013, based on 11 predominantly natural ecosystem types ('ecosystem assets') covering four broad biomes. The Reporting Units selected comprised aggregations of each of these 11 ecosystem types within San Martin. In addition, San Martin as a whole was selected as an aggregated Reporting Unit.

2.1.4.2.3 Action C: Determine estimation approach for composite indicators or indices

Composite indicators or indices are a manipulation of individual indicators or measures, and possibly weights, to produce an aggregate measure. While including analytic elements, they still represent a subjective view of reality, thus they sit between analysis and advocacy (Saltelli, 2007). The role of the composite indicator or index is to summarise the measures across the species or species groups in your Species Accounts (i.e. the columns) in order to present an overall picture of species status and diversity for your Reporting Unit(s). This aggregation necessarily reflects certain assumptions regarding differences, trends and values of the range of stakeholders established in Step 1 (Paruolo et al., 2012). Nonetheless, it remains imperative that your composite indicator or index communicates the negative impact of losing species diversity if it is to provide a useful indicator of ecosystem condition.

A significant body of work exists on the construction of composite indicators, with some indicators getting much attention and political traction, such as the Human Development Index (UN), the Environmental Sustainability Index (World Economic Forum), the Dashboard of Sustainability (EU), and Ecological Footprints (land, water and carbon) (Moldan et al., 2004). Where these have been successfully used in informing decision-making, they have been underpinned with a defensible scientific basis and transparent construction in order to be easily communicated to non-practitioners. This is particularly challenging when the issue being addressed is complex, as in the case of species diversity. However, when composite indicators are properly expert- and/or stakeholder-driven, they can be both accurate and acceptable to the appropriate stakeholder groups. For and against arguments for composite indicators are summarised in Table 2.6.

Table 2.6: The pros and cons of using composite indicators (CI; based on Saltelli, 2007)

Pros	Cons
CI can be used to summarise complex or multidimensional issues	**CI** may send misleading messages if they are poorly constructed or misinterpreted
CI provide the big picture	The construction of **CI** involves several stages where judgement and selection has to be made
CI help attracting public interest	There could be more disagreement about **CI** than individual indicators
CI can help to reduce the number of indicators	**CI** increase the quantity of data needed both for completeness and for statistical analysis

In order to have a use, a composite indicator or index must be worth more than the sum of its parts. Therefore, you need to carefully consider the purpose for the composite indicator or index and bear in mind the following when deciding how to calculate them:

1) The indicator or index should perform as ecologically expected. For example, if one species begins to dominate and the remaining species reduce in abundance, the indicator should reflect the negative impact of this homogenisation (Lamb et al., 2009).

2) The indicator or index should reflect stakeholder priorities as different parties will value changes in particular species or species groups differently (Van Strien et al., 2012). This subjective element is often not made explicit enough (Stiglitz, 2009).

3) The indicator or index should be easily understandable by stakeholders (Van Strien et al., 2012). This will be essential for providing a clear policy message.

Methods for constructing composite indicators or indices

The construction of your composite indicator or index will be driven by the pragmatic choices you made when constructing your Species Accounts based on data availability and the selection of your species or species groups of special concern. Ideally, there should be meaningful (arithmetic) relationships between the chosen species or species groups and chosen stocks entered in the columns within your accounting table. However, available species data are likely to be heterogeneous in nature (as per the example Species Account in Section 1.6). Therefore, in most cases, you will need to calculate relative measures for each species or species group using a common reference point in order to allow aggregation as a composite indicator or index.

Van Strien et al. (2012) reviewed the performance of a variety of different indicators for measuring change based on relative measures of abundance.[4] They found that arithmetic and geometric means across relative species measures have the most favourable properties. Similarly, Buckland et al., (2005) found the geometric mean to perform well in their own review. As populations tend to grow geometrically (i.e. populations decline or increase logarithmically), it is likely to be ecologically intuitive to use a geometric mean when you have accounts based on observations or estimates of species abundance (e.g. population counts, estimates, relative abundance or biomass; Van Strien et al., 2012). This also serves to reduce the influence of very abundant species (Bello et al., 2007). If your accounts have been obtained using habitat-based methods, however, arithmetic means may provide a more rational means of aggregation. The methods for calculating composite indicators or indices using arithmetic and geometric means are presented in Box 2.9.

Box 2.9: Calculation of arithmetic or geometric means using species data

Where you have direct or habitat-based observations for a species or species group i these should be scaled by dividing the observation for a given time period t (d_{it}) by the value reference condition (d_{ir}) (i.e. d_{it} / d_{ir}). This ratio is entirely equivalent to the relative measures of species abundance in your accounting tables. The arithmetic mean average composite indicator or index across the number of species or species groups in time t (CI_t) is then calculated as:

$$CI_t = \frac{1}{m} \sum_i \frac{d_{it}}{d_{ir}}$$

The geometric mean average composite indicator or index is calculated as:

$$CI_t = exp\left(\frac{1}{m} \sum_i log \frac{d_{it}}{d_{ir}}\right)$$

Where m is the number of different species of species groups. Where the relative abundance of a species is zero, you should employ the common practice of adding a small positive constant when calculating geometric means (Loh et al., 2005; Buckland 2005). Additional rules may be required for dealing with naturally colonising species, or significantly declining species, whose abundance cannot be measured reliably.

A number of other approaches are available and may be better suited for the key analytical uses / policy questions determined in Step 1. For example the Living Planet Index employs the Chain Method (which is a development of the Geometric Mean approach).

As such, you will need to carefully consider which procedure is most appropriate, considering the approach you have adopted for constructing your accounts and the specific measures contained within them.

You may also wish to consider the incorporation of weights to reflect different ecological priorities for species or species groups in the calculation. Any such weighting procedure must be developed with caution and supported by ecological expertise throughout. Where species groups are to be weighted, ecological criteria, such as the number of species, functional importance and phylogenetic uniqueness in each group, can inform the procedure. This is specifically discussed with respect to aggregating discrete community class distributions in Step 3, Strategy 2.

[4]This is based on accrual approach, where the first year of observation is taken as the reference condition and the abundance measure for that year set to 100%.

In order to inform weighting, you could consider participatory approaches. 'Budget allocation' is a useful tool, for instance, inviting stakeholders and experts to distribute a set budget of points in order to establish a relative importance for different species or species groups (Saisana et al., 2005). Similarly, 'analytical hierarchy processes' may be used, where stakeholders and experts make pair-wise comparisons between species or species groups (Saisana et al., 2005). Weighting is not compulsory, however; for example, the Living Planet Index takes the unweighted geometric mean at each point in time and links it back to a reference condition using the aforementioned Chain Method (described in Loh et al., 2005).

In mathematical terms, the incorporation of weights into the calculation of arithmetic means is straightforward, with the weights applied directly to the relative measure for each species or species group of concern (i.e. d_it / d_ir). However, weights should be applied to the log of the relative species measure when using geometric means. Other approaches are likely to apply if you opt to use a different procedure for calculating your composite indicator or index. It remains important to ensure that the weighting procedure does not overly compromise the scientific validity of the metric.

For your Accounts of Red List Status, the Red List Index (RLI; described in Step 6, Action B) provides the approach for summarising constituent data in a single statistic.

2.1.4.3 Expertise and capacity

To complete Step 4, you will need:

- Expertise in the policy context in order to ensure the spatial and temporal scale of reporting will be relevant to policy requirements.
- Ecologists, GIS experts and ecological modellers to determine the options for Reporting Units based on the spatial resolution of available data.
- Ecologists, statisticians and social scientists to develop composite indicators or indices that are both ecologically and policy relevant (potentially developed through representative participatory processes).

2.2 IMPLEMENTATION

The implementation phase for constructing Species Accounts comprises five steps:

Step 5. *Collate and prepare data*. The data scoped in Step 2 is collected and prepared in a format suitable for populating Species Accounts.

Step 6. *Populate Species Accounts.* The data collated and prepared in Step 5 is inputted into the set of Species Accounts and summary statistics (composite indicators or indices) are calculated.

Step 7. *Identify and fill gaps in the Species Accounts.* The Species Accounts are reviewed and any data gaps identified. Where data gaps exist, options for addressing these are assessed and implemented where necessary.

Step 8. *Organise and aggregate Species Accounts.* Procedures for presenting multiple Species Accounts for different ecosystem types within Reporting Units and aggregating species information to larger scales are reviewed and implemented where necessary.

Step 9. *Analyse and integrate Species Accounts.* The information contained in the Species Accounts is analysed in the context of the key analytical uses and policy questions identified in Step 1. Information in the Species Accounts is integrated within the wider SEEA-EEA Accounts, and with other spatial statistics, where appropriate.

2.2.1 Step 5: Collate and prepare data

2.2.1.1 Rationale

The purpose of Step 5 is to gather the data identified in Step 2 in the format and quality needed to construct the set of Species Accounts which you have decided upon in the planning phase.

Specific outputs at the end of Step 5:

- A list of all licensing requirements and data protection issues for the use of data.
- A clean dataset for species accounting.
- A list of all errors and how they were fixed for the species data.
- A list of quantified or qualified uncertainties with respect to your species data.

2.2.1.2 Actions

In order to populate the Species Accounts (Step 6), you will need to prepare the following data items:

- Opening measures of species status (such as population abundance, biomass or hectares of suitable habitat) for a common opening year (or period).
- Closing measures of species status for a common closing year (or period). This may be a future activity when data for a closing period becomes available.

In order to inform Species Accounts, these measures must exist at the spatial resolution required, provide a time series of observations, and be consist across both space and time. During Step 2, you will have scoped available data, and strategies for collecting it, and developed a metadatabase. Despite this, limitations in the use of these data may still exist. Some limitations may simply be related to licensing and protection issues. Others may necessitate some iteration between Step 5 and previous steps in the planning phase. Where there is a lack of data, and priorities for filling such gaps are well understood, Step 7 may now be initiated in order to plug any existing data gaps.

Additionally, accuracy is a fundamental component of the 'quality' of information recorded in your accounts and should be addressed at this stage. However, quality is a multidimensional concept and you will need to consider trade-offs between accuracy and relevance, timeliness, interpretability and coherence when collating and conditioning data for your Species Accounts (Statistics Canada, 2009).

2.2.1.2.1 Action A: Establish institutional arrangements, licensing and data protection issues

A number of relevant datasets will be available under open-access arrangements, although there may still be some restrictions on their use. For example, species datasets within the GBIF network are publically available, but have different licensing requirements, broadly reflecting creative common licenses (GBIF, n.d.b). In other circumstances, there may have been considerable expenditure associated with data collection and the data holders may request payment before licensing the data for use in species accounting (Vardon, 2012). Investment may also be required in order to continue collecting, and making available, compatible data in future years, ensuring continuity of the Species Accounts.

Given the sensitive nature of certain species data, there may also be important data protection issues. For instance, organisations monitoring species that are subject to poaching will not want the locations of these species to be broadly advertised. These types of issues will require consideration during the construction and reporting of your Species Accounts, and for any associated outputs. For example, you may need to prevent the public dissemination of high-resolution maps or reduce the original data's spatial resolution when reporting on species that may be at risk from poaching

Once you have reviewed and established required licenses and data protection requirements, you should obtain the full data for your Species Accounts.

2.2.1.2.2 Action B: Validate and clean data

The quality of data used to construct Species Accounts must be sufficient to inform their intended uses. This reflects Chrisman's (1983) definition of quality applied to geographic data as that of 'fitness for use'. Using data without consideration of the potential errors that they contain can lead to erroneous results, mislead users of the accounts and result in poor decision-making. Chapman (2005) identifies the following stages of the data generation and management process that can result in the loss of quality:

- Data capture and recording at the time of gathering
- Identification of the collection (specimen, observation) and its recording
- Data manipulation prior to digitisation (label preparation, copying of data to a ledger, etc.)
- Digitisation of the data
- Documentation of the data (capturing and recording the metadata)
- Data storage and archiving
- Data presentation and dissemination (paper and electronic publications, web-enabled databases, etc.)
- Using the data (analysis and manipulation)

Identifying and addressing data errors are fundamental to ensuring that Species Accounts are fit for purpose. This broadly requires validation and cleaning of the data. Data validation is the process of determining whether data are inaccurate, incomplete or unreasonable, and may include: format checks; completeness checks; reasonableness checks; limit checks; identification of outliers and other errors; and expert assessment of data (Chapman, 2005). Where validation identifies errors, these should be fixed during a 'cleaning process'. The identified errors, and the actions taken to fix them, should be clearly documented during the validation and cleaning process. Before the elimination of any data (such as outliers), it is important to understand why they appeared, whether it is likely similar values will continue to appear, or if the data points are just bad data (McRae et al., 2008).

2.2.1.2.3 Action C: Harmonise data (if required)

Existing spatial datasets for species that you have identified for use may suffer from heterogeneity in terms of data origin, form (such as raster vs. vector) and measurement parameters (such as currency, spatial resolution or spatial reference system). As such, you may need to undertake the harmonisation of data to bring these inputs into a form suitable for extracting statistics on species or other selected parameters, and in order to populate your accounting tables at the spatial resolution required. This is especially relevant if you are using existing GIS data on species distributions and status. As an example, Box 2.10 describes the process of data harmonisation and downscaling undertaken by Ivanov et al., (2013) to inform Species Accounts for the EU.

Box 2.10: Example of processing data for Species Accounts in the EU (Ivanov et al., 2013)

Information from the EU's Habitat Directive reported dataset for the cycle 2000-2006 was used to test the possibility of developing EU-wide accounts on species and habitats of European conservation importance. The reported dataset included species ranges and assessed changes/trends in species abundance (population size), range, habitat and future prospects. The changes referred to the period from the designation of national sites and protected species in the 1990s, until the assessment period 2000-2006. The ranges were mapped and reported in varying spatial detail, so were harmonised using the standard European land cover dataset, CORINE, for the year 2000. This harmonisation was possible because the distribution of each species and habitat had been allocated to most likely ecosystem types based on expert knowledge, and these broad ecosystem types allocated to a grouping of land cover classes derived from CORINE land cover maps.

During this assessment, the following steps were undertaken:

a) Species were linked to broad ecosystem type and aligned with conservation assessment values.

b) Species were separated into groups (subsets) according to which one of eight possible broad ecosystem types they belonged.

c) Each of these eight subsets were intersected with a 10 km x 10 km European reference grid.

d) Counts of species numbers per grid cell were extracted for six accounting items: decreasing trend, stable trend, unknown trend, non-assessed, increasing trend and total number.

e) Each of the accounting items was linked to the 10 km x 10 km European grid.

f) Each of the six accounting items was converted (per ecosystem type) to a raster layer for both habitats and species.

g) The eight subsets were used as filters (Boolean, with value 0 or 1) in a raster layer by grouping the non-overlapping CORINE land cover classes.

h) These filters were applied at a 250 m x 250 m spatial resolution for each of the six accounting items individually.

i) Accounting outputs of interest were estimated, including total number of species and habitats of community importance, and total number of species and habitats with increasing, decreasing and stable trends of change.

The assessment provided data on the species mapped at the 250 m x 250 m spatial resolution for EU countries in a form suitable to populate accounting tables at various levels, ranging from local to EU-level.

If you have decided to downscale existing information on species status, you should be aware that this is unlikely to match the actual status of species within a given sub-unit (e.g. BSU or Ecosystem Unit). This reflects the challenges of representing species at this scale in a meaningful way. Figure 2.8 captures this conundrum: conservation status for a species (Species A) has been mapped for a biogeographic region (Figure 2.8a) and applied to the distribution of that species (Figure 2.8b). Accordingly, all grid cells within which Species A occurs are assigned the average status (represented by orange in Figure 2.8c), although this may be different to the on the ground reality (some may have good status and some poor, as shown by green and red cells respectively in Figure 2.8d).

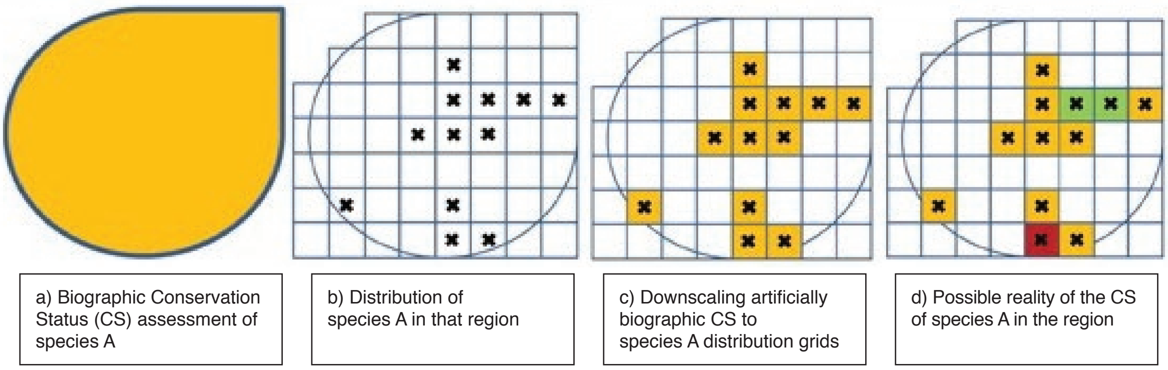


Figure 2.8: An example of the challenges in downscaling species status data (EEA, 2016)

2.2.1.2.4 Action D: Undertake habitat-based methods

If you are employing habitat-based methods, you can now undertake your chosen methods and generate species data in the measurement units decided in Step 3. Ideally, you should generate your species data for each ecosystem type within the Reporting Unit. You will also need to consider the implications of applying these measurement units for any subsequent aggregations you may wish to undertake (this is discussed in Step 8, Action B). In order to facilitate meaningful spatial aggregation, it is important that measurement units remain consistent for each different habitat-based method employed.

2.2.1.2.5 Action E: Estimate uncertainties

An estimate of accuracy and other measures (such as relevance, timeliness, interpretability and coherence) of data quality is needed to accompany the species data used for populating the accounting tables. Data quality limitations and uncertainties may be particularly important when employing estimates from direct observations for larger geographic areas, downscaling or using habitat-based methods involving expert judgement and analysis of data. Where expert judgement has contributed to the process of estimating species status, the continued improvement of Species Accounts in organising data on direct observations presents a means of ameliorating uncertainty over time.

At this stage, it is recommended that you review, identify and qualify (or quantify) the uncertainties in species data to be used in the Species Accounts, so they can be communicated with your key findings in Step 10.

2.2.1.3 Expertise and capacity

To complete Step 5, you will need:

- Expertise in arrangements regarding data sharing and use.
- Ecologists, statisticians, data analysts or GIS experts to convert data to a common format.
- Ecologists or statisticians to validate and clean the data.
- Ecologists and statisticians, and remote sensing and GIS experts, to undertake habitat-based modelling and capture data.

2.2.2 Step 6: Populate Species Accounts

2.2.2.1 Rationale

The purpose of Step 6 is to input the data collated and prepared on species into the set of accounting tables for the Reporting Units determined during the planning phase.

Specific outputs at the end of Step 6:	
	• A set of compiled Species Accounts that can inform the analytical uses and answer the policy questions established in Step 1.

2.2.2.2 Actions

The time and resources needed to populate your Species Accounts depend on the complexity of the accounting tables and the quality and suitability of the input data collected in Step 5. From an ecosystem accounting perspective, your species data would ideally be in a spatial format that can be assigned to different Ecosystem Units (i.e. either via aggregation of BSUs or directly at the Ecosystem Unit scale) and, subsequently, organised by Reporting Unit. However, it is recognised that data availability may limit these options and, for some species, this may not be a realistic ambition. In these situations, species data should be organised directly by ecosystem type or in aggregate at the Reporting Unit scale.

© Orhan Cam / shutterstock.com

At this stage, you will need to review the actual set of accounts decided upon in Step 3. In particular, you will need to decide whether to organise your data on species into a single account for your Reporting Unit, or whether to organise the data in separate accounts for:

- Species of conservation concern
- Species important for ecosystem condition and/or functioning
- Species important for ecosystem service delivery

Given the likely heterogeneity of data available for different Reporting Units, ecosystems and species, you may wish to adopt a mix of approaches for populating your Species Account. With such a mixed approach, it is important to bear in mind that a common reference year should be adopted across all species measures if these measures are to be aggregated (i.e. contribute to the calculation of a composite indicator or index). You will also need to decide whether to supplement these accounts with Accounts of Red List Status and Accounts of the Extent of Important Places for Species.

2.2.2.2.1 Action A: Populate Accounts of Species of Special Concern

You will have generated data for the Accounts of Species of Special Concern using either direct observations, habitat-based methods, or a combination of both. Direct observation data can be used to populate the account directly if data exist at a scale matching your Reporting Unit (ideally by ecosystem type). This may be the case when the accounting tables are prepared for a specific site (such as a Protected Area), or for large Reporting Units (such as counties or countries), where population estimates for species are routinely generated. Where direct observation data has been organised at the Ecosystem Unit or another smaller scale, they will need to be aggregated by ecosystem type within the Reporting Unit (or across the Reporting Unit as a whole) and the results populated in the accounting table. Methods for aggregating direct observations are discussed in Step 8, Action B. If you have employed habitat-based methods, you can now populate your accounting tables using the species data generated in Step 5.

Table 2.7: Hypothetical example Account of Species and Species Groups of Special Concern for ecosystem service delivery in grassland ecosystems within an administrative area (2005-2010)

	Species or Species Group 1	Species or Species Group 2	Species or Species Group 3	Species or Species Group 4	Species or Species Group 5	Species or Species Group 6	Composite indicator or index
Examples Species	Elephant	Birds	Bees	Black Rhino	Wilder beast	Vertebrates	
Unit of measurement	No. individuals	Relative abundance	Relative abundance	Probability of persistence	Hectares of suitable habitat	Proportion of original species complement	N/A
Reference (2005)							1.0
Opening (2005)							N/A
Additions							N/A
Reductions							N/A
Closing (2010)							N/A
Net change							N/A
Opening (% of reference, 2005)							
Closing (% of reference, 2010)							
Net change (% of reference)							
Change (% of opening)							

© Pierre-Jean Durieu / shutterstock.com

Table 2.7 provides the structure for the Accounts of Species of Special Concern, where temporal changes of stocks – defined as abundance, biomass, suitable habitat, proportion of species remaining, or some other quantitative measure – are tracked by rows for species or species groups provided in columns. Table 2.7 provides an example of a Species Account for measures of species or species groups important to ecosystem service delivery in grassland ecosystems within a particular administrative area (i.e. the Reporting Unit). However, the same structure will apply for Species Accounts that consider all species, species of conservation concern, or species important for ecosystem condition and functioning, whether by ecosystem type or for the entire Reporting Unit.

The composite indicator or index in the final column should be estimated following the procedure chosen in Step 4, using relative measures anchored in a common reference year or condition. Where a mix of direct observation and habitat methods are employed, it may be necessary to use an accrual approach, where the common reference year is set to the start of the first accounting period (Table 2.7).

When presenting Species Accounts for your Reporting Unit, they should be supported by a clear narrative on how the species or species groups were selected, how species measures were generated, and how the composite indicator or index was calculated. Box 2.11 presents an example of a Species Account populated using direct observations of species of conservation concern in Wales. Box 2.12 provides an example of a Species Accounts populated using habitat-based method (GDM) for the San Martin region in Peru. While the format of the accounting tables does not exactly match that proposed in Table 2.7, the individual data items could easily be converted.

Box 2.11: An example of a Species Account populated using direct observations of species important for conservation in Wales

This table presents an account for conservation species of concern in Wales at the national scale using relative measures of population densities. Data have been populated for the opening period (2013-2016) based on the first round of GMEP monitoring. The closing period will be populated using data from the second round of GMEP monitoring, due to be completed in 2020. As relative measures are an accrual approach, a composite indicator or index has not been calculated at this stage.

	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Species 9	Species 10	Species 11	Species 12	Species 13
Data type and source	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)
Species	Common bullfinch	Black-headed gull	chough	Common cuckoo	Eurasian curlew	Hedge accentor	Common grasshopper warbler	Herring gull	House sparrow	Kestrel	Northern lapwing	Common linnet	Lesser redpoll
Unit	Mean species abundance in GMEP squares (1 km^2 sampling locations)												
Reference (benchmark)	2.327	1.562	0.181	0.646	0.686	7.739	0.403	6.482	11.881	0.208	0.836	6.288	1.690
Opening (% of reference)	100	100	100	100	100	100	100	100	100	100	100	100	100
Opening (2013-2016)	2.327	1.562	0.181	0.646	0.686	7.739	0.403	6.482	11.881	0.208	0.836	6.288	1.690
Closing (2017-2020)													
Change (% of opening)													
Closing (% of reference)													
Net change (% of reference)													

All species selected are priority species for Wales as indicated by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. GMEP data provides actual abundance data available from 2013-15 (with 2016 data currently being collected). Future 'Opening' will, therefore, be 2013-2016. Historical trend data using an index of abundance for many of these species, e.g. from the BBS, is available, but was considered less appropriate to the actual abundance data from GMEP. Change values varied from -31% to + 182% from the period 2005-2009 to 2013-2015.

Box 2.11: *Continued*

	Species 14	Species 15	Species 16	Species 17	Species 18	Species 19	Species 20	Species 21	Species 22	Species 23	Species 24	Species 25	Species 26
Data type and source	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Birds (GMEP)	Butterflies (GMEP)	Butterflies (GMEP)
Species	Marsh tit	Pied flycatcher	Reed bunting	Skylark	Spotted flycatcher	Common starling	Song thrush	Tree pipit	Wood warbler	Willow tit	Yellowhammer	Small heath	Wall brown
Unit	Mean species abundance in GMEP squares											Mean count per 1km^2	
Reference (benchmark)	0.239	0.473	1.296	5.752	0.850	5.593	4.504	0.987	0.235	0.088	0.434	8.03	1.3
Opening (% of reference)	100	100	100	100	100	100	100	100	100	100	100	100	100
Opening (2013-2016)	0.239	0.473	1.296	5.752	0.850	5.593	4.504	0.987	0.235	0.088	0.434	8.03	1.3
Closing (2017-2020)													
Change (% of opening)													
Closing (% of reference)													
Net change (% of reference)													

All species selected are priority species for Wales as indicated by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. GMEP data provides actual abundance data available from 2013-15 (with 2016 data currently being collected). Future 'Opening' will, therefore, be 2013-2016. Historical trend data using an index of abundance for many of these species, e.g. from the BBS, is available, but was considered less appropriate to the actual abundance data from GMEP. Change values varied from -31% to + 182% from the period 2005-2009 to 2013-2015.

86

Box 2.12: Example Species Accounts populated using habitat-based methods for the San Martin region in Peru (CI & CSIRO, 2016)

Reporting Units were defined for the San Martin region in Peru on the basis of 11 ecosystem types. For forest ecosystems, the following Species Accounts were estimated for the whole of San Martin:

- Continuous variation in community composition using Generalised Dissimilarity Modelling (GDM) dependent upon environmental change.
- Change in suitable habitat for individual threatened species.

Using the GDM method

GDM models were developed for San Martin for vertebrates, vascular plants and invertebrates. The table below shows the change across the three taxonomic groups over the accounting periods; it reveals an ongoing loss of approximately 0.8% of species as a function of habitat condition change between 2009 and 2013. For a biodiverse group like invertebrates, this may represent the loss of many species per year.

Ecosystem type	Invertebrates (% biodiversity retained)			Vascular plants (% biodiversity retained)			Vertebrates (% biodiversity retained)		
	2009	2011	2013	2009	2011	2013	2009	2011	2013
Palm swamps	90.3%	90.1%	90.0%	87.0%	86.9%	86.8%	91.2%	91.1%	91.1%
Humid forest with high hills	88.3%	87.8%	87.4%	89.2%	88.8%	88.4%	83.7%	83.3%	83.1%
Humid forest with low hills	87.7%	87.3%	86.9%	88.6%	88.2%	87.8%	83.2%	82.8%	82.6%
Humid montane forest	91.1%	90.8%	90.5%	91.1%	90.7%	90.5%	87.5%	87.3%	87.1%
Lowland terra firme forest	86.5%	86.0%	85.6%	86.1%	85.5%	85.1%	80.9%	80.5%	80.3%
Floodplain forest	86.7%	86.2%	85.8%	86.6%	86.1%	85.7%	81.9%	81.5%	81.3%

Using the individual species distribution method

The second approach focused on threatened species, which are often the focus of conservation because they are the most at risk of extinction. This approach was taken to measure habitat change within predicted distributions for the yellow-tailed woolly monkey and the San Martín titi monkey (Mono tocón).

Box 2.12: ***Continued***

The extent of suitable habitat for these species across the whole of San Martin was estimated using individual species distribution method (Maxent modelling; Phillips et al., 2006). The results are presented in the table below, which reveals small changes in suitable habitat for the yellow-tailed woolly monkey, but much greater change for the titi monkey. These results are expressed relative to a benchmark (aka reference condition) indicative of minimal human disturbance

San Martín				
	Reference condition	2009	2011	2013
Important species	Extent (ha)	Extent ha/(%)	Extent ha/(%)	Extent ha/(%)
Yellow-tailed woolly monkey	103,142	97,225 (94.3%)	96,714 (93.8%)	96,509 (93.6%)
Titi monkey	984,577	396,066 (40.2%)	365,836 (37.2%)	354,418 (36%)

2.2.2.2.2 Action B: Populate the Account of Red List Status

The SEEA-EEA (2014) suggests an account for threatened species based on the IUCN Red List. This has been updated and is presented in this document (Table 2.8). When constructing this account, you should capture transfers between extinction risk categories over the accounting period using the options for 'reasons for change' outlined by the IUCN (2016). Genuine changes are those resulting from genuine improvements or deteriorations in status, which are sufficient to cross the category thresholds for a higher or lower Red List category. Re-appraisals of species' categories are the combined sum of changes from: criteria revision, new information, taxonomic change, mistakes, incorrect data and other explanations. While an Account of Red List Status captures the net transfers between categories (e.g. Endangered to Critically Endangered), additional accounts are required if you are interested in understanding from which specific categories these transfers are originating. Following Butchart et al. (2004) and Rodrigues et al. (2014), species in the data deficient category should be excluded from the account.

Table 2.8: Account of Red List Status (SEEA-EEA, 2014)

	Extinct (5)	Critically Endangered (4)	Endangered (3)	Vulnerable (2)	Near Threatened (1)	Least Concern (0)	Red List Index
Unit of measurement	Number of species	Number of species	Number of species	Number of species	Number of species	Number of species	
Reference							
Opening (e.g. 2007)							
Additions							N/A
Additions (genuine)							N/A
Additions (re-appraisals)							N/A
Total additions							N/A
Reductions							N/A
Reductions (genuine)							N/A
Reductions (re-appraisals)							N/A
Total reductions							N/A
Closing (e.g. 2012)							

The Red List Index (RLI) in the final column of Table 2.8 follows IUCN's calculation (Bubb et al., 2009). This is calculation is expressed as follows:

$$RLI_t = 1 - \frac{\sum_{s=1}^{N} W_{c(t,s)}}{W_{EX}.N}$$

Where $W_{c(t,s)}$ is the weights (ranging from 0 for Least Concern to 5 for Extinct) of species s at time t, W_{EX} is the weight for extinct and N is the number of species in the account. This will yield an index value between 0 and 1.

2.2.2.2.3 Action C: Populate Accounts of the Extent of Important Places for Species

Measuring change in the extent of ecologically important places for species within Reporting Units may provide useful information to supplement your other Species Accounts. Box 2.13 provides an example of this type of account for KBAs in the San Martin region of Peru.

2.2.2.3 Expertise and capacity

To complete Step 6, you will need:

- Ecologists to extract information for populating the Accounts of Red List Status.
- Ecological modellers, statisticians or GIS experts to work with GIS outputs, databases, spreadsheets and pivot-tables to extract data for species accounting tables.

Box 2.13: An example of an Account of the Extent of Important Places for Species from San Martin, Peru (CI and CSIRO, 2016)

As part of a wider ecosystem accounting project for the San Martin region in Peru, an Account of the Extent of Important Places for Species was created. This account was based on Key Biodiversity Areas (KBAs), which are areas that are identified nationally using simple, standardised criteria, based on their importance in maintaining species' populations (Langhammer et al., 2007). The account is presented in the table below, with substantial variation in change noted between the nine KBAs between 2009, 2011 and 2013.

San Martín				
	Benchmark	2009	2011	2013
Key Biodiversity Areas	Extent (ha)	Extent ha/(%)	Extent ha/(%)	Extent ha/(%)
Moyobamba	87,839	35,770 (40.7%)	33,832 (38.5%)	33,089 (37.7%)
Jesús del Monte	4,481	4,479 (99.9%)	4,475 99.8%)	4,474 (99.8%)
Parque Nacional Cordillera Azul	481,772	476,919 (99%)	476,496 (98.9%)	476,424 (98.9%)
Río Abiseo y Tayabamba	192,405	185,073 (96.2%)	184,462 (95.9%)	184,035 (95.6%)
Laguna de los Cóndores	212,197	202,380 (95.4%)	201,784 (95.1%)	201,572 (95%)
Abra Pardo de Miguel	1	1 (100%)	1 (100%)	1 (100%)
Abra Tangarana	3,694	3,533 (95.7%)	3,513 (95.1%)	3,497 (94.7%)
Entre Balsa Puerto y Moyobamba	155,950	117,523 (75.4%)	108,019 (69.3%)	104,538 (67%)
Tarapoto	170,729	113,360 (66.4%)	111,225 (65.1%)	109,202 (64%)

2.2.3 Step 7: Identify and fill gaps in the Species Accounts

2.2.3.1 Rationale

The purpose of Step 7 is to review the Species Accounts you have constructed and identify and address any data deficiencies in order to make the accounts fit for their intended use.

Specific outputs at the end of Step 7:

- The identification of any gaps in the accounting tables that need to be filled.
- A strategy for improving Species Accounts to meet their analytical uses and answer policy questions of interest.

2.2.3.2 Actions

You will have assessed the suitability of the input data available to inform accounting tables in Steps 2, 3 and 5. This assessment will have included a range of criteria, including spatial coverage, spatial resolution, accuracy, temporal coverage, interpretability and relevance to the species and species groups in question. You may have detected gaps, deficiencies and other quality issues for each of these criteria. In addition, you may also have identified another set of gaps and quality issues after populating the accounting tables in Step 6. Since, by design, the tables aim to establish the trends within and between species and species groups, the inability to establish consistent relations between given rows and columns will be indicative of where data gaps may be found. Such gaps may occur, for example, within data related to: locations of species; populations or statuses of species; and changes in populations or statuses of species.

If additional data are required in order to satisfy the analytical uses and policy questions established in Step 1, it should be explicitly recognised. Once this has been determined, you have two options: 1) improve available direct observation data; or 2) revise the mix of approaches employed.

2.2.3.2.1 Action A: Identify data gaps

Where the initial data on direct observations are insufficient for species or species groups of special concern, you should clearly identify the gaps preventing completion of the Species Accounts. In doing so, you will inform which option will be most appropriate for addressing such gaps. An example of identified data gaps for biodiversity in the EU is presented in Box 2.14.

2.2.3.2.2 Action B: Improve direct observation data (if required)

You may wish to explore targeted collection and development of new data or additional records to fill exposed gaps. This will require you to engage with your core group of stakeholders and, possibly, expand this group. You may wish to organise a workshop to facilitate a coordinated review of data held by all your stakeholders. This may identify records held by institutions and individuals in a variety of formats. As the scoping exercise in Step 2 will have identified easily accessible data, it is likely that significant effort will be required to collect and use additional data in a format suitable for accounting. For example, records may be held in hard copy or excel spreadsheets that need to be validated, cleaned and manipulated into spatial formats.

A second option is to establish further monitoring programmes to increase the pool of primary data for species or species groups of special concern. Modelling and expert opinion (each with different drawbacks) can be used to guide further monitoring in this regard. For example, models can be used to identify novel conditions, where presently unidentified species might be observed and where further surveying could be targeted (Guisan et al., 2006). Fieldwork could survey ecological conditions of habitats on the ground, as well as species' status.

Box 2.14: Identified data gaps for mapping ecosystem condition in the European Union (EU) (EEA, 2016)

At the EU level, biodiversity datasets have been used within the Mapping and Assessment of Ecosystems and their Services (MAES) project for the assessment and mapping of ecosystem condition across the European Member States. Within MAES, ecosystem condition was mapped on the basis of the conservation status of habitats and species. Experience gained from assessing ecosystem condition based on data from the first reporting cycle shows that inconsistencies in the data collection and reporting exercises occurred. These included:

- Gaps in European datasets regarding the state, trends and spatial distribution of species. For example: only non-bird species and habitats of 'conservation interest' are covered; there are missing data for some countries (including all non-EU countries); and 26% of terrestrial and 50% of marine species were reported as 'unknown conservation status' under the Habitats Directive.
- Inconsistent quality and comparability of available datasets and indicators across Europe, with challenges related to monitoring; for instance, the proportion of habitats reported as 'favourable' varies from 4 to 95% across the different datasets and indicators.
- Poor availability of indicators for the impacts of some of the pressures on biodiversity, such as pollution, climate change and invasive alien species.
- Lack of coverage of features too small to be detected by satellite land cover mapping, such as green and blue linear features like hedgerows and streams.
- Lack of time series data due to infrequent (six-yearly) reporting of CORINE land cover data, EU Nature Directives, Water Framework Directive and Marine Strategy Framework Directive.
- Lack of quantitative data for meeting the targets of the EU Biodiversity Strategy to 2020.

2.2.3.2.3 Action C: Revise the mix of approaches employed (if required)

If direct observations are insufficient to populate accounting tables for species or species groups at the spatial and temporal resolution you desire, you may wish to supplement the accounts using habitat-based methods. This will require collating data on the necessary environmental variables in order to upscale the direct observation data available. Your options in this regard are discussed in Step 3, Action A, Strategy 2.

2.2.3.3 Expertise and capacity

To complete Step 7, you will need:

- Expertise in the policy context to assess the implications of species data gaps.
- Ecologists, ecological modellers and data analysts to identify data gaps and appropriate strategies for filling those gaps.

2.2.4 Step 8: Organise and aggregate Species Accounts

2.2.4.1 Rationale

The purpose of Step 8 is to organise your Species Accounts for your Reporting Unit(s). You may also wish to employ aggregation procedures for reporting across multiple Reporting Units if the intended analytical uses or policy questions determined in Step 1 require this.

Specific outputs at the end of Step 8:

- A collated set of Species Accounts across ecosystem types within your Reporting Unit.
- A set of Species Accounts that cover multiple Reporting Units.
- Composite indicators or indices to communicate species information at relevant scales.

2.2.4.2 Actions

The purpose of populating the accounting tables is to construct information in a way that makes it possible to scale, aggregate and compare it with other geographical domains – a particular challenge in the context of Species Accounts. This is because species or species groups selected for inclusion in the accounts for different ecosystem types and Reporting Units are likely to vary, and species data will often be heterogeneous in nature (particularly when a mix of direct observations and habitat-based methods are employed).

2.2.4.2.1 Action A: Organise the Species Accounts in your Reporting Unit(s)

If you have organised your Species Accounts by ecosystem type, it may be useful to present a Species Account that captures the information on species for the different ecosystems within the Reporting Unit. An example based on the format presented in the Peru case study for forest ecosystems (Box 2.12) is presented in Table 2.9.

The usefulness of Table 2.9 will depend on whether your accounts contain species or species groups that span across ecosystem types. You may wish to organise your Species Accounts into different sets, for example as a ‘Forest Account’, where accounts have been constructed for different forest ecosystems. For species that are dependent on multiple ecosystems, it may be more challenging to discretely split them across individual ecosystems. As such, you will need to decide if this further organisation will be useful in informing your key analytical uses and policy questions, as determined in Step 1.

The Species Account for the whole Reporting Unit should follow the organisation of data as established during the planning phase (i.e. for species of conservation concern, or species important for ecosystem condition and functioning, or species important for ecosystem service delivery). The final row in Table 2.9 allows for aggregation of species information across ecosystems. The challenges for aggregation apply equally within Reporting Units as across Reporting Units, and your options in this regard are discussed under Action B.

Table 2.9: Species Account for species of conservation concern in different ecosystems within a Reporting Unit (2010-2015)

		Species / Species Group 1		Species / Species Group 2		Species / Species Group 3		Species / Species Group 4		Species / Species Group 5		Species / Species Group 6		Composite Indicator / Index	
		Measurement unit		Measurement unit		Measurement unit		Measurement unit		Measurement unit		Measurement unit			
		Open (2010)	Close (2015)	Open (2010)	Close (2015)	Open (2010)	Close (2015)	Open (2010)	Close (2015)	Open (2010)	Close (2015)	Open (2010)	Close (2015)	Open (2010)	Close (2015)
Ecosystem type	Type A														
	Type B														
	Type C														
	Type D														
	Type E														
	Type F														
	Type G														
Reporting Unit															

2.2.4.2.2 Action B: Review and implement options for aggregation (if required)

For any aggregation to be meaningful, it is important that species measures be consistent in terms of their method of production, measurement units and the species they represent (for instance, across the measures for each species for each ecosystem type represented by the rows in Table 2.9). The decisions you have made regarding the approach to constructing your accounts, and the nature of the data you have available, will have implications for the feasibility of further aggregation. These implications are discussed here with respect to the different approaches and associated measurement units.

Direct observations

The potential to aggregate direct observations on species across different Reporting Units is likely to be limited to well-studied species (such as birds) or particular Reporting Units (such as National Parks). In addition, there may also be some well-studied broad ecosystem types (such as forests) for which data could be aggregated across, or within, Reporting Units.

Where you have absolute measures for species or species groups, you will be able to express aggregated information simply as the sum of these direct observations, thus combining them easily to larger spatial scales. Other absolute measures, such as tonnes of biomass or areas of occupancy or cover, will also be suitable for aggregation in a similar fashion.

On the other hand, relative measures of abundance (such as those based on population density, indirect indictors or percentage of canopy cover) will not be amenable to aggregation in an additive manner. While a mean could be calculated across a larger spatial area, these units are scale dependent. As such, you should employ area weighting to ensure your aggregated relative measure remains proportionate.

Habitat-based methods

All the habitat-based methods proposed in Step 3 employ grid cells (or BSUs in ecosystem accounting terms) as the spatial analytical unit to which species information is assigned. Such units can be spatially aggregated to any reporting scale. However, depending on the specific habitat-based approach method employed, there will be constraints on how actual species information estimated and assigned to grids under separate analyses can be combined. Your options for aggregating Species Accounts generated via habitat-based methods modelling are discussed here.

Individual species distributions

Where you have employed individual species distributions, you will be able to aggregate species information for some measurement units. This is because the approach is based on assigning a ‘condition score’ to indicate whether the portion of habitat contained within the grid cell / BSU is suitable for a given species. Cells that have been identified as suitable can be combined with other suitable cells to form separate analyses for different ecosystem types and Reporting Units in an additive manner. Once the total area of suitable habitat has been determined across the larger spatial area, this information can be presented in terms of proportion of suitable habitat compared to the historic baseline.

However, where more sophisticated models have been employed to estimate the probability of occurrence of species or species groups, you will need to re-run the model for the whole of the larger spatial area.

Discrete community class distributions
If you have mapped discrete community classes consistently across Reporting Units, the constituent grid cells / BSUs can be combined additively both within, and across, Reporting Units. This could be expressed on the basis of total condition score or condition-weighted hectares for each community class. Both measures can be expressed as a proportion of the sum obtained if all cells for the historic base of that community class were in perfect condition across the entirety of the larger spatial area.

If you have used community-level modelling that employs multiple species records to map discrete community classes, the 'condition score' of grid cells / BSUs from separate analyses in different Reporting Units can only be combined additively if the model has been fitted at a scale that covers all ecosystems or Reporting Units of interest. If the model is run for individual ecosystem types or Reporting Units in separate analyses, inconsistent community classes will emerge that will not lend themselves to meaningful aggregation.

Where SARs are employed to estimate the proportion of species expected to persist in community classes, the analysis will need to be repeated each time the spatial area changes.

Continuous variation in community composition
Continuous community level approaches assume that each grid cell / BSU contains a unique community of species. As GDM and SAR conversions are scale dependent, the analysis will need to be repeated every time the spatial area changes.

Options
You should now consider you aggregation options with respect to Table 2.9 and across reporting units. You should undertake aggregation or repeated analyses at larger scales if it is necessary to inform your key analytical uses or policy questions; thus generating relevant Species Accounts for the appropriate scales.

If aggregating species data in the absence of such repeated analyses, you should be aware that different aggregations can often generate different results for given Reporting Units. Specifically, Bond et al. (2013) discuss how the Modifiable Areal Unit Problem (MAUP) can potentially lead to different management options being recommended in specific sub-areas as a result of different geographical aggregation approaches. The MAUP arises from the measurement and subsequent aggregation of individual units in reporting areas of interest. Different aggregations of individual data points produce different results, meaning the same base data can tell a different story depending on the boundary used for aggregation.

2.2.4.2.3 Action C: Construct composite indicators or indices for larger scales
The composite indicators or indices you have calculated represent relative measures of the condition of your selected species or species groups. As such, they lend themselves to aggregation. The Nature Index for Norway (NI; Box 2.15), for instance, aggregates similarly derived indicators over spatial units by using area weighting. This is necessary to ensure that the relative measures of species condition are aggregated in a proportional manner (Certain et al., 2011).

Box 2.15: The Nature Index for Norway (NINA, n.d.)

The Nature Index (NI) is a composite biodiversity index recently developed in Norway. It is based on combining the abundance of species and surrogate indicators within Species Accounts to form a national index. This index demonstrates the state of biodiversity within major terrestrial, limnic and marine ecosystems, related to basic spatial units. The current version of the NI includes about 300 indicators representing different taxonomic and functional groups.

Data sources are monitoring data, models and expert judgement (where monitoring data are too scarce). Data are defined for geographical units and major ecosystems. Key indicators (i.e. indicators with an important function in ecosystems) are given higher weight than other indicators. All functional groups are given equal weight. However, weighting may be adapted to specific user needs. It is also possible to use the NI's conceptual framework and online database to focus on selected species or trophic interactions.

The NI is calculated as a weighted average of the abundances of species of interest. A statistical framework has been developed to combine and correct for missing data and assess uncertainty. The online web portal for entering data in the database and conducting statistical analyses is available for free and may be adjusted for use in other areas. Costs related to this adaptation must be covered by users. The method has also been tested in Costa Rica, and pilots are currently being tested in Bulgaria and India. The steps to constructing the NI are detailed here.

Decide basic spatial units (grid/municipalities etc.) and implement polygons in the NI-database

↓

Define major ecosystem in focus (forests, freshwater etc.)

↓

Select species of interest

↓

Define reference state

↓

Gather data on species abundance

↓

Enter data into online NI-database at a feasible geographic scale

↓

Calculations: weighted average of reference-scaled indicators

↓

Presentation

A public website which publishes trends and state of ecosystems, selected thematic indices (e.g. selected species) and single species based on the NI is available at: http://naturindeks.no/About

The NI presents a good example of using national headline indicators to assess the status and trends of biodiversity (or species) for different ecosystems. It provides a method for acquiring a single 'value' that delivers a readily available overview of whether progress is being made towards policy goals of halting biodiversity or species loss. The NI can be presented at different levels of aggregation, and the choice of resolution depends on the underlying questions to be addressed. This ability to organise information on species for aggregation across scales is a key feature of Species Accounts. Accordingly, you should calculate composite indicators or indices at the scale(s) required to inform your key analytical uses and policy questions.

2.2.4.3 Expertise and capacity

To complete Step 8, you will need:

- Expertise in the policy context to guide aggregation requirements.
- GIS experts and ecologists to assist in aggregation of direct observation data.
- GIS experts and ecological modellers to assist in the aggregation (or estimation at larger scales) of species data generated using habitat-based modelling.

2.2.5 Step 9: Analyse and integrate Species Accounts

2.2.5.1 Rationale

The purpose of Step 9 is to review the information organised within your Species Accounts in the context of the key analytical uses and policy questions determined in Step 1. You may directly infer species' trends and statuses from the Species Accounts. You should also review the insights that integrating information within the Species Accounts with information in other ecosystem accounts, and with wider statistics, can provide.

Specific outputs at the end of Step 9:

- An identification of the trends and status of species relevant to your key analytical uses and policy questions.
- A review of the potential for Species Accounts to inform accounts of ecosystem extent (Ecosystem Extent Accounts).
- An Integration of Species Accounts into accounts of ecosystem condition (Ecosystem Condition Accounts).
- An Integration of Species Accounts into ecosystem services supply and use accounts (Ecosystem Services Accounts).
- An assessment of interlinkages between Species Accounts and other statistics (such as thematic accounts for land, water and carbon, as well as SEEA-CF accounts).

2.2.5.2 Actions

Species Accounts provide an insight into spatial trends in species status. Yet, in combination with spatially referenced socio-economic and ecosystem accounts, they can also provide the information needed for socio-economic planning to achieve more sustainable uses of ecosystems (for example, Sustainable Development Goals 17 and 18) and conservation commitments (for example, Aichi Targets or legislation, and EU Birds and Habitat directives). The integration of ecosystem accounts and Species Accounts remains a highly experimental area. Therefore, Step 9 provides you with some ideas on how you can use the information in your Species Accounts in the context of the SEEA-EEA and how to link them to wider environmental-economic statistics to inform decision-making. This integration not only provides an insight into the benefits provided by species, but will also help you to understand the drivers that are impacting species.

2.2.5.2.1 Action A: Analyse Species Accounts

You should review your Species Accounts (constructed in Steps 6 and 8) to identify the trends in species that are directly relevant to the key analytical uses and policy questions determined in Step 1. While this will be dependent on the context in which you are generating the accounts, some common insights include:

- In general, Species Accounts will reveal which species are experiencing negative trends and are likely require further assessment and conservation actions. They will also identify those ecosystems and Reporting Units in which these concerns are greatest.
- Accounts of species of conservation concern will identify status and trends of concern with respect to conservation priorities. They will also reveal in which Reporting Units or ecosystem types such concerns are greatest.
- Accounts of species important for ecosystem condition and functioning will reveal if ecosystems are being degraded and their resilience compromised. They will also show which ecosystems are most threatened and the Reporting Units in which they are located.
- Accounts for species important for the delivery of ecosystem services will show if there are risks to future service provision. In this regard, they will identify which ecosystems are most at risk, and in which Reporting Units they are located.
- Accounts of Red List Status will reveal aggregate trends in the conservation status of species and if these trends are of concern.
- Accounts of the Extent of Important Places for Species will identify which important habitats are under pressure from land conversion, and in which Reporting Units they are located. They will also establish any potential correlations with species' trends and status.

You should document the insights that your Species Accounts provide for wider communication (Step 10). When drawing your insights, consider any effects of scale on the information organised within Species Accounts for different Reporting Units. For example, if your Reporting Units represent different watersheds, they will vary in size, hence it would be expected that species abundance and diversity would increase with the size of the Reporting Unit. Beyond direct summaries of information in Species Accounts, the accounts can also be used to support: future trend analyses; scenario analyses (particularly land-use impacts using habitat-based methods); and investment analyses.

2.2.5.2.2 Action B: Integration with wider SEEA-EEA ecosystem accounts

The key constraint to integration is the consistency of Reporting Units and frequency of production between Species Accounts and other ecosystem accounts. In order to allow full integration of statistics in a flexible framework, species information will need to be organised at Ecosystem Unit (or BSU) scale, so that it can be matched to the fundamental ecosystem accounting unit. This presents many challenges for Species Accounts, however, from both conceptual and measurement perspectives. Therefore, integrating species information at Reporting Unit scales may be more meaningful. This will provide useful information to decision-makers on the statuses of species and ecosystems, and allow trade-offs to be explored at this aggregated level.

Figure 2.9 demonstrates the conceptual linkages between your Species Accounts and other accounts in the SEEA-EEA framework. It also shows how the integration of this information can provide a platform for informing policy action and incorporating ecosystem statistics in wider statistics captured in SEEA-CF and national accounts.

Depending on your analytical uses or policy questions from Step 1, you will have constructed holistic Species Accounts, or organised species under themes of conservation, ecosystem condition and functioning, and/or ecosystem service delivery for your Reporting Units (middle column, Figure 2.9). This information links with several components of the wider ecosystem accounts developed during the steps indicated in the left hand column of Figure 2.9. Species Accounts will have relationships with other standalone thematic accounts via their shared spatial structure, as indicated in the right hand column of Figure 2.9. For example, there will be interactions between land use, harvesting biomass, sequestering carbon, abstracting water, and species.

The full integration of ecosystem accounts and Species Accounts within the SEEA-EEA and beyond is an area of continuing research. At this stage, however, you should review how the information you have collected within your Species Accounts can be integrated with wider accounts and aligned with other relevant statistics to help inform decision-making.

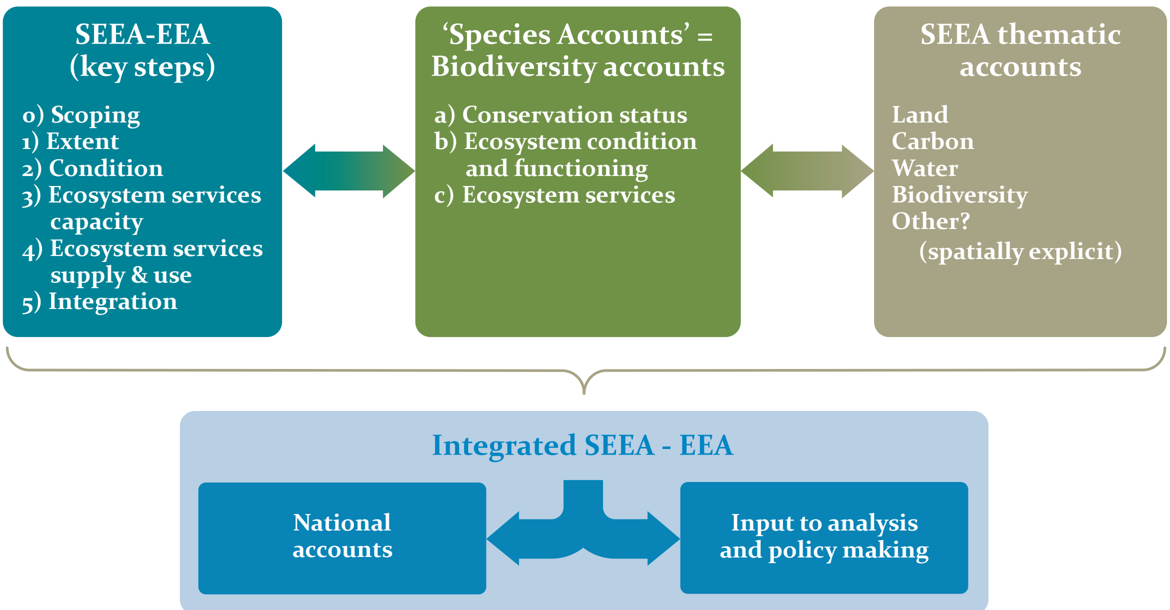


Figure 2.9: Diagram demonstrating the integration of Species Accounts with wider ecosystem and thematic accounts

Integrate with SEEA-EEA Ecosystem Extent Account

Depending on the spatial resolution of your species data, you may be able to use this information to inform the delineation of Ecosystem Units. For instance, where you have employed community-based methods to identify community classes this may provide an option for helping to refine areas of similar species compositions (providing these have been mapped consistently). This approach has been employed for a number of applications using discrete Vegetation Classes (e.g. Parks et al., 2003; Driver et al., 2015) to determine the extent of different ecosystems. Conversely, where Ecosystem Extent accounts have already been produced, you can potentially use these to understand how changes in the extent of different ecosystems could be impacting species.

Integrate with SEEA-EEA Ecosystem Condition Account

The Ecosystem Condition Account organises information on ecosystem characteristics that are important for maintaining ecosystem processes, functions and, ultimately, the ability of ecosystems to deliver ecosystem services. The composite indicators or indices for your Species Accounts can inform the Ecosystem Condition Account for your Reporting Unit (or the different ecosystems within it). You can organise this statistic alongside a suite of other relevant indicators in the Ecosystem Condition Account, thus capturing a wider range of ecosystem characteristics that will help to address the key analytical uses and policy questions determined on Step 1. This suite of indicators can also be summarised as a composite indicator or index in order to provide an overall assessment of the condition of an ecosystem. Such an indicator or index can then be compared with accounts related to ecosystem service provision and associated economic activities, such as agriculture and ecotourism. Tables 2.10 and 2.11 provide example Ecosystem Condition Accounts based on the SEEA-EEA (2014).

Ecosystem Condition Accounts remain an area of ongoing development and the suite of condition indicators is likely to vary by context. For example, Nel and Driver (2015) present Ecosystem Condition Accounts for rivers in South Africa which are populated with indicators for flow quantity, water quality, instream habitat and riparian habitat. Box 2.16 demonstrates how the Species Accounts generated via the GDM habitat-based method were integrated into an Ecosystem Condition Account for San Martin, Peru.

Table 2.10: Integrating information from Species Accounts into the Ecosystem Condition Account

	Reporting unit: Geographical Aggregation (Reporting Unit or Ecosystem Type in Reporting Unit)										
							Species				
	Vegetation	Water resources	Soil	Carbon	Soil regulation	Other characteristics	Species for conservation Composite Indicator / Index	Species for condition & functions Composite Indicator / Index	Species for services Composite Indicator / Index	Overall Species composite indicator/ index	Composite indicator/ index for ecosystem condition
Reference condition											
Opening (e.g. 2005)											
Additions											
Reductions											
Reappraisals											
Closing (e.g. 2010)											

Table 2.11: Integrating information from Species Accounts into Ecosystem Condition Account over a time series

	Reporting unit: Geographical Aggregation (Reporting Unit or Ecosystem Type in Reporting Unit)										
							Species				
	Vegetation	Water resources	Soil	Carbon	Soil regulation	Other characteristics	Species for conservation Composite Indicator / Index	Species for functions Composite Indicator / Index	Species for services Composite Indicator / Index	Overall Species composite indicator/ index	Composite indicator/ index for ecosystem condition
Reference year											
Year 1											
Year 2											
…..											
Latest reporting year											

Box 2.16: Ecosystem Extent and Condition Account, for San Martin, Peru (CI and CSIRO, 2016)

A condition score for the biodiversity retained in each of the forest ecosystem types assessed in San Martin was calculated using the mean average of the retained percentages of invertebrates, vertebrates and vascular plant biodiversity (Box 2.14; Step 6). This was integrated into Ecosystem condition accounts for the six forest ecosystems considered in the table below for 2009). A composite index for the overall condition of each ecosystem type was then estimated as the mean average of the biodiversity condition and fragmentation condition.

The extent and condition of ecosystems San Martin in 2009; condition scores are scaled from 0-1

Time 2009		San Martín					
Ecosystem asset		Extent		Condition scores			
		Current area (ha)	% Original	Fragmentation	Biodiversity retained (%)	Composite index
Forests	Palm swamps	27,997	98.7%	0.91	89.50%	0.90
	Humid forest with high hills	203,601	53.3%	0.39	87.00%	0.63
	Humid forest with low hills	159,703	82.7%	0.72	86.50%	0.79
	Humid montane forest	2,966,134	82.0%	0.72	89.90%	0.81
	Lowland terra firme forest	53,179	51.7%	0.42	84.50%	0.63
	Floodplain forest	189,224	40.0%	0.28	85.10%	0.57

Integrate with Ecosystem Service Accounts

You may have constructed Species Account(s) for species or species groups that are relevant to ecosystem services and their delivery. For species providing direct benefits (such as provisioning services, nature-viewing opportunities and medicinal plants), Species Accounts can be used to understand the capacity of ecosystems within Reporting Units to provide these services; for example, by providing the information needed to estimate sustainable yields, or the information needed to maintain a sufficient population of iconic species for visitor attractions. Linking accounts of species important to ecosystem services to accounts that capture the supply and use of these species will reveal the benefits species provide and identify any over exploitation. Ultimately, it is desirable to link these services with monetary values. This can support arguments for investment in species conservation or reducing the intensity of harvesting or other activities that negatively impact on species.

Linking species information to ecosystem structures and functions and, consequently, other ecosystem services that result in indirect benefits can be problematic (McDonald, 2011). Conceptually, it is possible to link species to ecosystem service flows using a relevant ecological production function (Boyd and Banzhaf, 2007). Despite the fact that this remains an area for further research, organising species into accounts relevant to specific ecosystem services is a pragmatic option at this stage for directing precautionary action. At the Reporting Unit scale, this will also prove useful for capturing information on species that are difficult to attribute to specific ecosystems.

2.2.5.2.3 Action C: Link with information on economic activities and other drivers of species loss

To address the analytical uses and policy questions determined in Step 1, you will find it useful to compare Species Accounts with other environmental and economic accounts. For instance, you can infer impacts, identify benefits and explore trade-offs relevant to different land-use issues; indeed, multiple comparisons can be made.

McDonald (2011) identifies the potential to link Species Accounts with the Environmental Protection Expenditure Accounts in the SEEA-CF. These are functional accounts of financial transactions resulting from environmental protection activities. Linking these financial transactions to changes in species can have significant policy implications. In particular, they will be useful in understanding the ecological returns on investments in species and species-level biodiversity.

Bond et al. (2013) discuss the environmental-economic linkages in the context of agricultural systems in Australia (Box 2.17). This could inform policy objectives, such as 'No Net Loss' of biodiversity and offset programmes, by spatially analysing alternative land-use profitability with species stocks.

Box 2.17: Links between species and agricultural data

Bond et al. (2013) link spatial statistics on bird species richness to agricultural land use and profit in the table below. The spatially explicit agricultural profits data were calculated from statistics on land use, commodity yields from the agricultural census, and average market process and farm costs. The results show that land used for vegetable production not only had the highest relative bird species richness, but also the highest profit. Land used for cereal production had the lowest relative bird species richness. This example illustrates how Species Accounts could be linked to statistics contained within a Land Account.

Links between species and agricultural statistics

Commodities	Bird species per ha	Profit per ha
Cereals	37	$4,000
Cotton	45	$2,000
Sugar cane	65	$1,100
Grazing	67	$25
Vegetables	70	$11,000

To link species data with other statistics in a meaningful way, you should identify spatially explicit indicators to inform analysis relevant to your key questions and analytical uses (Step 1). The challenge here is to mobilise statistics that can help inform sustainable ecosystem management in the context of multiple environmental and socio-economic objectives. Box 2.18 provides an example in the context of managing fisheries, agriculture, tourism and climate change impacts through an integrated biodiversity and ecosystem account for the Great Barrier Reef.

Box 2.18: Great Barrier Reef ecosystem accounts (Australian Bureau of Statistics, 2015)

Ecosystem accounts for the Great Barrier Reef explicitly describe the environmental-economic linkages between Australia's lands and coastal waters. They highlight the increasing value of agriculture during the accounting period, and the contribution of nature to agriculture as measured through resource rents – which rose from $730 million to $1,344 million. They also demonstrate the impact that these activities have on riverine and oceanic water quality, and on declining seagrass and coral reef condition.

Water, coral and seagrass quality did not change evenly across six major catchments of the Great Barrier Reef; some catchments saw stable conditions or slight improvements over the accounting period, while others saw substantial declines in condition. Particularly notable were declines in water, coral and seagrass condition following an extremely wet year with high runoff in 2010-2011. During this period, resource rent from tourism grew – from $379 million to $575 million – but rent from fishing and aquaculture declined – from $69.6 million to $18.9 million – as reef management changed due to a major rezoning of the reef in 2004, and license buy-outs and quota limitations.

The Great Barrier Reef ecosystem accounts show that the economic value of tourism has grown as the value of the fishing sector has shrunk. This is partly due to major changes in management of the reef. As in many parts of the world, the challenge of addressing non-point source runoff from agriculture and other sectors has remained elusive, and the threat of climate change to the Great Barrier Reef remains a serious challenge for this nationally and internationally important resource.

The information organised within Species Accounts can also be used to identify and track the influence of different impact drivers on ecosystem condition. For example, where a particular species or group of species is known to be sensitive to climate change impacts, the trends in the status of that species or group can be used to infer the climate change impact on the ecosystems in a given location. The associations between species or species groups and different impact drivers can be informed by empirical analysis or expert judgement. Box 2.19 provides an example of this approach based on the NI for Norway.

2.2.5.3 Expertise and capacity

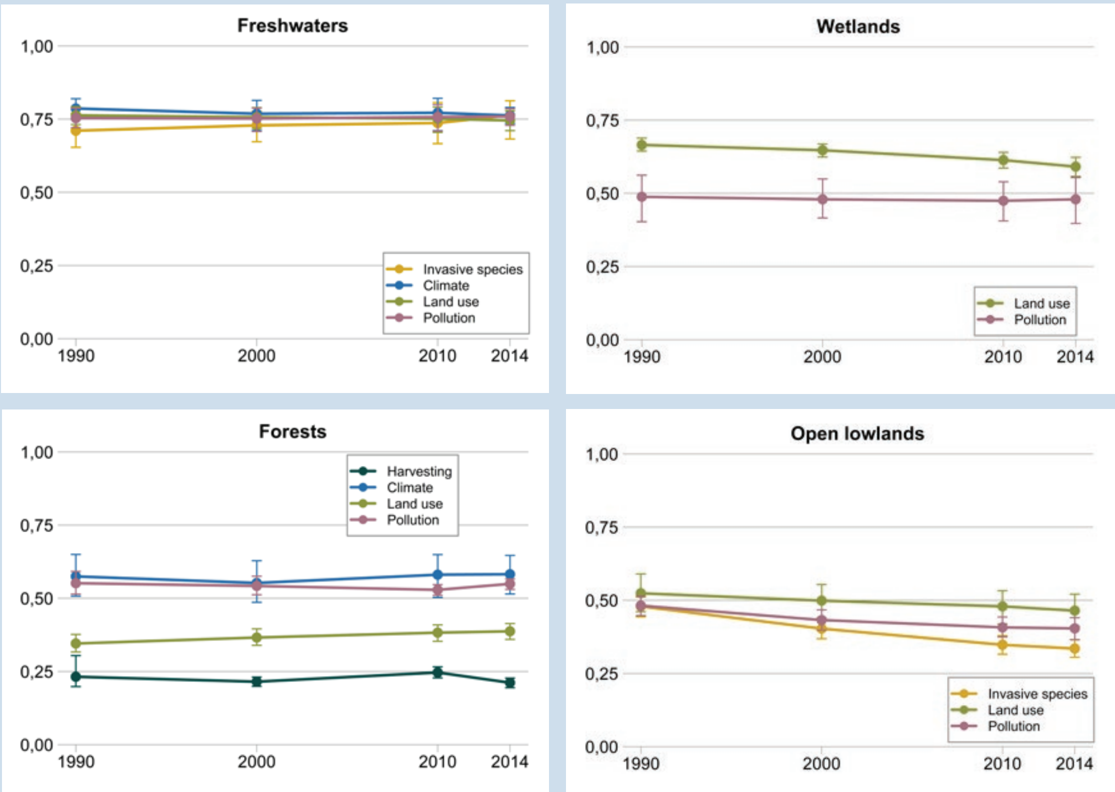
To complete Step 9, you will need:

- Ecologists and economists, and expertise in the policy context, to guide the analysis of Species Accounts and their integration with other statistics.
- Ecologists and environmental scientists to develop Ecosystem Condition Accounts and link Species Accounts with ecosystem extent.
- Economists to link species and ecosystem statistics to benefits.
- GIS, remote sensing and spatial modelling experts to spatially link species data to other ecosystem data and wider statistics.
- Statisticians and national accountants to mobilise socio-economic statistics.

Box 2.19: Trends in Nature Index (NI) indicators sensitive to impact drivers in terrestrial ecosystems and freshwaters

The condition of terrestrial ecosystems in Norway is measured via the aggregation of a number of different individual indicators (mostly species-related) within the NI. Using expert judgment, a set of individual indicators has been identified for different ecosystem types that are sensitive to the impact drivers of land use, pollution, harvesting, invasive species and climate change. Tracking trends in these indicators reveals where these different drivers are impacting on ecosystem condition.

The graphs below shows trends for an index estimated from a set of indicators that are sensitive to specific impact drivers in terrestrial ecosystems and freshwaters in Norway over time. Only indexes based on a set of at least four individual indicators, with a total weight of at least 10% in the NI in the respective ecosystems, are represented in the graphs. This graphs shows that the identified impact drivers generally have a higher impact (lower index value) on the major ecosystems of forests and open lowlands, compared to freshwaters and wetlands. The information provided on the relative impact of the different drivers can be valuable for policymakers, demonstrating the need for changes in environmental management to support ecosystem condition and biodiversity.



Trends in NI indicators sensitive to impact drivers (NINA / Statistics Norway, pers. comm.).

2.3 COMMUNICATE AND USE

2.3.1 Step 10: Communicate and use

2.3.1.1 Rationale

The purpose of Step 10 is to communicate the findings of your Species Accounts, and their integration with other statistics, to decision-makers and the wider community. You will have had significant interaction with key stakeholders and technical partners during the construction of your Species Accounts. Beyond this, knowledge of your Species Accounts, and their potential uses, is likely to be limited and may well be misunderstood. Therefore, a clear communication strategy is important in order to raise awareness of the findings and manage expectations of this experimental work (ONS, 2015). This strategy will be fundamental in maximising the policy impact of the accounts and securing support for their continuing production.

Specific outputs at the end of Step 10:

- A list of target audiences.
- A set of key messages, supporting material (e.g. summary statistics, maps, graphs, etc.), and information on uncertainty and limitations to communicate to target audiences.
- A format to communicate key messages to each target audience.

2.3.1.2 Actions

Your strategy for communicating the findings of the Species Accounts should support the key analytical uses and inform the key policy questions identified in Step 1. In order to be effective in communicating these findings, your communication strategy should be guided by clear communication goals with key audiences. Box 2.20 presents the key elements for communicating the results of ecosystem accounting proposed in the SEEA-EAA (2014).

Box 2.20: Proposed areas of work for communicating the results of ecosystem accounting (SEEA-EEA, 2014)

- Presentations that provide ecosystem accounting information as evaluated against data from the SEEA-CF, the System of National Accounts (SNA) and other sources.
- Proposing ecosystem accounting tables, dashboards, headline and composite indicators, maps and other communication tools.
- Illustrating the range of uses of ecosystem accounting information, such as the analysis of trade-offs between alternative land uses.

Identify Target Audience

2.3.1.2.1 Action A: Identify target audiences

When developing your communication strategy, you will need to identify who your target audiences are. These will include the stakeholders identified in Step 1 and involved throughout the accounting process. It will also include all persons and organisations that can influence interventions relevant to biodiversity and species stocks. This is a potentially broad audience; Ash et al. (2010) suggest this could include:

- Government (at various levels)
- Planners
- Politicians
- Researchers and analysts
- NGOs
- General public
- Schools and businesses
- Women's groups
- Indigenous peoples groups
- Media

2.3.1.2.2 Action B: Identify key messages

As a useful definition, key messages are "strategic culling of the points most relevant to each audience, presented in a way that promotes the credibility of the findings". In comparison, key findings are often more technical, and contain a fact or a figure (Ash et al., 2010).

Species Accounts are good tools for communication between researchers and decision-makers because they translate scientific data into policy-relevant information. Despite this, synthesising their content into short, relevant and specific key messages is likely to be the best way to resonate with your target audiences (Ash et al., 2010). To increase the relevance and impact of such messages, you may wish to tailor them to the different audience groups you have identified (Action A). These messages should be supported with evidence and examples, drawing on both the trends and data captured in the Species Accounts and any integration with other statistics (Step 9). Your key messages should be supported by a technical report (such as the published accounts) and may be complemented by different communication tools (Action C).

It is important that your key messages remain relevant to the uses and policy questions you identified in Step 1. However, Species Accounts are intended to provide an evidence base for decision-making, so your key messages should avoid being prescriptive of specific actions in these regards.

2.3.1.2.3 Action C: Select communication tools

In many cases, summary statistics, such as composite indicators or indices, will gain more traction than accounting tables with decision-makers and the public. There are also a number of other ways to present the results of your accounting tables in order to engage different audiences:

Graphs

You may choose to present your summary statistics as a graph based on temporal trends for your Reporting Unit(s). This readily communicates trends for conservation, ecosystem condition or ecosystem services dependent on species.

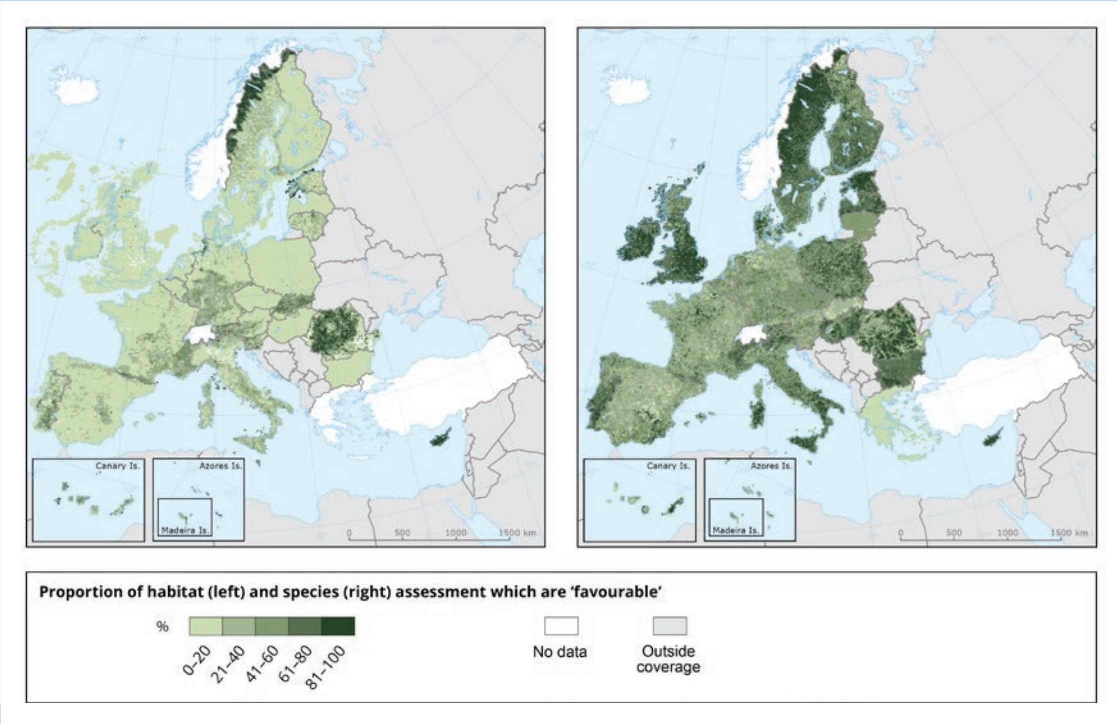
Maps

Maps are useful communication tools to show spatial trends in species, ecosystems and ecosystem services. Since most of the input data to populate the accounting tables (Step 6) will come in spatially and temporally explicit forms (possibly enhanced and harmonised due to data processing), it may be possible to construct maps to support decision-making and communication. One objective of constructing maps would be to convey the status of species generally within a country. Other objectives may include: illustrating how species hotspots or species trends are located in relation to land use, infrastructure and urban development; other drivers of species loss; or important ecosystem services – all of which, may, or may not, be in conflict with conservation measures. Box 2.21 provides examples of mapped-based analysis at the EU level with regards to the conservation status of habitats and species (EEA, 2016).

Non-specialists (i.e. excluding geographers and GIS specialists) should be aware that, while maps can be powerful communication tools, important trade-offs exist in map design and interpretation. Therefore, geographers and GIS specialists should be involved in map design and interpretation to enable their use in an objective manner (Hauck et al., 2013).

Box 2.21: Maps of species status in Europe

The map below shows an output from the Mapping and Assessment of Ecosystems and their Services (MAES) project, which mapped ecosystem condition at the EU level based on the conservation status of habitats and species. The map shows the sum of species of community importance in three European countries (extracted per 10 km resolution grid cell) followed by the number of species with decreasing and increasing abundances (assessed as trends in population size).



Proportion of habitats (left) and species (right) assessments that are favourable per grid cell (10 km spatial resolution; EEA, 2016)

Species and ecosystem service matrix
In some cases, it may be possible to use species abundance as a proxy for the delivery of specific ecosystem services. Information on such species would be organised in an account of important species for ecosystem services, or could be extracted from more holistic Species Accounts. These relationships could be summarised in a matrix, linking species to ecosystem services.

An example from the UK National Ecosystem Assessment (UK NEA, 2011) matrix is provided in Figure 2.10; it shows the importance of different species groups in underpinning final ecosystem services. Expert judgement is used to consider the link between the species group and the extent to which it supports the delivery of different ecosystem services. Information from Species Accounts could be incorporated into this matrix by including trend data (e.g. positive or negative arrows) in relevant cells. This could be used to reveal where trends in species may be expected to impact on the delivery of specific ecosystem services.

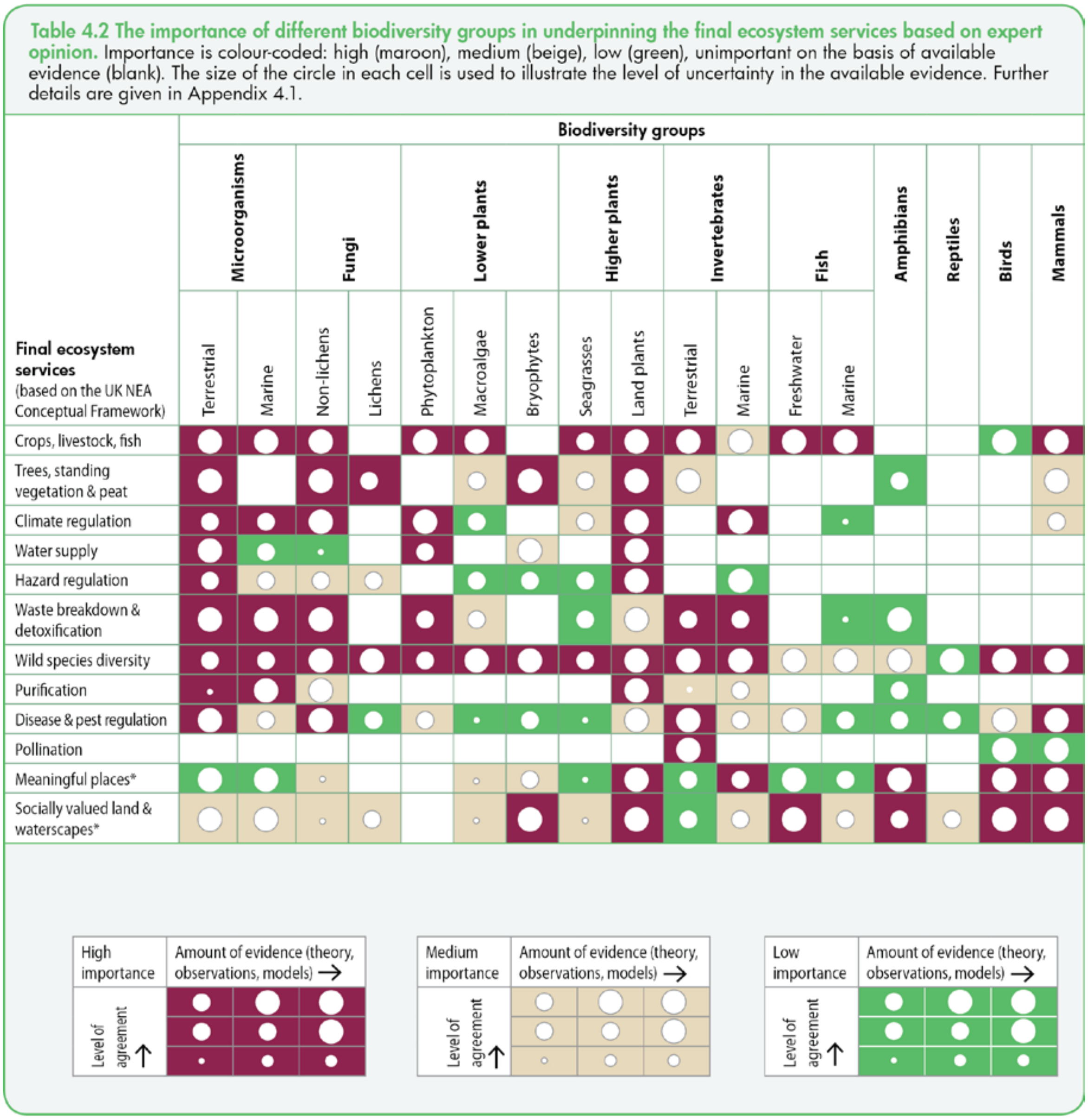


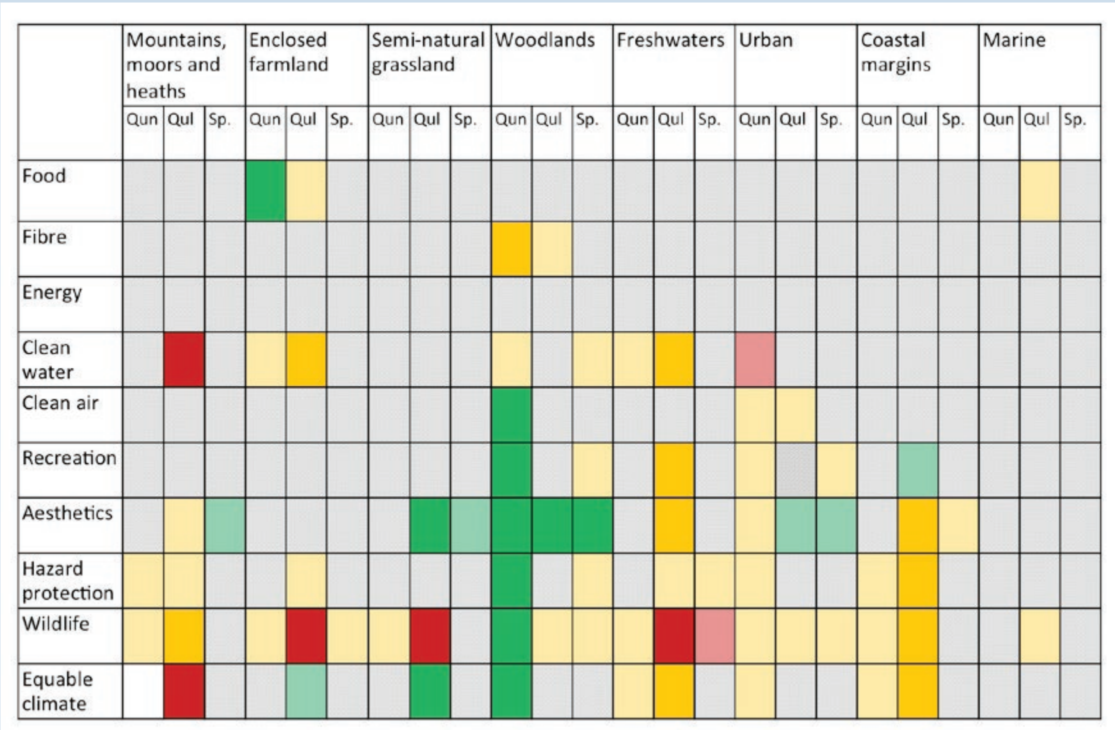
Figure 2.10: The importance of different species (biodiversity) groups in underpinning final ecosystem services, based on expert judgement (Table 4.2, UK NEA, 2011)

Risk register

The 'risk register' is related to species-ecosystem service matrices, but allows for the explicit communication of trends that infer a risk to ecosystem service delivery. The register consists of a matrix of ecosystem service benefits and the ecosystem or habitat types from which they originate. Using a traffic light approach, the matrix communicates the consequences of trends in the status of quantity, quality or spatial configuration of the ecosystem or habitat for given ecosystem service benefits. Red indicates high risk, orange medium risk and green low risk. This can be adapted for communicating species trends within ecosystems or habitats by considering them as a defining characteristic of quality. Where you have an assessment of the thresholds for species, the register can communicate the benefits at risk from approaching these (i.e. the relevant cell is coded red). The application of the risk register in the broader context of natural capital is discussed in Box 2.22.

Box 2.22: Use of the Risk Register approach in England (Mace et al., 2015)

The risk register matrix based on the eight 'broad habitat' categories (columns) from the UK NEA (2011) against benefits (rows) is presented below. It shows that seven asset-benefit relationships have been allocated as high risk (red). For example, goods and benefits at risk due to the poor quality of mountains, moors and heath habitat include clean water and equable climate (relating to carbon storage capacity).



Risk register for natural capital assets in England

Dashboards

'Dashboards' provide a snapshot of current conditions based on a set of key indicators or metrics, providing decision-makers with a range of summary statistics. A dashboard can be a useful visual tool if you are interested in communicating summary statistics on species alongside economic or social statistics. For Species Accounts constructed under separate themes (i.e. conservation, ecosystem condition and functioning, or ecosystem services), or for ones that have employed multiple approaches, a dashboard can provide an effective means of communicating the information set. The Biodiversity Indicators Dashboard (NatureServe, 2015) provides such an example.

2.3.1.2.4 Action D: Decide communication format

Having identified your target audience, and decided on your key messages, you now need to decide your communication formats. To some degree, this will be dependent on the available budget, but Ash et al. (2010) highlight some common formats:

- Tailored reports
- Summaries and/or policy briefs (short documents which include key messages and findings, alongside graphics, mainly for policymakers)
- Electronic communications (e.g. newsletters and websites)
- Workshops and meetings
- Traditional media (news, radio, TV, print)
- Non-traditional means (e.g. video, blogs, and other forms of social media)

2.3.1.2.5 Action E: Communicate uncertainty and limitations

During Step 5, you will have captured the uncertainty in the species data presented in your accounts. Where there is significant uncertainty around estimates of data, this needs to be communicated effectively, transparently and consistently (ONS, 2015). In addition, the uncertainty of distinguishing what may be natural variability in species measures from other drivers of change needs to be communicated (Magurran et al., 2010).

Uncertainty analysis can go a long way in ensuring that the composite indicators or indices you have calculated are robust and not unduly sensitive to any subjective assumptions associated with the weightings employed. Sensitivity analysis can be employed to establish which weighting assumptions drive uncertainty. It will be important to capture in your communications strategy which subjective assumptions in the weighting procedure are particularly influential. Possible options include:

- The use of simulation techniques (such as Monte Carlo analysis) to evaluate uncertainty in composite indicator or index values (Certain et al., 2011).
- The use of error propagation analysis, where all assumptions feeding into the construction are 'perturbed' as to obtain an understanding of which assumptions drive the uncertainty (Saisana et al., 2005; Saisana et al., 2011)
- Testing whether the declared importance of the index ingredients (such as sub-dimensions or variables) corresponds to their effective importance (Paruolo et al., 2012). For example, where the composite indicator or index is computed by aggregating data for different habitats for a given country, the effective weight of each habitat in the index should not be too far away from the fraction of that habitat with respect to the total area of the country.

© Kim Pin Tan / shutterstock.com

Depending on the nature of the data that is underpinning the key messages in your communication strategy, it may be possible to express confidence in the message in qualitative and quantitative terms. Qualitative assessments are based on the expert evaluation of the quality and quantity of evidence and scientific agreement (IPBES, 2016). In many cases, it will be possible to communicate confidence in quantitative terms using confidence interval or probability approaches to support key messages.

Species Accounts are intended to be used in conjunction with wider ecosystem accounts and other sources of information to communicate a coherent picture of the environment and ecosystems to decision-makers. However, they will not be able to communicate all the subtleties of biodiversity and ecosystem interactions. For example, data gaps will exist because it is not possible, or practical, to capture all species in the accounts. There will also be gaps in species information in both space and time. It is important that limitations such as these are communicated to users of the accounts.

2.3.1.3 Expertise and capacity

To complete Step 10, you will need:

- Expertise in developing communication strategies for target audiences.
- Mathematical ecologists, statisticians and/or data analysts to help establish uncertainty.

2.4 REVIEW AND REFINE

2.4.1 Step 11: Review and refine

2.4.1.1 Rationale

The purpose of Step 11 is to identify how your Species Accounts can be refined and improved. The experience you will have gained from the construction of initial Species Accounts will be fundamental to the improvement of future versions, and will be essential for ensuring their continued relevance to policy, optimising their impact, and meeting users' current and future needs. Reviewing and refining your Species Accounts may form part of the refinement process of your ecosystem accounting system in its entirety.

Specific outputs at the end of Step 11:

- A list of challenges, limitations and other issues encountered during the construction of the accounts.
- Documented feedback from stakeholders on the accounts and how user demands have been, and are being, met.
- A list of interventions to improve future versions.

2.4.1.2 Actions

Your review process should engage both technical specialists, key users of the accounts and other relevant stakeholders (identified in Step 1) in order to provide a broad range of comments that can feed into a refinement of the accounts. This refinement will be expressed as a set of 'intervention options'.

2.4.1.2.1 Action A: Review challenges, limitations and other issues

The challenges you have faced during the construction of your Species Accounts will depend on your specific circumstances. Overcoming these challenges in future versions is a natural part of the 'learning-by-doing' process. Nonetheless, a non-exhaustive discussion of potential challenges, limitations and issues you should consider in your review is provided in this action.

A common issue will be the format and availability of primary data (Vardon et al., 2015). In the initial set of accounts, it is likely that important data gaps will be encountered. These may reflect a lack of data on species, geographic or ecosystem coverage, or time series, or they may relate to accessibility and quality issues (Vardon et al., 2015). If you were unable to plug these gaps in knowledge during Step 7, you should review interventions for future collection of relevant data with key stakeholders. Furthermore, where expert judgement has contributed to the process of estimating species status, the continued improvement of primary data presents a means of addressing the long-term risks of relying solely on this type of input.

The SEEA-EEA (2014) recommends that the accounting period used across the accounts is a year. This supports alignment with economic data that are usually compiled on this basis (SEEA-EEA TR, 2015). For many species, monitoring data may not be updated on such a regular frequency. Therefore, you may wish to consider increasing the rate of data collection or making data adjustments (for example, via interpolation and forecasting) as intervention options, so that species data can be integrated with other statistics on a yearly basis.

Spatial scale is a fundamental issue in ecosystem accounting. While national or sub-national accounts will provide useful macro information on species trends, disaggregating this information in future accounts (for example, by watershed or administrative area) will allow you to better integrate the information with other statistics on ecosystems and economics. You should consider this as one of your intervention options.

Using a common reference condition provides a means of comparing stocks and trends of different species, but it does not necessarily convey that non-linear relationships and thresholds for species-level biodiversity and delivery of ecosystem services exist (Luck et al., 2009). Establishing safe thresholds for species will be useful for putting the findings of your Species Accounts in context. However, this is likely to be challenging due to significant gaps in ecological science relating to the consideration of thresholds and non-linearities (Mace et. al., 2015).

2.4.1.2.2 Action B: Review policy impact
Species Accounts are intended to provide an evidence base to inform decision-making among your key stakeholders and target audiences.

In order to understand if the accounts have policy impact, you should engage with your stakeholders using outputs from the Species Accounts. This will help you to establish whether the information summarised from your accounts is understandable, meets analytical requirements and can inform policy requirements. Any feedback from stakeholders should be clearly documented as it will allow you to prioritise intervention actions in order to improve the Species Accounts and meet users' needs. In particular, it will be important to validate the construction of composite indicators with stakeholders. They may be subjective and context-dependent, and the approach taken needs to be tested according to policy priorities and data availability.

2.4.1.2.3 Action C: List interventions to improve Species Accounts

Given that the first set of Species Accounts you construct will be experimental, there are likely to be a number of interventions for improvement that you will recommend, for instance:

- Securing the future provision of data. The ongoing production of Species Accounts will depend on the availability of suitable spatial species data that is comparable over time. This will be particularly relevant in the context of addressing important primary data gaps, and addressing frequency and scale issues you may have identified. Accordingly, you should work with relevant stakeholders to identify and secure the investments required for building institutional and technical capacity to secure the future provision of data.
- Backcasting or renewing time series data in light of new methods and data sources. When new methods and data sources become available, it becomes necessary either to backcast prior years' data to maintain the continuity of the time series, or to sacrifice temporal continuity and begin the time series afresh, at the point where the new data and methods become available.
- Revising indicators based on evolving policy needs. When policy demands evolve, it may be necessary to consider revisions to the construction of indicators generated from the accounts. However, you should be wary of adjusting the calculation approach between accounting periods as this will render the indicator incomparable over time. Accordingly, in future accounts, changes should be justified formally and kept to a minimum.

In conjunction with key stakeholders and users' of the accounts, you should, at this stage, generate a list of intervention options that will improve your Species Accounts.

2.4.1.3 Expertise and capacity

To complete Step 11, you will need:

- Economists, ecologists, statisticians, GIS experts and data analysts to contribute to the technical review process.
- Policymakers and other decision-makers to contribute to the review of the usefulness of the accounts.
- Expertise of institutions and organisations with respect to building capacity and securing investment.
- Capacity for stakeholder engagement (e.g. workshop facilitators) in order to ensure optimal stakeholder understanding and participation.

3 Conclusions and future research

This step-by-step document is intended to support those interested in developing spatial accounts of species status as standalone accounts or as part of the wider SEEA-EEA accounting process. The approach supports the construction of national or sub-national Species Accounts for species important to conservation, ecosystem condition and function, and ecosystem services. Supplementary Accounts of Red List Status and Accounts of the Extent of Important Places for Species are also proposed.

Although Species Accounts cannot address all the subtleties of biodiversity and ecosystem interactions, they can provide an insight into aggregate and spatial trends in selected species status. This will provide decision-makers with key insights, for example:

- Which species are experiencing negative trends, and in which ecosystem types and Reporting Units are these concerns the greatest?
- Which ecosystems are being degraded and their resilience compromised?
- Where do trends or status of species infer a risk to future ecosystem service provision?
- Which species of conservation concern are experiencing negative trends, and in which ecosystem types and Reporting Units are these concerns the greatest?
- Where are important habitats for species under pressure from land conversion?

In combination with spatially referenced socio-economic data and wider ecosystem accounts, Species Accounts can provide the information needed for socio-economic planning to achieve more sustainable uses of ecosystems (for example, Sustainable Development Goals 17 and 18) and conservation commitments (for example, Aichi Targets). For instance, they can reveal how species hotspots or species trends are located in relation to land use, infrastructure and urban development; other drivers of species loss; or important ecosystem services – all of which, may, or may not, be in conflict with conservation measures. This can further inform policy objectives, such as 'No Net Loss' of biodiversity and offset programmes, by spatially analysing alternative land-use scenarios with species status.

For species providing direct benefits (such as provisioning services, nature-viewing and medicinal plants), Species Accounts can be used to understand the capacity of ecosystems within Reporting Units to provide these services. Indeed, linking capacity to species-use can identify if species are being exploited sustainably. This can help to make the case for species conservation or reducing the intensity of harvesting or other activities that negatively impact on species.

Organising species information within accounts makes data readily available to a wide range of users and for various analytical uses, including identifying returns on investment in species and species-level biodiversity, trend and scenario analyses, and informing expert judgements.

The construction of composite indicators or indices as summary statistics provides a method for aggregating and communicating species trends across all scales. These can be organised alongside a suite of other indicators relevant to ecosystem condition and, ultimately, be compared with accounts related to ecosystem service provision and economic activities, such as agriculture and ecotourism.

3.1 FUTURE RESEARCH AND TESTING

Data quality and availability. This is a key issue for the construction of Species Accounts. In a large number of contexts, it is unlikely that primary data will be of sufficient coverage to generate accounts that meet the users' needs. The construction of pilot accounts, alongside other reporting requirements, may help generate momentum towards more standardised and extensive monitoring programmes. In the interim, the testing, application and use of the habitat-based methods presented in this document will reveal their usefulness in land-use management and as a means of informing policy action.

Using Species Accounts. Information organised within Species Accounts could support many key analytical uses, including: forecasting or interpolating trends; analysing scenarios (particularly the impacts of land use using habitat-based methods); comparing species status with information on economic activities and other drivers of species loss; providing objective statistics; communicating aggregated trends; revealing returns on investment; or, supporting expert assessment. Further research into the use of Species Accounts in these analyses is required, specifically in the context of informing and monitoring policy actions.

Linking species and ecosystem services. Capturing information on the importance of species to ecosystem services is challenging. This remains an area of wider research, generally. In the interim, the use of approaches like risk registers and accounting for species important for ecosystem service delivery should be tested. These tools, in conjunction with information on the direct benefits species provide (such as provisioning services), should be evaluated for their decision-making and policy impacts. Ultimately, the ambition is to link species to the economy using monetary valuation approaches via ecosystem services accounts. Further research and testing of approaches for linking species to both physical and monetary ecosystem supply and use accounts should be undertaken.

Accounting for species groups. Grouping species according to characteristics of interest can be incredibly useful. In the context of understanding functional diversity and resilience, such grouping may inform analysis of the sustainability of ecosystem service delivery. However, testing of such groupings, and associated weighting procedures, is required to appraise how such groups can be meaningfully captured in an accounting framework.

Spatial scales for species accounting. The life cycles and turnover of species in landscapes present challenges for assigning species information at finer scales. From a measurement perspective, assigning species information at the Ecosystem Unit scale is likely to prove problematic in most circumstances due to the density of monitoring required. Potentially, habitat-based methods or downscaling existing distributional data may generate data on species at the BSU scale. However, this is likely to be limited to information on habitat suitability, or may inherently suffer from error by applying average values from larger-scale assessments.

More sophisticated estimates of species status require analysis to be completed over larger scales to generate, for instance, a proportion of species retained measure. Such measures are more likely to resonate with target audiences, so moving directly to accounting for species at the Reporting Unit scale may be the most pragmatic approach in the initial phase. Further testing of the application of Species Accounts at this scale is required because it presents challenges for wider integration within the SEEA-EEA framework (testing should also consider making the link to economic agents owning and managing land via the use of cadastre information). Despite this, larger scales do present an opportunity to capture information on species that move between individual ecosystems; as such, they may be used in the context of supporting wider ecosystem accounting.

Aggregation of Species Accounts. The main purpose of populating the accounting tables is to construct information in a way that makes it possible to scale, aggregate and compare with other geographical domains. This requires that species data is consistent by type and unit both within (i.e. across columns in the table) and across Reporting Units. Given the generally heterogeneous nature of species data, and the variation in species assemblages between both ecosystems and locations, this may not be easily achievable at present. At this stage, a relative condition metric (i.e. composite indicator or index) is likely to be the most pragmatic approach to aggregating information on species. Further research into how measures of status for different species can be meaningfully aggregated in Species Accounts across species, ecosystems and geographical domains is required.

Composite indicator or index development. A number of approaches are reviewed for summarising information from Species Accounts as composite indicators or indices. While these provide a useful starting point, further testing of methods to develop ecologically sound weighting criteria and aggregation procedures is required. In particular, this should consider the aggregation of composite indicators or indices across multiple Reporting Units as a communication tool, particularly in the context of aggregation issues, such as the MAUP.

Specifying thresholds. The stock-flow model of ecosystem accounts masks the existence of thresholds or 'tipping-points' in a system, beyond which ecosystem service delivery or species' populations could collapse. Further research is required into thresholds that can be incorporated into Species Accounts in order to establish safe operating spaces for species and ecosystems, and the sustainable delivery of ecosystem services to people. Specifying a reference condition on the basis of such thresholds provides an opportunity in this regard. Further ecological research is required in order to establish a useful set of rules for setting such parameters.

Invasive species and disservices. The incorporation of invasive species and species that deliver disservices (for example, as disease vectors) should be captured in the accounting framework. One possible approach is to include such species in the accounts with negative weights where they are a threat to conservation or ecosystem condition, or indicative of disservices. Accounting for ecosystem disservices should not, however, ignore the role of natural processes that keep disservice organisms and processes in check (which themselves represent regulatory ecosystem services), and/or mitigate human exposure and vulnerability to disservices (Villa et al., 2014). Further research, development and testing of suitable approaches are required.

Distinguishing human-induced change. It will be important to be able to distinguish natural variations (i.e. additions and reductions in species status) from those associated with human impacts in the accounting table. The ideal would be to populate relevant additions and reduction rows, reflecting natural and human influences. Further research is required in these regards.

Applying big data and cloud-based modelling approaches. Given the massive amount of data being collected by satellite remote sensing (e.g. European Copernicus Programme), in situ monitoring and citizen science, along with the rise of supercomputing and cloud-based computing, the potential exists to rapidly quantify changes in species abundance and distribution across multiple taxa using spatial modelling; this will service constructing and updating Species Accounts (e.g., USGS, n.d.) Computer scientists and specialists in bioinformatics and ecoinformatics should be engaged in the process of generating species distribution and abundance data when pilot testing the construction of Species Accounts using high-performance computing methods.

The construction of Species Accounts, and their integration into decision-making, remains a highly experimental area. In consideration of this fact, it is reiterated that the approach proposed in this document requires testing, refining and validation in different contexts (for instance, in different biomes or ecoregions, in nations of different physical size, wealth and population sizes, and in data availability). As a next step in the process, it is hoped that this approach will be tested by agencies, organisations and research institutes to determine its applicability in these different contexts. This will help to determine the practicalities of implementing and integrating Species Accounts into national accounting and decision-making. It will also assist in developing guidelines on constructing Species Accounts that can be implemented in all the world's countries. Hence, feedback from users of this document will be greatly appreciated.

References

Allnutt, T., Ferrier, S., Manion, G., Powell, G., Ricketts, T., Fisher, B., Harper, G., Irwin, M., Kremen, C., Labat, J., Lees, D., Pearce, T. and Rakotondrainibe, F. (2008) A method for quantifying biodiversity loss and its application to a 50-year record of deforestation across Madagascar. Conservation Letters, 1, 173-181.

Ash, N., Blanco, H., Brown, C., Garcia, K., Henrichs, T., Lucas, N., Simpson, D. R. (2010) Stakeholder Participation, Governance, Communication, and Outreach. In Ecosystems and Human Well-being: A Manual for Assessment Practitioners. Washington DC: Island Press. http://www.unep-wcmc.org/resources-and-data/ecosystems-and-human-wellbeing--a-manual-for-assessment-practitioners

Australian Bureau of Statistics (2015) Experimental Ecosystem Accounts for the Great Barrier Reef. http://www.abs.gov.au/ausstats/abs@.nsf/papersbyTopic/FB46321B5BA1A8EACA257E2800174158?OpenDocument

Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J.-S. S., Nakashizuka, T., Raffaelli, D., and Schmid, B. (2006) Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology Letters, 9(10), 1146–1156. http://doi.org/10.1111/j.1461-0248.2006.00963.x

Barrows, C. W., Preston, K. L., Rotenberry, J. T. and Allen, M. F. (2008) Using occurrence records to model historic distributions and estimate habitat losses for two psammophilic lizards. Biological Conservation, 141, 1885-1893.

Baum, D. (2008) Reading a Phylogenetic Tree: The Meaning of Monophyletic Groups. Nature Education 1(1):190

Bello, F., Lepš, J., Lavorel, S. and Moretti, M., (2007) Importance of species abundance for assessment of trait composition: an example based on pollinator communities. Community Ecology, 8(2), pp.163-170.

Beresford, A., Buchanan, G., Donald, P., Butchart, S. H. M., Fishpool, L. D. C. and Rondinini, C. (2011) Poor overlap between the distribution of Protected Areas and globally threatened birds in Africa. Anim. Conserv. 14: 99–107.

BirdLife (n.d.) http://www.birdlife.org;

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P. (eds.) (2016) Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, Version 1.0. Gland, Switzerland: IUCN. ix + 94pp.

Bond, S., McDonald, J., and Vardon, M. (2013) Experimental Biodiversity Accounting in Australia. Paper for 19th London Group Meeting, London, UK. 12-14 November 2013. Available at: http://unstats.un.org/unsd/envaccounting/londongroup/meeting19/LG19_16_1.pdf

Bonesi, L. and Macdonald, D.W. (2004) Evaluation of sign surveys as a way to estimate the relative abundance of American mink (Mustela vison).Journal of Zoology, 262(01), pp.65-72.

Boyd, J. and Banzhaf, S. (2007) What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics,63(2), pp.616-626.

Brown, C., King, S., Ling, M., Bowles-Newark, N., Ingwall-King, L., Wilson, L., Pietilä, K., Regan, E., and Vause, J. (2016) Natural Capital Assessments at the National and Sub-national Level. UNEP-WCMC, Cambridge, UK. http://wcmc.io/natcapassessment

Bubb, P.J., Butchart, S.H.M., Collen, B., Dublin, H., Kapos, V., Pollock, C., Stuart, S.N., Vié, J-C. (2009) IUCN Red List Index - Guidance for National and Regional Use. IUCN, Gland, Switzerland. Available at: https://portals.iucn.org/library/node/9321

Bubb, P.J., Almond, R., Kapos, V., Stanwell-Smith, D. and Jenkins, M. (2010) Guidance for national biodiversity indicator development and use. Cambridge, UK: UNEP World Conservation Monitoring Centre. Available online at: http://www.bipindicators.net/LinkClick.aspx?fileticket=brn%2FLxDzLio%3D&tabid=157

Buckland, S. T., Anderson, D. R., Burnham, K. P., and Laake, J. L. (2005) Distance sampling. John Wiley and Sons, Ltd.

Butchart, S.H., Stattersfield, A.J., Bennun, L.A., Shutes, S.M., Akçakaya, H.R., Baillie, J.E., Stuart, S.N., Hilton-Taylor, C. and Mace, G.M. (2004) Measuring global trends in the status of biodiversity: Red List Indices for birds. PLoS Biol, 2(12), p.e383.

Cadotte, M.W., Cardinale, B.J. and Oakley, T.H. (2008) Evolutionary history and the effect of biodiversity on plant productivity. Proceedings of the National Academy of Sciences, 105(44), pp.17012-17017.

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., … Naeem, S. (2012) Biodiversity loss and its impact on humanity. Nature, 486(7401), 59–67. http://doi.org/10.1038/nature11148

Caro, T. (2010). Conservation by Proxy: Indicator, Umbrella, Keystone, Flagship, and Other Surrogate Species. Island Press.

CBD. (1992). Convention on Biological Diversity. Article 2: Use of terms.

Certain, G., Skarpaas, O., Bjerke, J.W., Framstad, E., Lindholm, M., Nilsen, J.E., Norderhaug, A., Oug, E., Pedersen, H.C., Schartau, A.K. and van der Meeren, G.I. (2011) The Nature Index: A general framework for synthesizing knowledge on the state of biodiversity. PLoS One, 6(4), p.e18930.

Chapman, A. D. (2005) Principles of Data Quality, version 1.0. Report for the Global Biodiversity Information Facility, Copenhagen. ISBN 87-92020-03-8. Available online at: http://www.gbif.org/orc/?doc_id=1229.

Chow, J. (2016) SEEA Experimental Ecosystem Accounting and its implementation Strategy. Presentation prepared for the Biodiversity Accounting Workshop hosted by the UNEP-World Conservation Monitoring Centre, Cambridge, UK

Chrisman, N.R. (1983). The role of quality information in the long-term functioning of a GIS. Proceedings of AUTOCART06, 2: 303-321. Falls Church, VA: ASPRS.

CI and CISIRO (2016) Peru, San Martín Case Study. Presented as Appendix B

Corsi, F., de Leeuw, J. and Skidmore, A. (2000) Modelling species distribution with GIS. Research Techniques in Animal Ecology (eds L. Boitani and T. Fuller), pp. 389-413. Columbia University Press.

Devictor V, Mouillot D, Meynard C, Jiguet F, Thuiller W, Mouquet N. (2010) Spatial mismatch and congruence between taxonomic, phylogenetic and functional diversity: the need for integrative conservation strategies in a changing world. Ecol Lett 13: 1030-1040

Díaz, S., Lavorel, S., Chapin III, F.S., Tecco, P.A., Gurvich, D.E. and Grigulis, K., (2007) Functional diversity—at the crossroads between ecosystem functioning and environmental filters. In Terrestrial ecosystems in a changing world (pp. 81-91). Springer Berlin Heidelberg.

Drielsma, M. and Ferrier, S. (2009) Rapid evaluation of metapopulation persistence in highly variegated landscapes. Biological Conservation, 142, 529-540.

Driver, A., Nel, J.L., Smith, J., Daniels, F., Poole, C.J., Jewitt, D. and Escott, B.J. (2015) Land and ecosystem accounting in KwaZulu-Natal, South Africa. Discussion document for Advancing SEEA Experimental Ecosystem Accounting Project, October 2015. South African National Biodiversity Institute, Pretoria.

EEA (2016) MAES – Mapping and assessing the condition of Europe's ecosystems: Progress and challenges http://www.eea.europa.eu/publications/mapping-europes-ecosystems

Eigenraam, M., Chua, J., Hasker, J. (2012) Land and ecosystem services: measurement and accounting in practice Ottawa, Canada http://unstats.un.org/unsd/envaccounting/londongroup/meeting18/LG18_12.pdf

Eigenraam, M., Obst, C., Ivanov, E. (2016) An ecological approach to accounting for ecosystem assets and services. Prepared for the Biodiversity Accounting Workshop hosted by the UNEP-World Conservation Monitoring Centre, Cambridge, UK

Elith, J. and Leathwick, J. R. (2009) Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology Evolution and Systematics, 40, 677-697.

Elmqvist, T., Folke, C., Nyström, M., Peterson, G. D., Bengtsson, J., Walker, B., and Norberg, J. (2003) Response diversity, ecosystem change, and resilience. Frontiers in Ecology and the Environment, 1(9), 488–494. Retrieved from http://dx.doi.org/10.1890/1540-9295(2003)001[0488:RDECAR]2.0.CO

Elmqvist, T., Maltby, E., Barker, T., Mortimer, M., Perrings, C., Aronson, J., De Groot, R., Fitter, A., Mace, G., Norberg, J. and Pinto, I.S., (2010) Biodiversity, ecosystems and ecosystem services.(TEEB, Chapter 2)

Emmett B.E. and the GMEP team (2015) Glastir Monitoring and Evaluation Programme. Second Year Annual Report to Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology and Hydrology (CEH Project: NEC04780) Available at: https://gmep.wales/

European Union. (2014) Mapping and Assessment of Ecosystems and their Services - Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Available at: http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/2ndMAESWorkingPaper.pdf (Accessed: 16 June 2015)

Faith, D.P. (1992) Conservation evaluation and phylogenetic diversity. Biological conservation, 61(1), pp.1-10.

Faith D.P. (2008) Phylogenetic diversity and conservation. S.P. Carroll and C. Fox (ed). Conservation Biology: Evolution in Action. Oxford University Press: New York.

Faith, D., Ferrier, S. and Williams, K. (2008) Getting biodiversity intactness indices right: ensuring that 'biodiversity' reflects 'diversity'. Global Change Biology, 14, 207-217.

Ferrier, S., Powell, G., Richardson, K., Manion, G., Overton, J., Allnutt, T., Cameron, S., Mantle, K., Burgess, N., Faith, D., Lamoreux, J., Kier, G., Hijmans, R., Funk, V., Cassis, G., Fisher, B., Flemons, P., Lees, D., Lovett, J. and Van Rompaey, R. (2004) Mapping more of terrestrial biodiversity for global conservation assessment. BioScience, 54, 1101-1109.

Ferrier, S. and Guisan, A. (2006) Spatial modelling of biodiversity at the community level. Journal of Applied Ecology, 43, 393-404.

Ferrier, S., Manion, G., Elith, J. and Richardson, K. (2007) Using generalized dissimilarity modelling to analyse and predict patterns of beta diversity in regional biodiversity assessment. Diversity and Distributions, 13, 252-264.

Ferrier, S., Faith, D., Arponen, A. and Drielsma, M. (2009) Community-level approaches to spatial conservation prioritization. Spatial Conservation Prioritization: Quantitative Methods and Computational Tools (eds A. Moilanen, H. Possingham and K. Wilson). Oxford University Press.

Ferrier, S. (2011) Extracting more value from biodiversity change observations through integrated modeling. Bioscience, 61, 96-97.

Fleishman, E., Jonsson, B.G. and Sjögren-Gulve, P. (2000) Focal species modeling for biodiversity conservation. Ecological Bulletins, pp.85-99.

Gallai, N., Salles, J. M., Settele, J., and Vaissière, B. E. (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological economics, 68(3), 810-821.

Gaston, K. J., Blackburn, T. M., Greenwood, J. J., Gregory, R. D., Quinn, R. M., and Lawton, J. H. (2000) Abundance–occupancy relationships. Journal of Applied Ecology, 37(s1), 39-59.

GBIF secretariat (n.d.) GBIF participation. Available at: http://www.gbif.org/participation/membership (Accessed: 20 May 2015)

GBIF secretariat (n.d.b) http://www.gbif.org/newsroom/news/data-licensing-and-endorsement

Giam, X. L., Sodhi, N. S., Brook, B. W., Tan, H. T. W. and Bradshaw, C. J. A. (2011) Relative need for conservation assessments of vascular plant species among ecoregions. Journal of Biogeography, 38, 55-68.

Great Elephant Census (n.d.) http://www.greatelephantcensus.com/

Guisan, A., Broennimann, O., Engler, R., Vust, M., Yoccoz, N.G., Lehmann, A. and Zimmermann, N.E. (2006) Using niche-based models to improve the sampling of rare species. Conservation biology, 20(2), pp.501-511.

Guisan, A., Tingley, R. and Baumgartner, J. B. (2013) Predicting species distributions for conservation decisions. Ecology Letters, 16, 1424-1435.

Haddon, M. (2010). Modelling and quantitative methods in fisheries. CRC press

Han, X., Smyth, R.L., Young, B.E., Brooks, T.M., Sánchez de Lozada, A., Butchart, S.H.M., Larsen, F.W., Rodrigues, A.S.L. and Turner, W.R. (2014) A biodiversity indicators dashboard: addressing challenges to monitoring progress towards the Aichi biodiversity targets using disaggregated global data. PloS ONE 9: e112046.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O. and Townshend, J. R. G. (2013) High-resolution global maps of 21st-Century forest cover change. Science, 342, 850-853.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N. and Geertsema, W. (2014) Linkages between biodiversity attributes and ecosystem services: a systematic review. Ecosystem Services, 9, pp.191-203.

Hooper, D.U., Chapin III, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer, J., Wardle, D.A. (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75(1): 3–35.

Hörandl, E. and Stuessy, T.F., (2010) Paraphyletic groups as natural units of biological classification. Taxon, pp.1641-1653.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., Maes, J., Wittmer, H. and Jax, K. (2013) "Maps have an air of authority": potential benefits and challenges of ecosystem service maps at different levels of decision making. Ecosystem Services, 4, pp.25-32.

IBAT (n.d) The Integrated Biodiversity Assessment Tool (IBAT) for Research and Conservation Planning https://www.ibat-alliance.org/ibat-conservation/login [Accessed 20/04/16]

IPBES (2016) Guide on production and integration of assessments from and across all scales. IPBES Deliverable 2(a). Available online at: http://www.ipbes.net/sites/default/files/downloads/IPBES_3_INF_4.pdf

IUCN (n.d.) http://www.iucnredlist.org

IUCN Standards and Petitions Subcommittee (2016) Guidelines for Using the IUCN Red List Categories and Criteria. Version 12. Prepared by the Standards and Petitions Subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

IUCN (2016b) A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition. Gland, Switzerland: IUCN. http://media.wix.com/ugd/6cb462_e07b0dc7cae644a7aacaa2c330df9039.pdf

Ivanov, E.D., Weber, J.-L., Spyropoulou, R., Haines-Young, R., and Potschin, M. (2013) Developing an accounting method for species and habitats of European conservation importance. CEM Working Paper No 11_Version 3.0, 20 pp.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J. and Warner, R.R. (2001) Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Jetz, W., McPherson, J. M. and Guralnick, R. P. (2012) Integrating biodiversity distribution knowledge: toward a global map of life. Trends in Ecology and Evolution, 27, 151-159.

Keith, D. A., Orscheg, C., Simpson, C. C., Clarke, P. J., Hughes, L., Kennelly, S. J., Major, R. E., Soderquist, T. R., Wilson, A. L. and Bedward, M. (2009) A new approach and case study for estimating extent and rates of habitat loss for ecological communities. Biological Conservation, 142, 1469-1479.

Kellert, S.R. (1997). The Value of Life: Biological Diversity and Human Society. Island Press, Washington D.C.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunnigham, S.A., Kremen, C., Tscharntke, T. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society 274, 303–313.

Kunz, T.H., Braun de Torrez, E., Bauer, D., Lobova, T. and Fleming, T.H. (2011) Ecosystem services provided by bats. Annals of the New York Academy of Sciences, 1223(1), pp.1-38.

Lamb, E.G., Bayne, E., Holloway, G., Schieck, J., Boutin, S., Herbers, J., Haughland, D.L. (2009) Indices for monitoring biodiversity change: are some more effective than others? Ecol. Indic. 9, 432–444.

Langhammer, P.F. (2007) Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems (No. 15). IUCN.

Lavorel, S., Díaz, S., Cornelissen, J.H.C., Garnier, E., Harrison, S.P., McIntyre, S., Pausas, J.G., Pérez-Harguindeguy, N., Roumet, C. and Urcelay, C., (2007). Plant functional types: are we getting any closer to the Holy Grail?. In Terrestrial ecosystems in a changing world (pp. 149-164). Springer Berlin Heidelberg.

Leathwick, J., Moilanen, A., Ferrier, S. and Julian, K. (2010) Complementarity-based conservation prioritization using a community classification, and its application to riverine ecosystems. Biological Conservation, 143, 984-991.

Loh, J., Green, R.E., Ricketts, T., Lamoreux, J., Jenkins, M., Kapos, V. and Randers, J. (2005) The Living Planet Index: using species population time series to track trends in biodiversity. Philosophical Transactions of the Royal Society of London B: Biological Sciences, 360(1454), pp.289-295.

Luck, G. W., Daily, G. C., and Ehrlich, P. R. (2003) Population diversity and ecosystem services. Trends in Ecology & Evolution, 18(7), 331-336.

Lung, T., Peters, M. K., Farwig, N., Bohning-Gaese, K. and Schaab, G. (2012) Combining long-term land cover time series and field observations for spatially explicit predictions on changes in tropical forest biodiversity. International Journal of Remote Sensing, 33, 13-40.

McDonald, J. (2011) Key concepts for accounting for biodiversity (Prepared for the Technical Expert Meeting on Ecosystem Accounts on 5th December 2011). London, UK. http://unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue6_Aus.pdf

Mace, G.M., Gittleman, J.L. and Purvis, A. (2003) Preserving the tree of life. Science, 300, 1707–1709.

Mace, G. M. (2005) Biodiversity: an index of intactness. Nature, 434, 32-33.

Mace, G. M., Norris, K., and Fitter, A. H. (2012) Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology & Evolution, 27(1), 19–26.

Mace, G.M., Hails, R.S., Cryle, P., Julian, H., Clarke, S.J. (2015) Towards a risk register for natural capital Journal of Applied Ecology, 52 (3). 641-653. doi: 10.1111/1365-2664.12431.

Mackey, B. G., Berry, S. L. and Brown, T. (2008) Reconciling approaches to biogeographical regionalization: a systematic and generic framework examined with a case study of the Australian continent. Journal of Biogeography, 35, 213-229.

McRae, L., Loh. J., Bubb, P.J., Baillie, J.E.M., Kapos, V., and Collen, B. (2008) The Living Planet Index - Guidance for National and Regional Use. UNEP-WCMC, Cambridge, UK.

Maestre, F.T., Quero, J.L., Gotelli, N.J., Escudero, A., Ochoa, V., Delgado-Baquerizo, M., García-Gómez, M., Bowker, M.A., Soliveres, S., Escolar, C. and García-Palacios, P. (2012) Plant species richness and ecosystem multifunctionality in global drylands. Science, 335(6065), pp.214-218.

Magurran, A.E., Baillie, S.R., Buckland, S.T., Dick, J.M., Elston, D.A., Scott, E.M., Watt, A.D. (2010) Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends in Ecology & Evolution, 25(10), 574–82.

Martinez, S. and Mollicone, D. (2012) From Land Cover to Land Use: A Methodology to Assess Land Use from Remote Sensing Data. Remote Sensing, 4, 1024-1045.

Martín-López, B., Montes, C., Benayas, J. (2007) The non-economic motives behind the willingness to pay for biodiversity conservation. Biological Conservation, 139 (1–2), 67–82.

Maunder, M. N., and Punt, A. E. (2004) Standardizing catch and effort data: a review of recent approaches. Fisheries Research, 70(2), 141-159

Millennium Ecosystem Assessment (MA) (2005a) Ecosystem assessment: Ecosystems and human wellbeing. Current state and trends. Washington D.C.

Millennium Ecosystem Assessment (MA) (2005b) Ecosystems and Human Well-being: Policy Responses - Appendix. World Resources Institute, Washington, DC. Available at: http://www.millenniumassessment.org/documents/document.776.aspx.pdf (Accessed: 16 June 2015).

Millennium Ecosystem Assessment (MA) (2005c) Hassan R, Scholes R, Ash N (eds). Millenium Ecosystem Assessment: Ecosystems and Human Wellbeing, Volume 1, Current State and Trends. Island Press, Washington, DC. Available at: http://www.millenniumassessment.org/en/Condition.html

Mills, L.S., Soulé, M.E. and Doak, D.F. (1993) The keystone-species concept in ecology and conservation. BioScience, 43(4), pp.219-224.

Moldan, B., Hak, T. , Kovanda, J., Havranek, M. and Kuskova, P. (2004) Composite Indicators of Environmental Sustainability. OECD 2004.

Mori, A. S., Furukawa, T., and Sasaki, T. (2013) Response diversity determines the resilience of ecosystems to environmental change. Biological Reviews, 88(2), 349–364. http://doi.org/10.1111/brv.12004

National Red List (2012) Available at: http://www.nationalredlist.org/home/about/

Natureserve (2015) The Biodiversity Indicators dashboard. About the dashboard. [Accessed 22/04/16] http://dashboard.natureserve.org/faq-page

Nel, J.L. and Driver, A. (2015) National River Ecosystem Accounts for South Africa. Discussion document for Advancing SEEA Experimental Ecosystem Accounting Project, October 2015. South African National Biodiversity Institute, Pretoria.

Newbold, T., Hudson, L. N., Hill, S. L. L., Contu, S., Lysenko, I., Senior, R. A., Borger, L., Bennett, D. J., Choimes, A., Collen, B., Day, J., De Palma, A., Diaz, S., Echeverria-Londono, S., Edgar, M. J., Feldman, A., Garon, M., Harrison, M. L. K., Alhusseini, T., Ingram, D. J., Itescu, Y., Kattge, J., Kemp, V., Kirkpatrick, L., Kleyer, M., Correia, D. L. P., Martin, C. D., Meiri, S., Novosolov, M., Pan, Y., Phillips, H. R. P., Purves, D. W., Robinson, A., Simpson, J., Tuck, S. L., Weiher, E., White, H. J., Ewers, R. M., Mace, G. M., Scharlemann, J. P. W. and Purvis, A. (2015) Global effects of land use on local terrestrial biodiversity. Nature, 520, 45-NIL_86.

Nichols, E., Spector, S., Louzada, J., Larsen, T., Amezquita, S., Favila, M.E. and Network, T.S.R. (2008) Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. Biological conservation,141(6), pp.1461-1474.

NINA (n.d.) The Norweguian Nature Index http://www.nina.no/english/Environmental-monitoring/The-Norwegian-Nature-Index

ONS (2015) Natural capital accounting 2020 roadmap: Interim review and forward look. Office for National Statistics. London UK. Available online at: http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/environmental/uk-natural-capital/natural-capital-accounting-2020-roadmap--interim-review-and-forward-look/index.html

Paine, R.T., (1995) A conversation on refining the concept of keystone species. Conservation Biology, 9(4), 962-964

Pannekoek, J. and van Strien, A.J. (1996) TRIM – Trends & Indices for Monitoring Data. Research Paper No. 9634, Statistics Netherlands, Voorburg

Parkes, D., Newell, G. and Cheal, D. (2003. Assessing the quality of native vegetation: the 'habitat hectares' approach. Ecological Management & Restoration, 4(s1), pp.S29-S38.

Paruolo, P., Saisana, M. and Saltelli, A. (2013) Ratings and rankings: voodoo or science? Journal of the Royal Statistical Society: Series A (Statistics in Society), 176(3), pp.609-634.

Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., Verma, M., Armsworth, P., Christie, M., Cornelissen, H., Eppink, F. and Farley, J. (2010) Chapter 5: The economics of valuing ecosystem services and biodiversity. In: TEEB (The Economics of Ecosystems and Biodiversity) (2010). The economics of ecosystems and biodiversity ecological and economic foundations. Edited by Pushpam Kumar. Earthscan, London and Washington

Pe'er, I. (2015) Israel Butterflies Monitoring Scheme. Available at: http://eubon-ipt.gbif.org/resource?r=butterflies-monitoring-scheme-il (Accessed 20 May 2015)

Pearce, J., Cherry, K., Drielsma, M., Ferrier, S. and Whish, G. (2001) Incorporating expert opinion and fine-scale vegetation mapping into statistical models of faunal distribution. Journal of Applied Ecology, 38, 412-424.

Pereira, H. M. and Cooper, H. D. (2006) Towards the global monitoring of biodiversity change. Trends in Ecology & Evolution, 21, 123-129.

Pereira, H. M. and Daily, G. C. (2006) Modeling biodiversity dynamics in countryside landscapes. Ecology, 87, 1877-1885.

Petchey, O.L. and Gaston, K.J., (2006) Functional diversity: back to basics and looking forward. Ecology letters, 9(6), pp.741-758.

Phillips, S. J., Anderson, R. P. and Schapire, R. E. (2006) Maximum entropy modeling of species geographic distributions. Ecological Modelling 190, 231–259.

Pindilli, E. and Casey, F., (2015) Biodiversity and habitat markets—Policy, economic, and ecological implications of market-based conservation: U.S. Geological Survey Circular 1414, 60 p., http://dx.doi.org/10.3133/cir1414.

Pollock, K. H. (1991) Review papers: modeling capture, recapture, and removal statistics for estimation of demographic parameters for fish and wildlife populations: past, present, and future. Journal of the American Statistical Association, 86(413), 225-238

Power, M.E., Tilman, D., Estes, J.A., Menge, B.A., Bond, W.J., Mills, L.S., Daily, G., Castilla, J.C., Lubchenco, J. and Paine, R.T. (1996) Challenges in the quest for keystones. BioScience, 46(8), pp.609-620.

Proenca, V. and Pereira, H. M. (2013) Species-area models to assess biodiversity change in multi-habitat landscapes: The importance of species habitat affinity. Basic and Applied Ecology, 14, 102-114.

Rios-Munoz, C. A. and Navarro-Siguenza, A. G. (2009) Effects of land use change on the hypothetical habitat availability for Mexican parrots. Ornitologia Neotropical, 20, 491-509.

Roberge, J. M., and Angelstam, P. (2004). Usefulness of the Umbrella Species Concept as a Conservation Tool. Conservation Biology, 18(1), 76–85. doi:10.1111/j.1523-1739.2004.00450.x

Rodrigues, A.S., Brooks, T.M., Butchart, S.H., Chanson, J., Cox, N., Hoffmann, M. and Stuart, S.N., (2014). Spatially explicit trends in the global conservation status of vertebrates. PloS one, 9(11), p.e113934.

Rondinini, C., Wilson, K. A., Boitani, L., Grantham, H., and Possingham, H. P. (2006) Tradeoffs of different types of species occurrence data for use in systematic conservation planning. Ecology Letters, 9(10), 1136–1145. doi:10.1111/j.1461-0248.2006.00970.x

Saisana, M., Saltelli, A. and Tarantola, S. (2005) Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite indicators. Journal of the Royal Statistical Society: Series A (Statistics in Society), 168(2), pp.307-323.

Saisana, M., D'Hombres, B., and Saltelli, A. (2011) Rickety numbers: Volatility of university rankings and policy implications. Research Policy 40, 165–177.

Saltelli, A. (2007) Composite indicators between analysis and advocacy. Social Indicators Research. 81:65-77

Sayre, R., Dangermond, J., Frye, C., Vaughan, R., Aniello, P., Breyer, S., Cribbs, D., Hopkins, D., Nauman, R., Derrenbacher, W., Wright, D., Brown, C., Convis, C., Smith, J., Benson, L., Paco VanSistine, D., Warner, H., Cress, J., Danielson, J., Hamann, S., Cecere, T., Reddy, A., Burton, D., Grosse, A., True, D., Metzger, M., Hartmann, J., Moosdorf, N., Dürr, H., Paganini, M., DeFourny, P., Arino, O., Maynard, S., Anderson, M. and Comer, P. (2014) A New Map of Global Ecological Land Units - An Ecophysiographic Stratification Approach. Association of American Geographers, Washington, DC. http://www.aag.org/galleries/default-file/AAG_Global_Ecosyst_bklt72.pdf.

Scholes, R. J. and Biggs, R. (2005) A biodiversity intactness index. Nature, 434, 45-49.

Schröter, M., Remme, R.P., Sumarga, E., Barton, D.N. and Hein, L. (2015) Lessons learned for spatial modelling of ecosystem services in support of ecosystem accounting. Ecosystem Services, 13, pp.64-69.

SEEA CF (2014) System of Environmental-Economic Accounting 2012: Central Framework; New York: United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development, the World Bank. Available at: http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf

SEEA-EEA (2014) System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting; New York: United Nations, European Commission, Food and Agriculture Organisation of the United Nations, Organisation for Economic Co-operation and Development, World Bank Group. Available at: http://unstats.un.org/unsd/envaccounting/seeaRev/eea_final_en.pdf

SEEA-EEA TR (2015) SEEA Experimental Ecosystem Accounting: Technical Recommendations Consultation Draft – December 2015;. Prepared as part of the joint UNEP / UNSD / CBD project on Advancing Natural Capital Accounting funded by NORAD. Available at: http://unstats.un.org/unsd/envaccounting/ceea/meetings/eleventh_meeting/BK-11-3b-2.pdf

Semmens, D.J., Diffendorfer, J.E., López-Hoffman, L. and Shapiro, C.D. (2011) Accounting for the ecosystem services of migratory species: quantifying migration support and spatial subsidies. Ecological Economics,70(12), pp.2236-2242.

Soberon, J. and Peterson, A. T. (2009) Monitoring Biodiversity Loss with Primary Species-occurrence Data: Toward National-level Indicators for the 2010 Target of the Convention on Biological Diversity. Ambio, 38, 29-34.

Souza, D. M., Teixeira, R. F. M. and Ostermann, O. P. (2015) Assessing biodiversity loss due to land use with Life Cycle Assessment: are we there yet? Global Change Biology, 21, 32-47.

Spurr, E. B. (2012) New Zealand Garden Bird Survey – analysis of the first four years. New Zealand Journal of Ecology. (2012) 36(3)

Statistics Canada (2009) Statistics Canada Quality Guidelines. fifth ed. Statistics Canada, Ottawa. Available at: http://www.statcan.gc.ca/pub/12-539-x/12-539-x2009001-eng.pdf

Stiglitz, J. E., Sen, A. and Fitoussi, J. (2009). Report by the commission on the measurement of economic performance and social progress. Technical report, www.stiglitz-sen-fitoussi.fr.

Sundstrom, S.M., Allen, C.R. and Barichievy, C. (2012) Species, functional groups, and thresholds in ecological resilience. Conservation Biology, 26(2), pp.305-314.

Swenson NG (2009) Phylogenetic Resolution and Quantifying the Phylogenetic Diversity and Dispersion of Communities. PLoS ONE 4(2): e4390. doi:10.1371/journal.pone.0004390

Tilman, D., Reich, P. B., and Knops, J. M. H. (2006) Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature, 441(7093), 629–632. http://doi.org/10.1038/nature04742

Tracewski, L., Butchart, S. H. M., Di Marco, M., Ficetola, G. F., Rondinini, C., Symes, A., Wheatley, H., Beresford, A. E. and Buchanan, G. M. (2016) Impact of 21st century deforestation on the extinction risk of terrestrial vertebrates. Conserv. Biol. DOI: 10.1111/cobi.12715

Turak, E., Ferrier, S., Barrett, T., Mesley, E., Drielsma, M., Manion, G., Doyle, G., Stein, J. and Gordon, G. (2011) Planning for the persistence of river biodiversity: exploring alternative futures using process-based models. Freshwater Biology, 56, 39-56.

Turner, K.T., Paavola, J., Cooper, P., Farber, S., Jessamy, V., and Georgiu, S. (2003) Valuing nature: lessons learned and future research directions. Ecological Economics 46: 493–510.

UK National Ecosystem Assessment (2011) The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge. http://uknea.unep-wcmc.org/

UN (1992) Definition of genetic diversity. Available at: http://unterm.un.org/dgaacs/unterm.nsf/8fa942046ff7601c85256983007ca4d8/f30166c209bfdd9985256a0100530346?OpenDocument. (Accessed 15 May 2015)

UNEP (2014) Using Indicators for Green Economy Policymaking. http://web.unep.org/greeneconomy/sites/unep.org.greeneconomy/files/publications/unep_indicators_ge_for_weben.pdf

UNEP-WCMC (2015) Experimental Biodiversity Accounting as a component of the System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA-EEA). Supporting document to the Advancing the SEEA Experimental Ecosystem Accounting project. United Nations. Available at: http://www.unep-wcmc.org/news/guidance-on-experimental-biodiversity-accounting-using-the-seea-eea-framework

UNEP-WCMC (2016) Feasibility Study for Biodiversity Accounting in Uganda. Cambridge, UK

USGS (n.d.) National Gap Analysis Program (GAP): Species data portal. http://gapanalysis.usgs.gov/species/data

USGS (2015) North American Bat Monitoring Program. Retrieved from: https://www.fort.usgs.gov/science-tasks/2457 (accessed 20 May 2015)

Van Strien, A.J., Soldaat, L.L. and Gregory, R.D. (2012) Desirable mathematical properties of indicators for biodiversity change. Ecological indicators, 14(1), pp.202-208.

Vardon, M. (2012) Lessons from environmental accounting for improving biodiversity monitoring. In: Biodiversity Monitoring in Australia (eds D. B. Lindenmayer and P. Gibbons) pp. 79–88. CSIRO Publishing, Melbourne.

Vardon, M. Lindenmayer, D., Keith, H., Ferrier, S. and Gibbons, P. (2015) Progress, challenges and opportunities for biodiversity accounting. Paper for 21st London Group Meeting, The Hague, Netherlands. 2-4 November 2015. Available at: http://unstats.un.org/unsd/envaccounting/londongroup/meeting21/Vardon%20et%20al_Biodiveristy%20Accounting%20for%20LG%20(reduced).pdf

Vardon, M., Burnett, P. and Dovers, S., (2016) The accounting push and the policy pull: balancing environment and economic decisions. Ecological Economics, 124, pp.145-152.

Villa, F., Bagstad, K.J., Voigt, B., Johnson, G.W., Athanasiadis, I.N. and Balbi, S., (2014) The misconception of ecosystem disservices: how a catchy term may yield the wrong messages for science and society. Ecosystem Services, (10), pp.52-53.

Wagg, C., Bender, S.F., Widmer, F. and van der Heijden, M.G. (2014) Soil biodiversity and soil community composition determine ecosystem multifunctionality. Proceedings of the National Academy of Sciences,111(14), pp.5266-5270.

Watson, J., Freudenberger, D. and Paull, D. (2001) An assessment of the focal-species approach for conserving birds in variegated landscapes in southeastern Australia. Conservation Biology 15:1364–1373.

Wenny, D.G., Devault, T.L., Johnson, M.D., Kelly, D., Sekercioglu, C.H., Tomback, D.F. and Whelan, C.J. (2011) The need to quantify ecosystem services provided by birds. The auk, 128(1), pp.1-14.

WWF. (n.d.). Ecosystem diversity. Available at: http://www.wwf.org.au/our_work/saving_the_natural_world/what_is_biodiversity/ecosystem_diversity/ (Accessed: 16 June 2015)

Appendix A: Case study of national Species Accounts for Wales

Bridget A. Emmett and Simon Smart (Centre for Ecology and Hydrology) and Gavin Siriwardena (British Trust for Ornithology)

The Species Accounts presented here provide an initial attempt at exploring the approach set out in this document in order to help inform other organisations and countries about the issues identified during the process. No values or approaches taken should be seen as approved or ready to be cited in any capacity.

Wales has put the sustainable management of natural resources at the heart of its policy agenda to ensure the delivery of its constitutional commitment to sustainable development. The Environment (Wales) Act was passed in 2016 and commits Wales to managing its natural resources in a way, and at a rate, that can maintain and enhance the resilience of our ecosystems. It also ensures that management options meet the needs of the present generation, without compromising the ability of future generations to meet their own needs and contribute to the achievement of well-being goals. These goals are defined in the Well-being of Future Generations (Wales) Act 2015, which aims to deliver a prosperous economy, a healthy and resilient environment, and vibrant and cohesive communities.

Critically, the Environment (Wales) Act provides an integrated approach, considering both the benefits received from ecosystems, and the resilience of those ecosystems. Previous UK, EU and International legislation did not always offer such an approach, with individual resources and issues often being dealt with in silos, such as the EU Water Framework Directive, EU Habitats Directive and Aichi targets, and the UN framework Convention on Climate Change. However, the policies put in place in Wales will effectively ensure delivery of the new domestic legislation, as well as existing UK and international commitments.

Step 1. Define uses and users

This new domestic legislation requires the definition of a resilient ecosystem; in Wales, a resilient ecosystem is considered to be one that is healthy and functions in a way that it is able to tolerate pressures and address the demands placed on it, whilst remaining able to deliver benefits and services over the long term that meet social, economic and environmental needs. Translating this into practical ecosystem attributes that can be effectively and efficiently monitored over time required a review of the current knowledge regarding ecosystem resilience. Four key attributes whose measurement can be used to characterise the resilience of ecosystems were identified. These were considered likely to lead to the desired emergent property of 'ecosystem adaptability':

- Diversity between and within ecosystems
- Connections between and within ecosystems
- Scale or extent of ecosystems
- Condition of ecosystems (including their structure and functioning)

Natural Resources Wales, the environmental agency in Wales responsible for managing natural resources, is delivering a State of Natural Resources Report (SoNaRR) every five years. Progress towards the sustainable management of natural resources and the attributes that underpin ecosystem resilience will be captured in this reporting system. The SoNaRR will also provide an essential evidence base for the National Natural Resource Policy, which sets out the priorities for the sustainable management of natural resources at a national level. This policy moves beyond simply protecting natural resources, to enhancing both these resources and ecosystem resilience, thus providing benefits to society and the economy, as well as the environment.

This case study explores the potential value of developing terrestrial Species Accounts to track changes in species of conservation concern, and species important for ecosystem condition and functioning in order to inform future SoNaRR reporting and a range of other domestic, UK and international reporting requirements. Wales is an example of a data-rich country; major investment since 2012 has helped to develop a national integrated monitoring programme for tracking change in terrestrial natural resources and the impact of payments to land managers for environmental outcomes called the Glastir Monitoring and Evaluation Programme (GMEP, www.gmep.wales) (Emmett et al., 2015).

GMEP provides a rich source of potential data with which to populate Species Accounts due to the co-location of different species observation data capturing a wide range of ecosystem extent and condition information from a random sample (stratified according to land cover and policy priorities) of survey areas (1 km squares). This is combined with data from a range of independent, taxa-specific monitoring programmes and modelling activities to allow comparison across the time series, and forecasting, in order to capture ongoing change in a wide range of natural resources in Wales; this is all reported on the GMEP data portal. GMEP is operated over a four-year rolling cycle, providing data on changes in species and ecosystems that links with historical and ongoing change data from a range of other UK-wide initiatives, including:

- Countryside Survey http://www.countrysidesurvey.org.uk/
- National Forest Inventory http://www.forestry.gov.uk/forestry/beeh-a2shkn
- BTO/JNCC/RSPB Breeding Bird Survey (BBS) https://www.bto.org/volunteer-surveys/bbs
- UK Butterfly Monitoring Scheme http://www.ukbms.org/

Other sources of biodiversity data are available and have been combined to form the UK Biodiversity Indicator (http://jncc.defra.gov.uk/page-1824) but data limitations have not, as yet, enabled a similar indicator to be established for Wales.

Step 2. Select species of special concern and scope data

The policy priorities for Wales clearly require consideration of species beyond those important for conservation alone, to ensure tracking of species important for ecosystem resilience and condition and the resulting benefits. The approach developed in this document encourages this broader application of species importance, so is highly suitable for policy requirements in Wales. The selection of species in these accounts builds on work undertaken in 2015 with the GMEP stakeholder group to develop a range of biodiversity and other ecosystem indicators for national-scale reporting. Unfortunately, time constraints did not allow further consultation and refinement of the trial Species Accounts, but the work was informed by the many discussions currently ongoing in Wales to develop objective and transparent indicators to track the progress of new policy initiatives.

As the selection of species was being discussed, various issues and concerns were raised, including:

- Lags in the response of some species to habitat improvement and extent change.
- The highly variable spatial and temporal dynamics of different species, which could be lost in an aggregated account.
- Some species have multiple roles; for example, raptors are important to ecosystem functioning in their role as apex predators, but their presence is also indicative of condition, and some species may be of conservation concern.
- Some species are a positive attribute of ecosystem health in certain ecosystems but a negative indicator in others; for instance, heather is a positive attribute in moorland, but a negative one in blanket bog.
- The value of comparing different data sources with different strengths and weaknesses regarding precision, bias, spatial and temporal resolution.
- The problem of using some data sources due to their nature of being a rolling average or temporal trend, which cannot be easily accommodated in the accounting structure.
- The need to have a consistent baseline opening and closing year or year range, potentially restricting the use of many sources of data.
- The need to optimise future accounting, while taking account historical data formats and protocols, which could produce conflicting pressures on data processing.

Species of conservation concern

Species selected for inclusion in the accounts were ones previously prioritised by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006 as those of principal importance for the conservation of biological diversity in Wales (557 in total). This list is much broader than the IUCN Red List, which is already reported on through other pathways.

Previous studies have already identified major challenges in tracking ongoing change of many priority species in Wales. Such challenges include a lack of consistent data for some of the less charismatic species, which can require a high level of specialist expertise and effort to record adequately. This is due to these species having either restricted ranges or habitats very different to those of more commonly sampled species. Thus, the final set of species selected for this initial exploration were a pragmatic selection of those with sufficient, direct and easily available data for reporting, with a recognition that ongoing work will add to this list in the future. Inevitably, these data are those from the more charismatic, widespread and easily observed taxa, e.g. birds and pollinators.

Initial data for species of conservation concern, include direct observation data from the 2013 to 2015 GMEP structured survey of 225 1 km squares across Wales. Data from 75 further 1 km squares surveyed in 2016 will provide a total baseline of 300 1 km squares for future reporting. Some taxa are recorded via both GMEP and other schemes, notably birds and butterflies. For birds, GMEP provides precise data on absolute abundance at the 1 km^2 scale, as well as scaling up to the national scale. The BTO/JNCC/RSPB BBS provides complementary data on interannual changes (i.e. a finer temporal resolution) at the national scale, but with lower precision at more local scales. The differences in intensity of survey effort between the two schemes means that rarer species are covered better by GMEP, and the data it provides are also better suited to an accounting process (although there is no historical baseline for these data). The use of the GMEP data was considered the most appropriate for this scoping study in order to provide a new, consistent baseline for possible future assessments. However, moving forward, additional data sources will be explored with a range of data providers and stakeholders.

To capture change in a wider range of species assemblages identified as being most threatened and requiring conservation action, current estimates of Section 42 (Wales) Priority Habitats under the Natural Environment and Rural Communities (NERC) Act 2006 are reported. Once again, the source of these data is the GMEP structured survey, which provides a baseline for future assessment. Past estimates from Natural Resource Wales used a different methodology and were not collected over the required standard timeframe.

Species important for ecosystem condition and functioning

Within the UK, species used to assess ecosystem condition are a mix of: species critical for creating fundamental ecosystem structure and, therefore, many of the ecosystem functions from which services flow (i.e. keystone species or ecosystem engineers); umbrella species which indirectly provide information on other species that make up the ecological community of the ecosystem; and species identified as negative indicators, such as invasive species whose abundance is symptomatic of issues like air pollution, climate change or inappropriate management. In some situations a species may be important for a service, but is unrelated to function or condition. For example, red squirrels in monoculture non-native woodland provide a valuable cultural service as they attract wildlife tourists, but they would not be used as indicators of condition because their presence, or absence, is likely to be driven by geographical factors and interspecific competition/disease rather than habitat quality.

Woodland is presented as a test case and the accounting table includes plant, bird and soil metrics relevant for the assessment of woodland condition and four functions for which different species-ecosystem service relationships could be identified, and for which data were available: pollination, dispersal, flood mitigation, and soil functional resilience. Data for all other major habitat types are available on the GMEP data portal, and ongoing developments regarding collecting data on the condition of Priority Habitats are discussed here.

Scope data

Data availability and quality were assessed. The structured survey co-located approach within the GMEP programme was considered to provide high-quality data that builds on well-established statistical approaches published in the peer-reviewed literature. These approaches show transparency and accessibility of methodology with low bias and high precision, but low temporal resolution. For example, confidence intervals can be explicitly calculated and are provided for the indirect Priority Habitat data (for instance, see annual reports and citations in the resources section of the GMEP website).

The BTO/JNCC/RSPB BBS data were considered of high quality, with methodologies established in the peer-reviewed literature. These methodologies show low precision in actual abundance data, but high temporal resolution. Clearly, both approaches have value, and methods to develop a composite indicator may be productive, although there will be analytical challenges.

The UK is rich in other potential data sources, which are currently used, for example, in the UK Biodiversity Indicator, but could not be accessed in an appropriate format in time for inclusion in this scoping study. These data collection activities outside of the GMEP programme are primarily focused on species of conservation concern. Work needs to be done with a range of data providers to agree on what opening and reference date range to select; the balance between direct abundance values versus abundance indices; the potential of indirect approaches; and levels of uncertainty and confidence in data sources which are acceptable in Species Accounts for Wales and the UK as a whole.

Step 3. Decide the approach and type of Species Accounts

The strategy for data acquisition was a pragmatic one based on immediate data accessibility to the assessment team, spatial application for national accounts, and quality and relevance to policy. Primarily, this involved use of:

- Direct data (GMEP)
- A modified direct approach using published annual indices of abundance (BBS)
- One example of the use of indirect habitat data, i.e. Priority Habitats extent

Concern about the use of indirect methods included uncertainties in the direct relationship to species. However, work is ongoing as indirect methods may be the only pragmatic approach for many of the rarer and less charismatic species of conservation value, which are frequently not surveyed. Examples of this modelling work is available on the GMEP data portal (e.g. https://gmep.wales/biodiversity/ glastirimpact/BD032). Specific concerns included:

- Relationship shape between indirect measures and species abundance or presence as, often, this will not be linear.
- Lags in species' responses to change in an indirect metric e.g. habitat extent.
- Sampling area and/or effort, which translates into confidence that observed change reflects real change. This may be difficult to incorporate into accounting mechanisms where measurement uncertainty is not typically an issue.
- Some methodologies can provide certainty of a biased sample population. Others may provide less certainty but for an unbiased sample population. How these are differentiated and reflected in the accounts, and which should be selected, should be reviewed.

There is a complex mix of units in the tables produced due to the mix of taxa, and the use of direct and indirect methods of data acquisition. GMEP species counts are reported per 1 km²; soil biodiversity is the effective species count based on cores sampled in 5 randomly selected plots within the 1 km²; BBS data is an abundance index; Priority Habitat is extent in km².

Reference condition

The data in the accounting tables all need to be referenced to the same year (or a common interval if a rolling average is to be used). The use of a rolling average is frequently justified on the basis of high rates of temporal change related to sampling power and/or weather-related dynamics unrelated to true medium- to long-term population change. This caused a conflict as some data on species important for ecosystem condition and functioning, were available for the period 2005 to 2009, while others were only available for the period 2013 to 2016. In some cases, there is a single estimate within this period, but this is thought to represent the year range well. Historical analysis of data available prior to this will be possible, but identifying a common year or range of years across taxa and metrics requires further work. The final selection of an opening and reference year for consistency resulted in the loss of a rich set of historical trend data. This is concerning because it can provide important context as to whether populations are increasing or declining in response to changes in recent policy.

As historical trends have been well-described elsewhere, however, it was considered more important, in this case, to use the well-structured, actual abundance data of GMEP to establish both an opening and reference year range of 2013 to 2016.

Confirm strategy mix

This case study predominantly uses a direct observation strategy, but does include the use of one set of data from a habitat-based method due to the lack of immediately available information for many species of conservation concern.

Step 4. Decide the Reporting Units, frequency and summary statistics

Reporting Unit

Reporting at a national level (i.e. Wales) was agreed upon due to the need for a sound evidence base to support domestic legislation. Each country within the UK has its own policy priorities for both species for conservation and for natural resources management. Within this national unit, reporting by ecosystem type was considered the most practical way to align with important data sources, and to link to service accounts and other ecosystem assessments within Wales and the UK, such as GMEP (www.gmep.wales); Countryside Survey (www.countryside.org.uk); and the UK NEA (http://uknea.unep-wcmc.org). Reporting at smaller scales to support 'Local Area Statements' is a potential future ambition.

Reporting frequency

Ideally, annual changes would be reported, but this is often not possible for economic reasons and, also, could be ecologically unreliable due to the temporal dynamics of many species. Cycles of four to five years provide a good basis as this is likely to be policy-relevant (e.g. for the EU Rural Development Plan, which currently provides much of the economic support for payments to land managers to improve environmental outcomes). A four to five-year cycle is also highly relevant for the political cycle within Wales and UK.

The GMEP survey was designed to provide a rolling four-year cycle of data collection, with reporting in year five against criteria. It, therefore, provides a good basis on which to track future progress in the Species Accounts. Further work is needed to align data from other important taxa-specific monitoring programmes to this reporting framework.

Method of composite indicator and/or index construction

As data were standardised to provide only opening information, and aggregation is only possible on change data, no composite indicator is actually provided at this time.

Due to the variable contribution of some species to the ecosystem condition and functioning accounts, it proposed that a simple composite indicator of relative change for both condition and function, and for the account for conservation, will be calculated when change data becomes available. This is likely to comprise a simple arithmetic aggregation of relative change by different taxa (e.g. plants, birds, butterflies) and soil organisms. Finally, aggregation of these composite indictors will create the final composite index. This aggregation procedure is shown below for the example of woodland.

Individual metric	Taxa composite index	Final composite index
Plant Species 1	Plant composite index	e.g. Species Composite Index for Woodland Condition
Plant Species 2		
Plant Species 3		
Soil Metric 1	Soil composite index	
Soil Metric 2		
Bird Species 1	Birds composite index	
Bird Species 2		
Bird species 3		
Bird Species 4		
Etc.		

However, this could easily be challenged as:

- Only some taxa are included due to data availability
- Only certain species are included within these groups
- There are different numbers of species per group

However, by averaging within groups first, individual species in groups are effectively 'down weighted' where there are data for more species.

Other valid options for constructing a composite indicator or index from the Species Accounts for Wales include:

- Weighting by some other mathematical function or the number of species in the group
- Weighting habitats more than species
- Weighting by area of presence of species or habitats
- Weighting by policy, function or ecosystem service priority

This case study provides a first and overly simplistic test of the approach outlined in this document and requires more work. Approaches need to be explored in consultation with a wide range of stakeholders to ensure buy-in from the range of interested parties who may want to use the Species Accounts' final metrics.

Step 5. Collate and prepare data

Due to ongoing, current reporting requirements for both GMEP and BBS, there was limited requirement for this task as there are high-levels of quality assurance already (including, for example, independent quality control of a subsample of botanical surveys within GMEP). As described previously, the duplication of bird species within GMEP and BBS provide different types of information – the former with better abundance values, the latter better temporal values. Further consideration is needed regarding whether, in the future, only one is used, or they are combined in some way.

Step 6. Populate Species Accounts

A draft series of national Species Accounts have been trailed for:

- Species of conservation concern
- Species important for woodland ecosystem condition and functioning
- Accounts of Priority Habitat areas (Accounts of the Extent of Important Places for Species)

These are presented below. Next steps should involve full stakeholder involvement and a review of a wider set of potential data sources in order to develop these trial accounts further.

Table A1.1: National Species Accounts for Species of Conservation Concern

	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Species 9	Species 10	Species 11	Species 12	Species 13
Data type and source	**Birds (GMEP)**												
Species	**Common bullfinch**	**Black-headed gull**	**Chough**	**Common cuckoo**	**Eurasian curlew**	**Hedge accentor**	**Common grasshopper warbler**	**Herring gull**	**House sparrow**	**Kestrel**	**Northern lapwing**	**Common linnet**	**Lesser redpoll**
Unit	**Mean species abundance in GMEP squares**												
Reference (benchmark)	2.327	1.562	0.181	0.646	0.686	7.739	0.403	6.482	11.881	0.208	0.836	6.288	1.690
Opening (% of reference)	100	100	100	100	100	100	100	100	100	100	100	100	100
Opening (2013-2016)	2.327	1.562	0.181	0.646	0.686	7.739	0.403	6.482	11.881	0.208	0.836	6.288	1.690
Closing (2017-2020)													
Change (% of opening)													
Closing (% of reference)													
Net change (% of reference)													

All species selected are priority species for Wales as indicated by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. GMEP data provides actual abundance data and are available from 2013-15 (with 2016 data currently being collected). Future 'Opening' will, therefore, be 2013-2016. Historical trend data using an index of abundance for many of these species, e.g. from the BBS, is available, but was considered less appropriate to the actual abundance data from GMEP. Change values varied from -31% to + 182% from the period 2005-2009 to 2013-2015.

Table A1.1: Continued

	Species 14	Species 15	Species 16	Species 17	Species 18	Species 19	Species 20	Species 21	Species 22	Species 23	Species 24	Species 25	Species 26
Data type and source	Birds (GMEP)											Butterflies (GMEP)	
Species	Marsh tit	Pied flycatcher	Reed bunting	Skylark	Spotted flycatcher	Common starling	Song thrush	Tree pipit	Wood warbler	Willow tit	Yellow-hammer	Small heath	Wall brown
Unit	Mean species abundance in GMEP squares											Mean count per 1 km	
Reference (benchmark)	0.239	0.473	1.296	5.752	0.850	5.593	4.504	0.987	0.235	0.088	0.434	8.03	1.3
Opening (% of reference)	100	100	100	100	100	100	100	100	100	100	100	100	100
Opening (2013-2016)	0.239	0.473	1.296	5.752	0.850	5.593	4.504	0.987	0.235	0.088	0.434	8.03	1.3
Closing (2017-2020)													
Change (% of opening)													
Closing (% of reference)													
Net change (% of reference)													

All species selected are priority species for Wales as indicated by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. GMEP data provides actual abundance data and are available from 2013-15 (with 2016 data currently being collected). Future 'Opening' will, therefore, be 2013-2016. Historical trend data using an index of abundance for many of these species, e.g. from the BBS, is available, but was considered less appropriate to the actual abundance data from GMEP. Change values varied from -31% to + 182% from the period 2005-2009 to 2013-2015.

Table A1.2: National Species Accounts for Species Important for Woodland Ecosystems Condition and Functioning

Direct Observations	Species Group 1	Species Group 2	Species Group 3	Species Group 4
Species important for ecosystem condition and functioning	Plant composition for condition	Plant composition for condition and resilience function	Tree diversity for condition and resilience function	Nectar-producing plants for pollination service
Measurement Unit	No. of Ancient Woodland indicator plants per 4 m^2	Mean no. of vascular plant species richness per 4 m^2	Mean number of tree and shrub species recorded per 1 km^2	Mean cover-weighted nectar plant index per 4 m^2
Reference (2013- 2016)	1.2	11	14.3	0.64
Opening (% of reference)	100%	100%	100%	100%
Opening (2013-2016)	1.2	11	14.3	0.64
Closing (2017-2020)				
Change (% of opening)				
Closing (% of reference)				
Net change (% of reference)				

Direct Observations	Species Group 5	Species Group 6	Species Group 7
Species for ecosystem condition and function	Soil bacterial diversity for resilience function	Soil fungal diversity for resilience function	Soil invertebrate diversity for resilience function
Measurement Unit	Effective number of bacteria species per 1 km^2	Effective number of fungal species per 1 km^2	Effective number of mesofauna species per 1 km^2
Reference (2013- 2016)	27,152	335	49.7
Opening (% of reference)	100%	100%	100%
Opening (2013-2016)	27,152	335	49.7
Closing (2017-2020)			
Change (% of opening)			
Closing (% of reference)			
Net change (% of reference)			

Historical data from Countryside Survey (which uses the same method, but which cannot be used to enable consistency in opening years) indicates this represents a change of between -14% to +21% since 2007 for the vegetation species groups. For the birds, data from BBS (which provides an index of abundance incompatible with the GMEP abundance data) indicates a change of between -1% to +182% for the birds involved in wildlife tourism; and -20% to +62% for birds involved in seed dispersal.

Table A1.2: Continued

Direct Observations	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Species 9	Species 10	Species 11	Species 12	Species 13
Species important for ecosystem condition and functioning	Bird species for seed dispersal and condition												
Species	Blackbird	Blackcap	Bullfinch	Chaffinch	Crossbill	Hawfinch	Jay	Lesser redpoll	Nuthatch	Pheasant	Siskin	Song thrush	Wood-pigeon
Measurement Unit	Mean species abundance in GMEP squares												
Reference (2013-2016)	16.982	6.796	2.327	15.872	0.456	0.050	1.673	1.690	2.527	1.920	2.487	4.504	11.248
Opening (% of reference)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Opening (2013-2016)	16.982	6.796	2.327	15.872	0.456	0.050	1.673	1.690	2.527	1.920	2.487	4.504	11.248
Closing (2017-2020)													
Change (% of opening)													
Closing (% of reference)													
Net change (% of reference)													

Historical data from Countryside Survey (which uses the same method, but which cannot be used to enable consistency in opening years) indicates this represents a change of between -14% to +21% since 2007 for the vegetation species groups. For the birds, data from BBS (which provides an index of abundance incompatible with the GMEP abundance data) indicates a change of between -1% to +182% for the birds involved in wildlife tourism; and -20% to +62% for birds involved in seed dispersal.

Table A1.3: National Accounts of Priority Habitat areas (Accounts of the Extent of Important Places for Species)

Priority Habitat for conservation:	Lowland beech and yew woodland (GMEP)	Lowland hay meadows (GMEP)	Purple moor grass and rush pasture (GMEP)	Fen (GMEP)	Blanket bog (GMEP)	Maritime cliff and slope (GMEP)
Unit	'000ha	'000ha	'000ha	'000ha	'000ha	'000ha
Reference (benchmark)	3.01	4.8	56.5	14.3	41.6	2.7
Opening (% of reference)	100%	100%	100%	100%	100%	100%
Opening (2013-2016)	3.01	4.8	56.5	14.3	41.6	2.7
Closing (2017-2020)						
Change (% of opening)						
Closing (% of reference)						
Net change (% of reference)						

All habitats are examples of Priority Habitats for Wales as indicated by Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. No directly comparable historic figures are available. However, Jones et al. (2003) Priority Habitats of Wales: a technical guide, Countryside Council for Wales, provide potential values for future trend analyses. Area figures have large uncertainty, but Priority Habitat condition metrics are likely to have less uncertainty and will be explored as possible metrics for both conservation and condition accounts.

Step 7. Identify and fill gaps in Species Accounts

These have been noted throughout. In addition, future work should include:

- Exploring a broader set of data and aligning the accounts to an agreed reporting year range.
- Identifying the evidence for species directly, or indirectly, related to functions and services within each ecosystem type.
- Developing Species Accounts using available data for ecosystem condition and functioning for all dominant ecosystem types in Wales beyond woodlands.
- Exploring historical data, which are available for many decades in some cases. This will provide a useful context for the current rate of change, i.e. whether policies are slowing or accelerating the rate of decline or recovery of species and habitats relative to previous policies.
- Exploring likely future responses of species to proposed policies via modelling. This will provide useful insights for policymakers and also help to manage expectations or quantify likely outcomes of policy interventions. Lags in biological responses to such interventions are often not well understood and can lead to disappointment if not well managed. For instance, within GMEP, the Multimove model highlights the likely decadal lags in response for 26 species important for conservation https://gmep.wales/biodiversity/glastirimpact.

Step 8. Organise and aggregate Species Accounts.

Future aggregation of these Species Accounts into UK Ecosystem and/or Species Accounts will require further work as the reporting and policy priorities of domestic legislation have to be recognised alongside the need for UK, EU and international reporting.

With respect to ecosystem condition and functioning accounts, selecting 'ecosystem types' (effectively Broad Habitats) as the Reporting Units is a pragmatic choice. Ecosystem types were previously used in the UK NEA because data is often collected and aggregated on this basis and so many functions and services are aligned to this fundamental unit.

There are well-developed methods for aggregating basic data up to a national scale (Wales or UK, for instance). These use either a straight aggregation via structured, stratified surveys like GMEP, or use land cover data from earth observations to inform the aggregation procedure (e.g. Land Cover Map 2007; http://www.ceh.ac.uk/services/land-cover-map-2007)

Step 9. Analyse and integrate Species Accounts

Analyse Species Accounts

In the end, no change data were included as this will not be available until the next round of GMEP monitoring is complete. However, trend data for biodiversity and ecosystem extent and condition in Wales are available from a variety of sources. These data suggest stability and, in some cases, even recent improvement (last five to ten years) after historical loss and decline; however, certain species remain in decline.

Integrate with other accounts

The species important for ecosystem condition and functioning composite indicator is likely to be useful in contributing towards the Ecosystem Condition Account where other condition metrics, such as abiotic metrics of soil condition.

Appendix B: Case study of Species Accounts San Martin, Peru

Hedley Grantham, Daniel Juhn, Trond Larsen (Conservation International), Simon Ferrier (Commonwealth Scientific and Industrial Research Organisation) and the Government of Peru

This case study draws from a project to pilot ecosystem accounting for the region of San Martín, Peru. This was developed through a core partnership between the Government of Peru and Conservation International (CI), together with many others, including a biodiversity analysis led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The pilot originated under CI's Ecosystem Values and Accounting (EVA) initiative funded by the Gordon and Betty Moore Foundation. EVA's aim is to design and field-test a replicable and scalable framework for incorporating nature's benefits into societal decision-making processes. EVA's ultimate goal is to make explicit the relevance of natural capital to the economy, and to inform the development and implementation of more sustainable policies and practices.

Planning (Steps 1 -4)

Peru is often considered to support the highest biodiversity on the planet. San Martín is a region characterised by a complex landscape consisting of biologically diverse natural ecosystems and areas of agricultural production. The choice of geography was influenced by both the diversity of ecosystems and socioeconomic issues, and the progressive green development policies promoted by the regional government in order to sustainably address current rapid development.

The main aim of this pilot was to develop an operational model of ecosystem accounting that can be used in other regions of Peru and, ultimately, be scaled up to the national level. The ecosystem accounting approach we present here addresses gaps in the current SEEA framework by describing and implementing new methodologies. It accomplishes this by integrating spatially explicit measurements with information collected within national or sub-national administrative boundaries. These data are then used within a standardised monitoring approach to report on the values of biodiversity and natural capital in an accounting framework, and to inform land-use decisions, such as habitat restoration, land-use zoning and protected area expansion. The key policy decisions that could be informed by ecosystem accounting, including those relevant to species and biodiversity generally, are presented in Table A2.1

Table A2.1: Key policy decisions informed by ecosystem accounting in San Martin

Strategic goal	National	Regional	Question to be informed by ecosystem accounting
Sustainable economic development	Foster sustainable activities in ecosystems with little or no intervention (Amazon), and in transformed ecosystems.	Foster sustainable forestry, agriculture, tourism, aquaculture.	What considerations should be given toward the design and implementation of a land-use/zoning strategy and/or investment plan that seeks to balance private and public benefits associated with ecosystem services? • What areas are suitable for a certain activity given its dependencies on ecosystem services, as well as its impact? • What are the trade-offs associated with land allocation for some key economic activities, and what are the public benefits provided by ecosystem services in San Martín? • What ecosystem services are likely to restrict economic activities/deter investments, and where are these most evident in the department? • What economic activities generate the highest revenue and the lowest impact/reliance on ecosystem services?
Ecosystem-based management approaches	Promote the integrated management of watersheds. Improve water availability (priority use by agricultural sector).	Protect ecosystems (e.g. headwaters of various water bodies that supply economic production).	What should the management/conservation strategies be for watersheds/ ecosystems given their relevance to current/proposed economic uses? • What/where are critical areas for biodiversity conservation and the protection of ecosystem services in San Martín? • What are the most appropriate indicators for ecosystem health/degradation to inform an integrated management approach? • What approaches would ensure optimum production from economic activities, while generating minimum degradation?
Environmental regulation and management	Improve management of territory (reduce deforestation and promote conservation and sustainable use of forest). Understand valuation of ecosystem services. Provide evidence and incorporate the value of these services in environmental national economy.	Promote biodiversity conservation and protection of key ecosystems (support policy goal: protection of 65% of territory). Promote adequate environmental management planning (EIA, economic valuation, PES, etc.) and implementation (restoration, mitigation, protection).	What are key environmental regulations that should be considered for improved environmental management/biodiversity conservation in San Martín? • What are the recommended approaches for valuation of specific ecosystem services? What information should be collected to improve estimates of such values? • How could estimates of values of ecosystem services be used to inform: i. approaches for estimates of regulation/taxes/subsidies; and ii. measures to address unregulated/illegal resource exploitation and degradation? • What mechanisms could be envisioned as an incentive for: i. better management/stewardship/compensation of damage; and ii. supporting the restoration, mitigation and protection of key ecosystems?

To capture general patterns of biodiversity distribution and change, the first approach used was a modelling method called Generalised Dissimilarity Modelling (GDM). This is a community-level modelling method that allows differences in environmental conditions to be represented in terms of their effect on species composition for whole biological groups. It is then possible to compare the expected ecological similarity of any location with all other locations in the modelled environmental space. This allows the environmental uniqueness of a location, and its contribution to regional biodiversity, to be assessed. Using this method, it is then possible to determine the impact of anthropogenic land degradation on the long-term persistence of biodiversity. GDM models were developed for vertebrates, vascular plants and invertebrates.

The second approach focused on threatened species and the areas where they live. Some species have high value from ecological, economic, and/or social perspectives. Threatened species are often the focus of conservation because they are the most at risk of extinction. Habitat change was measured within: 1) specific, predicted species distributions; and 2) places important for threatened species. There were two species for which data were available on their predicted distributions: 1) the yellow-tailed woolly monkey; and 2) the San Martín titi monkey (locally known as Mono tocón). For important places, Key Biodiversity Areas (KBAs) were used, which are places of international importance for the conservation of biodiversity. KBAs are identified nationally using simple, standardised criteria, based on their importance in maintaining species populations (Langhammer et al., 2007).

Eight types of ecosystem accounts were explored and measured for 2009, 2011 and 2013, based on 11 predominantly natural ecosystem types ('ecosystem assets') covering four broad biomes. Both ecosystem extent and condition were measured, with biodiversity providing key information on the condition and health of ecosystems. In addition to the ecosystem condition account, the pilot produced various thematic accounts including a Biodiversity Account (Species Account) which reports on biodiversity values independent of ecosystem types, but was also used as an input for the Ecosystem Condition Account by reporting biodiversity values by ecosystem type.

As described above, Reporting Units and aggregation were based upon 11 ecosystem types, differences in species composition (GDM) dependent upon environmental change, change in habitat for individual threatened species, and change in habitat for KBAs.

Implementation (Steps 5, 6 and 9)

The results of the first approach (using GDMs) showed change across the three taxonomic groups over the accounting periods (Tables A2.2 and A2.3). There was an ongoing loss of approximately 0.8% of species as a function of habitat condition change between 2009 and 2013. For a biodiverse group, such as invertebrates, this may represent the loss of many species per year.

Table A2.2: Changes in the percentage of biodiversity retained in San Martín for invertebrates, vascular plants and vertebrates, reported within different forest ecosystem assets based upon GDM analysis

Ecosystem asset	Invertebrates (% biodiversity retained)			Vascular plants (% biodiversity retained)			Vertebrates (% biodiversity retained)		
	2009	2011	2013	2009	2011	2013	2009	2011	2013
Palm swamps	90.3%	90.1%	90.0%	87.0%	86.9%	86.8%	91.2%	91.1%	91.1%
Humid forest with high hills	88.3%	87.8%	87.4%	89.2%	88.8%	88.4%	83.7%	83.3%	83.1%
Humid forest with low hills	87.7%	87.3%	86.9%	88.6%	88.2%	87.8%	83.2%	82.8%	82.6%
Humid montane forest	91.1%	90.8%	90.5%	91.1%	90.7%	90.5%	87.5%	87.3%	87.1%
Lowland terra firme forest	86.5%	86.0%	85.6%	86.1%	85.5%	85.1%	80.9%	80.5%	80.3%
Floodplain forest	86.7%	86.2%	85.8%	86.6%	86.1%	85.7%	81.9%	81.5%	81.3%

Table A2.3: Changes in the percentage of biodiversity retained in San Martín for invertebrates, vascular plants and vertebrates, aggregated across ecosystem types

	San Martín			
	Original	2009	2011	2013
Biodiversity group	% biodiversity retained	% biodiversity retained	% biodiversity retained	% biodiversity retained
Invertebrates	100%	88.4%	88.0%	87.7%
Vascular plants	100%	88.1%	87.7%	87.4%
Vertebrates	100%	84.7%	84.4%	84.2%
Overall biodiversity retained	100%	87.1%	86.7%	86.4%

The KBAs used here were developed as part of the ecosystem profiling process by the Critical Ecosystem Partnership Fund, and a description of the methods used can be found in CEPF (2015). A total of ten KBAs were identified in San Martín. Species range data were available for two threatened species – the yellow-tailed woolly monkey and the San Martin titi monkey. Change in ecosystem extent and ecosystem condition was measured for each KBA and each threatened species (Table A2.4). The results for specific species and places indicate a variation in change in extent and condition of features. There has been little change with the yellow-tailed woolly monkey, but there was large variation in change with the San Martín titi monkey. Similarly, there was quite a big variation in change between the ten KBAs evaluated.

Table A2.4: Change in extent and condition of habitat within: 1) important species distributions; and 2) Key Biodiversity Areas (mean condition based on fragmentation)

San Martín								
Biodiversity values		Benchmark	2009		2011		2013	
		Extent (ha)	Extent ha/(%)	Mean condition	Extent ha/(%)	Mean condition	Extent ha/(%)	Mean condition
Species distributions	Yellow-tailed woolly monkey	103,142	97,225 (94.3%)	0.867	96,714 (93.8%)	0.810	96,509 (93.6%)	0.806
	San Martín titi monkey	984,577	396,066 (40.2%)	0.653	365,836 (37.2%)	0.652	354,418 (36%)	0.643
Key Biodiversity Areas (KBAs)	Moyobamba	87,839	35,770 (40.7%)	0.547	33,832 (38.5%)	0.534	33,089 (37.7%)	0.531
	Jesús del Monte	4,481	4,479 (99.9%)	0.990	4,475 (99.8%)	0.989	4,474 (99.8%)	0.987
	Parque Nacional Cordillera Azul	481,772	476,919 (99%)	0.979	476,496 (98.9%)	0.978	476,424 (98.9%)	0.976
	Río Abiseo y Tayabamba	192,405	185,073 (96.2%)	0.925	184,462 (95.9%)	0.921	184,035 (95.6%)	0.915
	Laguna de los Cóndores	212,197	202,380 (95.4%)	0.925	201,784 (95.1%)	0.923	201,572 (95%)	0.920
	Abra Pardo de Miguel	1	1 (100%)	0.790	1 (100%)	0.790	1 (100%)	0.790
	Abra Tangarana	3,694	3,533 (95.7%)	0.920	3,513 (95.1%)	0.918	3,497 (94.7%)	0.912
	Entre Balsa Puerto y Moyobamba	155,950	117,523 (75.4%)	0.829	108,019 (69.3%)	0.844	104,538 (67%)	0.836
	Tarapoto	170,729	113,360 (66.4%)	0.821	111,225 (65.1%)	0.822	109,202 (64%)	0.815

A condition score for 'biodiversity retained' was estimated for each ecosystem type as the mean average percent of the invertebrates, vertebrates and vascular plant biodiversity retained (Table A2.2). This was then integrated into ecosystem condition accounts for the six forest ecosystems considered (Tables A2.5, A2.6 andA2.7). A composite index for the overall condition of each ecosystem type was estimated as the mean average of the biodiversity condition and fragmentation condition. Finally, the extent and condition of each ecosystem type for 2009, 2011 and 2013 are reported in Table A.2.8

Table A2.5: The extent and condition of ecosystems in 2009 (condition scores are scaled from 0-1)

Time 2009		San Martín				
Ecosystem asset		Extent		Condition scores		
		Current area (ha)	% Original	Fragmentation	Biodiversity retained (%)	Composite index
Forests	Palm swamps	27,997	98.7%	0.91	89.50%	0.90
	Humid forest with high hills	203,601	53.3%	0.39	87.00%	0.63
	Humid forest with low hills	159,703	82.7%	0.72	86.50%	0.79
	Humid montane forest	2,966,134	82.0%	0.72	89.90%	0.81
	Lowland terra firme forest	53,179	51.7%	0.42	84.50%	0.63
	Floodplain forest	189,224	40.0%	0.28	85.10%	0.57

Table A2.6: The extent and condition of ecosystems in 2011 (condition scores are scaled from 0-1)

Time 2011		San Martín				
Ecosystem asset		Extent		Condition scores		
		Current area (ha)	% Original	Fragmentation	Biodiversity retained (%)	Composite index
Forests	Palm swamps	27,887	98.36%	0.9	89.40%	0.90
	Humid forest with high hills	189,153	49.50%	0.37	86.60%	0.62
	Humid forest with low hills	153,720	79.63%	0.7	86.10%	0.78
	Humid montane forest	2,901,212	80.18%	0.7	89.60%	0.80
	Lowland terra firme forest	51,698	50.22%	0.41	84.00%	0.63
	Floodplain forest	179,137	37.91%	0.27	84.60%	0.56

Table A2.7: The extent and condition of ecosystems in 2013 (condition scores are scaled from 0-1)

Time 2013		San Martín				
Ecosystem asset		Extent		Condition scores		
		Current area (ha)	% Original	Fragmentation	Biodiversity retained (%)	Composite index
Forests	Palm swamps	27,817	98.11%	0.9	89.30%	0.90
	Humid forest with high hills	183,399	48.00%	0.35	86.30%	0.61
	Humid forest with low hills	150,572	78.00%	0.68	85.80%	0.77
	Humid montane forest	2,874,803	79.45%	0.69	89.40%	0.79
	Lowland terra firme forest	50,345	48.91%	0.39	83.70%	0.61
	Floodplain forest	174,429	36.91%	0.26	84.30%	0.55

Table A2.8: Trends in the extent and condition of ecosystems. Condition is measured against a reference condition benchmark across different accounting periods. Note, this can be done for any Ecosystem Accounting Unit

		San Martín						
Ecosystem asset		Benchmark	2009		2011		2013	
		Extent (Ha)	Extent (%)	Condition	Extent (%)	Condition	Extent (%)	Condition
Forests	Palm swamps	28,353	98.7%	0.90	98.4%	0.90	98.1%	0.90
	Humid forest with high hills	382,089	53.3%	0.63	49.5%	0.62	48.0%	0.61
	Humid forest with low hills	193,040	82.7%	0.79	79.6%	0.78	78.0%	0.77
	Humid montane forest	3,618,298	82.0%	0.81	80.2%	0.80	79.5%	0.79
	Lowland terra firme forest	102,942	51.7%	0.63	50.2%	0.63	48.9%	0.61
	Floodplain forest	472,582	40.0%	0.57	37.9%	0.56	36.9%	0.55

www.unep.org

United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: publications@unep.org
www.unep.org

UNEP WCMC

ISBN: 978-92-807-3582-6
DEP/2017/CA