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Use it or lose it: measuring trends in wild species subject to substantial use

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Abstract

The unsustainable use of wild animals and plants is thought to be a significant driver of biodiversity loss in many regions of the world. The international community has therefore called for action on taking greater responsibility for ensuring the sustainable use of our living resources and safeguarding them so that they are available for future generations. For that reason, indicators that can track changes in populations of species used by humans are essential tools for measuring progress towards these ideals and informing management decisions. Here we present two indicators that could be used to track change in populations of utilised vertebrate species and levels of harvest sustainability. Preliminary results, based on example data at both the global level and for the Arctic, show that utilised species are faring better than other species overall. This could be a consequence of better management of these populations, as indicated by harvest levels becoming more sustainable in recent decades. Limitations of the indicators are still apparent, in particular, data on harvested populations of some vertebrate classes and those from specific regions are lacking. Focussing monitoring efforts on broadening the scope of data collected, as well as identifying interactions with other potential drivers of decline, will serve to strengthen these indicators as policy tools, and improve their potential to be incorporated into future sets of indictors used to track progress towards global biodiversity targets.

Keywords

Arctic, Aichi Targets, biodiversity indicators, Convention on Biological Diversity, population trends, sustainable use

Introduction

In many situations the use of wild animals and plants is essential for human livelihoods and well-being, while in others it is considered an active choice (Hutton & Leader-Williams, 2003). In many regions, the use of wild resources is thought to be unsustainable and a major driver of biodiversity loss (Butchart, 2008; Baillie et al., 2010). As the world's human population increases and demand for biological resources grows, this pressure that humans exert on exploited species and the ecosystems in which they live will become even greater. In order that wild species meet our needs now, and in the future, it is vital that these species are used in a biologically sustainable way.

Sustainable use is defined by the Convention on Biological Diversity (CBD) as the '*use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biodiversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations*' (CBD, 1992). Sustainable use was a focal area under the CBD target of significantly reducing biodiversity loss by 2010 (Decision VII/30). Failure to meet this target has resulted in the Parties to the CBD adopting a revised Strategic Plan for addressing biodiversity loss (CBD, 2010a). The new Strategic Plan, which includes 20 measurable targets (the 'Aichi Targets') maintains the goal of sustainable use.

Building on the existing CBD indicator framework, the CBD has called for the development of a new suite of indicators that can be used to track progress towards targets in the CBD Strategic Plan (CBD, 2010b). In conjunction to a new suite of indicators, it has been recommended that consideration be given as to how indicators can be 'linked' or presented as integrated sets (Walpole et al., 2009; Butchart et al., 2010; Sparks et al., 2011). Sparks *et al.* (2011) illustrate that linking indicators can create a more comprehensive understanding of trends and patterns observed, can aid in communicating complex messages, and that linked indicator sets can provide decision makers with a tool for effectively addressing biodiversity loss.

In order to determine whether the use of wild species is biologically sustainable, any indicator or set of indicators must reflect the status and trends of species in the wild, as well as the impact of this harvest on the species concerned. Despite the known importance of wild species to human economies and livelihoods, there are, however, relatively few indicators specifically developed to monitor the species that people use and rely upon, and few attempts to examine how indicators of species use and harvest sustainability could be linked to provide a broader picture of what, where and how people are using wild species.

In this paper we aim to develop, (1) an indicator that can track change in populations of species that are utilised by humans ('Utilised Species Index'); and (2) an indicator that tracks sustainability of the harvest of a selection of utilised species ('Harvest Index') with an overall view to examining their feasibility as effective and robust sustainable use biodiversity indicators. We first present trends in the Utilised Species Index at a global scale. We then use a case study to critically examine how the Harvest Index and the Utilised Species Index can be used together to provide a more thorough understanding of the state of utilised species in the Arctic – a region which is rich in biodiversity, but where species are subject to high levels of exploitation.

Arctic biodiversity is particularly vulnerable to the pressures of commercial, subsistence and traditional harvest and trade of its wild species because many are concentrated in limited areas of biological productivity, such as polynas and coastal plains. This pressure adds to that already being applied by rapid environmental change such as that observed in sea-ice extent (Gleason & Rode, 2009; CAFF, 2010; Heide-Jørgensen et al., 2010; Kovacs et al., 2010). Hence there is growing concern that, because of the limited functional redundancy in Arctic ecosystems, the loss of a single species could have cascading effects on the state and function of the entire system (Post et al., 2009).

The Conservation of Arctic Flora and Fauna (CAFF), through the Circumpolar Biodiversity Monitoring Programme (CBMP), is addressing these concerns by coordinating a number of programmes and projects that assess biodiversity status and trends, and which improve understanding of the drivers of change and of management options (Gill et al., 2008). An important contribution to the CBMP, and of tracking the response of Arctic wildlife to growing pressures, has been the development of the Arctic Species Trend Index (ASTI) (McRae et al., 2010). The ASTI is the Arctic disaggregation of the Living Planet Index (Loh et al., 2005; Collen et al., 2009), which tracks trends in vertebrate populations. In the case study presented here, we examine whether the indicators we developed can be applied to track changes in Arctic species which are utilised by people, and can complement the findings of the ASTI, thereby providing further information for managing these populations.

Methods

Two indicators for wild commodities were developed. The first, based on the Living Planet Index (LPI, Loh et al., 2005; Collen et al., 2009) tracks changes in populations of vertebrate species utilized by humans since 1970 and which we refer to as the 'Utilised Species Index'. The second combines population and harvest data to track the sustainability of the harvest of a selection of vertebrate utilized species, herein, the 'Harvest Index'.

Utilized Species Index

Selection of Species: Vertebrate population data was sourced from the LPI and ASTI databases as compiled in October 2010. General information on each population in the LPI and ASTI is coded including: to which vertebrate class it belongs, and what system (freshwater, marine, terrestrial) and zone (LPI: temperate, tropical; ASTI: polar) it is most dependent on for survival and reproduction (Loh et al., 2005; Collen et al., 2009).

A decision tree (**Appendix I**) was used to further code species within the LPI database as ‘utilized’ by humans, based on cross-referencing information on the ‘use’ of each species contained in a variety of publically available databases. These databases included: the IUCN Red List (www.iucnredlist.org), the World Bird Data Base (http://avibase.bsc-eoc.org/avibase.jsp?lang=EN&pg=home), the CITES trade database (www.cites.org/eng/resources/trade.shtml), FAO forestry country profiles (www.fao.org/forestry/nwfp/en/ and www.fao.org/forestry/country/en/), the International Tropical Timber Organisation (www.itto.int), publications by the Centre for International Forestry Research (www.cifor.cgiar.org), the University of British Columbia Sea Around Us Project (www.seaaroundus.org), and the Fishbase online database (www.fishbase.org/search.php). The coding generated a ‘utilised species’ database.

The type of use each species in the utilised species database is subject to, was classified, where possible, according to the IUCN Utilisation Classification Scheme (http://intranet.iucn.org/webfiles/doc/SSC/RedList/AuthorityF/utilization.rtf) which divides use into 17 different categories: food (for humans or animals), medicine, poison, manufacturing chemicals, other chemicals, fuels, fibre, construction/structural materials, wearing apparel, household goods, handicrafts, pets, research, sport hunting, other and unknown. Note, these categories are not mutually exclusive. Due to small sample sizes in other categories, analyses on specific types of use were restricted to those where species are used as food for humans, for sport hunting or as pets.

Species in the utilised species database were also categorized as ‘substantially used’ where sufficient evidence existed that they are widely used and are particularly important to people. Evidence on the scale of trade or volume of harvest at the local, national, regional and international level was obtained from the databases listed above, the global Forestry Resources Assessments (www.fao.org/forestry/fra/en/), regional reports and expert knowledge (pers comm., IUCN Sustainable Use Steering Group). Evidence for each species was subjectively ranked from 1 to 5, where 1 equated to a low amount of evidence for substantial use, and 5 equated to a high amount of evidence for substantial use. Results of this whole process generated a list of 'substantially used species'. Trend analyses on 'substantially used species' were only conducted on those species with evidence scores ≥3.

Vertebrate Arctic species within the ASTI database were coded as 'utilized' by humans based on expert opinion (pers comm. C. Zöckler), generating a list of 'Arctic utilised species'.

Indices calculated: Data were extracted from these datasets (Utilized Species, Substantially Used Species, Arctic Utilized Species), and used to generate different indices to assess change in populations of wild species used as commodities: a) Utilized Species; b) Freshwater Utilized Species; c) Marine Utilized Species; d) Terrestrial Utilized Species; e) Index of species used to provide food for humans; f) Index of species used for sport hunting; g) Index of species used as pets; h) Substantially Used Species; i) Arctic Utilized Species.

A description of each index and the number of species and populations in each dataset can be found in Table 1. For a further breakdown of the number of species and populations in each data set by system (freshwater, marine, terrestrial), zone (temperate, tropical) and vertebrate class (amphibian, bird, fish, mammal, reptile), see Appendix II.

Calculation of index: The indices of utilized and substantially used species were calculated using the technique developed for the global LPI (see Loh et al., 2005 for more details; Collen et al., 2009). Briefly, the index was calculated using population time series data (1970-2007) on 6,214 populations of 1,501 species coded as utilised, and 1100 populations of 187 species coded as substantially used. The changes in the population size of each species were aggregated and presented as an index relative to 1970, which is given a value of 1. Tropical and temperate species were weighted equally within each system (freshwater, marine, terrestrial) to account for the over-representation of temperate compared to tropical species.

The index of Arctic utilised species was calculated using the technique developed for the ASTI (McRae et al., 2010), using time series data from 1970 to 2007 on 663 populations of 147 Arctic species coded as utilised. It should be noted that the authors are aware that the ASTI database has been updated and a new ASTI generated since the analyses for the study presented here were conducted (see Eamer et al., 2012). However, because the overall pattern of Arctic vertebrate abundance has not changed between the two iterations of the ASTI, we only include comparisons of our results with the ASTI trend line published in 2010 (McRae et al., 2010), but are mindful of the revised, disaggregated regional and system differences depicted in the ASTI trend line published in 2012 (Eamer et al., 2012).

Following Loh *et al.* (2005) as adapted by Collen *et al.* (2009), a bootstrap re-sampling technique was used to generate annual 95% confidence intervals (95% CI) around each index value (10,000 iterations).

Harvest Index

The Harvest Index is the ratio of the estimated annual harvest rates to the potential for biological recovery (the theoretical maximum recovery rate). If harvest rates exceed this recovery rate then this implies that harvest rates are more likely to be unsustainable than if the harvest rates are less than the recovery rate. The estimates of annual population recovery rates are made using a single simple equation (the Potential Biological Removal

[PBR] model (Wade, 1998); see below) derived from insights from simple theoretical models (principally based on the logistic equation) (Elert, 2007).

The Harvest Index was calculated by the following:

Step 1: For each year in each population, the PBR was calculated – i.e. the maximum number of individuals that can be harvested whilst still allowing the population to reach/maintain its maximum stable population:

$$PBR_{(t)} = n_{(t)min} \times (0.5 \times R_{max}) \times F_R \qquad (1)$$

Where,

$n_{(t)min}$ = An estimate of the minimum number of individuals in the population at time *t*. As population sizes are extremely difficult to measure accurately, this component is routinely estimated as 90% of the number of individuals thought to be present (Wade, 1998).

R_{max} = The maximum theoretical productivity rate of the species. This parameter will vary within a species from population to population, however, if unknown, this value is given a weight of 0.5 which is considered a conservative estimate of the current net production of a depleted population (Wade, 1998).

F_R = This represents a recovery factor which is the proportion of the net production of the population which contributes to population growth (default value = 0.5).

Step 2: The ratio between the PBR (i.e. the theoretically sustainable harvest) and the actual number of individuals harvested (H) was calculated. At each time point (*t*) the ratio between H and PBR is calculated in the following way:

$$H_{(t)ratio} = H_{(t)} / PBR_{(t)} \qquad (2)$$

To calculate the ratio in Step 2, PBR and H for all populations of a specific species was calculated from the mean PBR and mean H of each individual population of that species.

Step 3: The Harvest Index (HI) was then calculated from the geometric mean of all populations for each time point. If HI>1.5, then this indicates that the harvest is unsustainable (coded as being in the 'red' zone); if HI<0.5 then this indicates that the harvest is within sustainable limits (coded as being in the 'green' zone); and if HI is between 0.5-1.5, this indicates the harvest is on the threshold of sustainable limits (coded as being in the 'orange' zone).

In this study the HI was calculated for species in the Arctic Utilized Species dataset where information on the harvest of a species was also available, which was possible for 73 populations of 20 species of birds, fish and mammals (Table 1). Harvest data were recorded by volume or number of individuals taken.

Results

Utilized Species Index

Trends in utilized species: The utilised species index (USI) shows a decline of around 14% between 1970 and 2007 (Figure 1a: 2007 USI value 0.86; 95% CI 0.77-0.97). The decline started at about the same time as that seen in the global LPI (i.e. early 1980s) but declined by approximately half the amount (Figure 1a: LPI value 0.72; 95% CI 0.64-0.80). The utilised species index is based on trends in amphibian, bird, fish, mammal and reptile species from freshwater, marine and terrestrial systems around the world, however a large proportion (88%) of the time-series data used to generate this global index is from information on birds (Appendix II).

Trends in utilised freshwater, marine and terrestrial vertebrate species: Trends in utilised species from each system vary: between 1970 and 2007 populations of utilised freshwater species declined by around 3% (2007 Freshwater USI value 0.97; 95% CI 0.78-1.23), populations of utilised marine species by around 17% (2007 Marine USI value 0.83; 95% CI 0.66-1.04), and populations of terrestrial utilised species by around 21% (2007 Terrestrial USI value 0.79; 95% CI 0.68-0.93) (Figure 1b). Since the early 2000s the rate of decline in marine and terrestrial utilised species indexes slowed or stabilised. The freshwater utilised species index has shown a steady increase since 2000.

Trends in utilised vertebrate species according to what they are used for: The indices shown in Figure 1c display trends for species where their end use is food for people, being hunted for sport by humans, or as pets. These categories are not mutually exclusive, and the majority of species have more than one use. Therefore some species may be represented in more than one trend line.

Trends are variable between use types. The index for species used to provide food for humans, and that for species used as pets declined by 17% (2007 Food USI value 0.83; 95% CI 0.72-0.97) and 9% (2007 Pets USI value 0.91; 95% CI 0.77-1.08), respectively, between 1970 and 2007, however both show a pattern of stabilizing since the early 2000s. The index for species which are hunted by humans has shown an overall increase by 14% between 1970 and 2007 (2007 Sports hunting USI value 1.14; 95% CI 0.94-1.42); however the pattern has varied over time, with the index increasing between 1970 and the early 1980s before a slow decline to about 2005 and then increasing again in recent years.

The indices track change in populations of amphibians, bird, fish, mammal and reptile species from freshwater, marine and terrestrial systems, however data is biased towards birds and fish (Appendix II).

Trends in substantially used vertebrate species: This index tracks change in populations of birds, fish, mammal and reptile species that they are widely traded and used at local, national, regional, and international levels (Appendix II). It shows that apart from an apparent rise starting in the early 2000s, there has been a constant trend of no change in the populations of this selection of species since 1970 (Figure 1d: 2007 Substantially Used Species Index value 1.11; 95% CI 0.75-1.68). Data is biased towards fish and mammals.

Trends in Arctic utilised species: Populations of utilised Arctic species has shown an upward trend between 1970 and 2007, increasing by 83% in this time (Figure 2a: Arctic Utilised Species Index value 1.83; 95% CI 0.75-1.68). This is five times the increase seen in the 2010 ASTI, which increased by 16% between 1970 and 2004 (Figure 2b: 2004 ASTI value 1.16; 95% CI 1.02-1.32) (McRae et al., 2010). The trend in utilised Arctic species has not been constant, rising between 1970 and 1994, then undergoing a period of apparent stabilization, before rising again as of 2005. This index is based on bird, fish and mammal species only, from freshwater, marine and terrestrial systems (Appendix II).

Harvest Index

This index is made up of trends in the harvest and stock estimates of Arctic species of birds, fish, and mammals. Harvest levels between 1970 and 1985 were generally predicted to be unsustainable (i.e. they are in the red zone; Figure 2b). However, the Harvest Index has shown a steady decrease in value from a high of greater than 2.0 in 1976 to about 0.3 in 2006, meaning that the overall level of harvesting is now within predicted sustainable limits (green zone). For many years (1985 to early 2000s), the levels of harvest fluctuated around predicted sustainable harvest thresholds (orange zone). It should be noted, though, that a number of individual populations in the index (particularly fish) are still predicted as being over-harvested.

Discussion

The international community has called, though Multi-Lateral Environmental Agreements such as the CBD, that greater responsibility is taken for ensuring the sustainable use of our living resources. Indicators that can track changes in populations of species used by humans (both status and harvest levels) are therefore essential tools for measuring progress towards this ideal and making informed management decisions. The two indicators presented here have the potential to provide valuable input into future guidelines for the sustainable use of wild species at global, regional and national levels, and, after further development could be incorporated into future sets of indictors used to track progress towards global biodiversity targets.

Global trends in the Utilised Species Index

At a global level, the Utilised Species Index shows a decline of about 14% between 1970 and 2007, implying that our use of these species has not been sustainable. The decline began in the early 1980s and although it has been declining in a relatively steady pattern ever since, it does appear to have started to stabilize in recent years. Although it was not possible to generate a separate index of non-utilised species, (given that a lack of evidence for use does not mean non-use can be automatically assumed), and hence not possible to compare trends of non-utilised with utilised species, it was possible to compare the Utilised Species Index with the global LPI, which contains species whether their use is known or not. Trend lines of both indicators showed similar trajectories, however a striking difference between the two is that the Utilised Species Index has only declined by about half as much as the LPI. This suggests that utilised species are, in general, faring better than other species overall. This could be because people are more likely to use and rely upon common, and hence more easily exploited species rather than rare ones, or because populations of utilised species are likely to be managed more effectively or under greater protection than populations of non-utilised species. This creates what might be considered a paradoxical situation in terms of conservation management in that species subjected to significant utilisation have a lower risk of being threatened (i.e. a ‘use it or lose it’ scenario). Similarly, the Red List Index of Threatened Species has shown that the conservation status of known utilised species, particularly birds, was better than non-utilised species and that they were less threatened with extinction (Butchart, 2008).

The concept of this ‘use it or lose it’ scenario is further strengthened when the trend in Substantially Used Species is examined. This index included species which are most widely used and which are considered most important to people. Although the confidence intervals are relatively broad (in part due to reduced sample sizes), the trend shows that there has been no overall change in the size of these populations in relation to the start of the index. When compared against the Utilised Species Index trend, this suggests that species which are used more widely or more intensely are likely doing better than species that have a lower incidence of use.

Sufficient data were available to examine trends in only three use categories (food, sport hunting, pets) in detail. However differences in trends between categories also support the idea of ‘use it or lose it’. While populations of vertebrates used for food and pets declined below the 1970 baseline, suggesting their use is unsustainable, the trend for species that are hunted for sport has remained relatively stable after an initial rise from the start of the index. The apparent rise in these latter populations may be because in many places sport hunting has become much more highly managed and regulated in recent years (Lamoureux, 1999; Robinson et al., 2008; Reid et al., 2010).

Trends in wild commodities indicators for Arctic Species

A majority of Arctic species are utilised either in commercial, subsistence, or traditional harvest and trade. It is evident that both local and global environmental and economic changes in the last 60 years, in particular, have altered and complicated harvest trends in the Arctic, and are exerting growing pressure on Arctic biodiversity (CAFF, 2010). However there is still a limited understanding of how Arctic wildlife populations are responding to these changes.

The wild commodities indicators calculated for Arctic species in this study provide an initial insight into the response by utilised species to these pressures. The Arctic Utilised Species Index shows that the average abundance of utilised Arctic vertebrates increased by a total of 83% between 1970 and 2007. The greatest period of increase was between 1970 and 1994, before a slight decline and stabilisation until 2005, when the trend appears to be on the rise again. This increase is substantially higher than that seen for all species in the 2010 ASTI, which only increased by 16% between 1970 and 2004 (McRae et al., 2010). Therefore this also implies that, in general, utilised Arctic species are faring even better than all Arctic vertebrate species for which data is available, and in particular from the early to mid-1990s where there is little overlap between the confidence intervals of the Arctic Utilised Species Index with that of the ASTI.

It has been suggested the increasing trend in the ASTI may be partly driven by the recovery of some vertebrate populations (e.g. marine mammals) from historical overharvesting, as well as the rapid increase of some populations (e.g. Bering Sea Pollock, *Boreogadus saida* and lesser snow geese, *Chen c. Caerulescens*) both inside and outside the Arctic as a result of recent changes in environmental conditions (CAFF, 2010). Indeed, these reasons could help explain the trend seen in the Arctic Utilised Species Index.

Further insight can be obtained by examining trends of the ASTI and Arctic Utilised Species index alongside those of the Harvest Index developed and presented here. The Harvest Index combines data on biological characteristics of a species with information on population changes and harvest levels in order to determine a threshold above which individuals harvested can be replaced. When applied to a subset of utilised Arctic species, it predicted that harvest levels have become more sustainable since 1970, and although it is not known if they have recovered to pre-exploitation levels, they are likely to currently be within sustainable limits. Therefore, this could also help to explain the increasing trend observed in populations of Arctic utilised species. It also highlights that by examining related indicators in concert with each other, instead of in isolation, a stronger narrative of the potential responses of various taxa to human induced and natural pressures can be revealed.

Strengths and weakness of the wild commodities indicators

If biodiversity indicators are to be used as tools to inform decisions about conservation and management it is important to assess the strengths and limitations of their utility and identify ways in which they may be improved. The two indicators proposed here show potential to track changes in components of the use of wild species that are pertinent to the management of those species, however they should still be considered under development and the trends presented as illustrative of their usefulness as a mechanism or tool. With this in mind, we outline current strengths and limitations of each indicator, and some suggestions for their future development.

Strengths

Both the Utilised Species Index and the Harvest Index have characteristics as to what constitutes an effective indicator (Gregory et al., 2005; 2010 Biodiversity Indicators

Partnership, 2010). Both are relatively easy to understand and communicate conceptually and empirically. They are tractable, with data on most species available over a long time-period. They appear to be responsive to change and, given the growing demand to develop tools for addressing issues related to sustainable use of wild species (Hutton & Leader-Williams, 2003; UNEP/CBD/COP/11/2, 2011), they are policy-relevant. However the ultimate test of their effectiveness will be if they are used to measure progress, enhance understanding, or raise awareness of these issues (2010 Biodiversity Indicators Partnership, 2010).

The Utilised Species Index, like the LPI upon which it is based, also has the potential to be applied at multiple scales (e.g. global, regional, national) or disaggregated to examine population trends in different systems, biomes or vertebrate classes, and hence provide further insight into overall trends. Although not possible to disaggregate the Utilised Species Index by vertebrate class (due to insufficient sample sizes), it was possible to examine trends by system. In this study, different trends in the abundance of populations of freshwater, marine and terrestrial species were observed. Although the species populations of all three have declined since 1970, they have done so at different rates, and in recent years, populations of freshwater species appear to be increasing. Similar patterns were seen in the global LPI (WWF, 2012). Due to inadequate sample sizes it was not possible to examine trends in Arctic utilised species disaggregated by region (e.g. high, low, sub-Arctic), ecological system or vertebrate class. However, as seen in the latest ASTI trend (Eamer et al., 2012), it is likely that significant differences in these categories exist. For example, trends in population abundance of sea-ice dependent species of the high Arctic currently show a decline (McRae et al., 2010; Eamer et al., 2012). It is not known exactly why differences between systems or classes might exist in either the Utilised Species Index or the ASTI indices, but could, in part, be influenced by the availability of underlying data (see further discussion below).

The Harvest Index is an extension of the established and tested Potential Biological Removal model (Wade, 1998; Johnston et al., 2000; Milner-Gulland & Akcakaya, 2001; Marsh et al., 2004), therefore giving the Harvest Index credibility and added strength. Although the PBR has some limitations (see below), using this model as a basis for the Harvest Index is also advantageous because it is relatively simple, adopts a precautionary approach in its assumptions and accounts for some of the uncertainties in the parameters it uses (Wade, 1998; Milner-Gulland & Akcakaya, 2001; Cooke et al., 2012).

Limitations

A limitation of both indicators is that they rely on estimates of total population size, which can be difficult to obtain. Estimates are more commonly available for only part of the population in part of its range, which may not be representative of the species on the whole. Related to this, population estimates may not always be from harvested populations. In this study, data were only coded to the species level and so it is likely that there are population contributing to the index that are not utilised; it is just that they belong to a species which is used in another part of its range. The specificity of the indices could be improved by coding threats to the population level. This can difficult (see further discussion below), however should be attempted where possible so that only estimates from those populations which are harvested are used in calculations of the wild commodities indicators.

A second limitation of both indicators is that not all populations, taxa, systems and regions are adequately represented – at the global level, more data are available for tropical areas. In the Arctic, crucial data from many fish, most whales and seals and polar bears are lacking. The imbalance of geographic representativeness is somewhat accounted for in the Utilised

Species Index by weighting species evenly in tropical and temperate regions, however it is more difficult to address biases introduced by over-representation of certain vertebrate classes (Loh et al., 2005; Collen et al., 2009). The majority of data underlying both the global and Arctic Utilised Species Indices were from birds, followed by fish and then mammals. Intrinsically, the indices are not invalidated if, for arguments sake, there is more bird than mammal species in the index, if more species of bird are truly used or threatened by use. However, there is a considerable lack of data on how many species in each vertebrate class are used and how much is harvested. For example, data on harvested Arctic species is biased towards that on marine mammal and marine fish populations which could mask declines in some seabird colonies that are over-harvested. Once these factors are known an assessment of the representativeness of the dataset(s) can be assessed and potential biases accounted for. Therefore, prioritising research and monitoring programmes to fill data gaps in under-represented classes will serve to make these indices more robust and enhance their usefulness in providing guidance for wildlife management and in tracking sustainable use.

Other limitations are indicator specific. For the Utilised Species Index, although all species in the index are used, it is likely that the cause of decline for most populations of these species is something other than harvest alone. For example, the house sparrow (*Passer domesticus*), which is used in traditional Chinese medicine, may be harvested intensively in some parts of Asia, but is unlikely to be harvested at a similar level in other parts of its range around the world. Therefore this index (and its associated cuts) can reflect changes in the species people use and by proxy their availability to people, but as yet it cannot determine the extent to which use is a driver of those changes. In order to improve this, it may be possible to go through the index and classify each population by its cause of decline. But, diagnosing threat can be difficult due to the diverse nature of both threatening processes and species' response to threats, resulting in threats being distributed in a heterogeneous manner across the globe, certain species being intrinsically more vulnerable to specific threat-types (see Owens & Bennett, 2000; Purvis et al., 2000; Issac & Cowlishaw, 2004; Kotiaho et al., 2005; Price & Gittleman, 2007; Corey & Wait, 2008; Thomas, 2008), and particular extrinsic pressures resulting in non-linear population responses (Lomolino & Channell, 1995; Rodriguez, 2002; Thomas, 2008). Therefore a decline in the index by no means implies that use is universally detrimental to the species as a whole, that use in every population is unsustainable, or that by simply reducing harvest pressure will result in improved trends, particularly if other (potentially larger) factors are driving negative trends.

For the Harvest Index, in addition to incorporating data from a broader range of species, we recommend three other steps to improve its development: (1) harvest and population abundance estimates should ideally be from the same population to avoid skewing estimates of harvest sustainability; (2) it is widely recognised that R_{max} values for many species are highly uncertain. Therefore R_{max} should ideally be based on maximum rates of recovery likely to be witnessed in the field, rather than based on theoretical principals, especially for high R_{max} species. High R_{max} species may have high recovery potential, but may also have highly variable population dynamics (even natural population dynamics) which could result in mis-representative estimates of n_{min} and population status; (3) populations should be between their PBR abundance and carrying capacity. If the method is used on over-depleted populations, the index will not yield correct results because even harvests less than the PBR will be unsustainable if they are greater than the rate of recovery of a heavily depleted population.

Future Directions

To provide a complete picture of the trade and use of a given species, information needs to be collected on both the status of species in the wild ('supply') and the volume of products from those species in the market (‘demand’). Indicators have the potential to provide an overview of trends and drivers of both these elements. The wild commodities indicators presented here currently provide information on ‘supply’ only – i.e. trends in individual source populations over time or trends in the amount and sustainability of harvests. Future work, in addition to addressing the caveats outlined above, should also focus on developing a complementary indicator for ‘demand’– i.e. an indicator that can be used to track changes in market value and market size for wild commodities, or how much end consumers are willing to pay for products from wild species and what motivates them to buy them.

Further, and specific to the Arctic, in particular, there is a need for more information on whether species are used inside or outside the Arctic region (or both). Many migratory species, such as geese, plovers, some fish, sharks and whales, that breed in the Arctic and hence are classified as Arctic species, are almost exclusively harvested outside of the Arctic region. Examination of trends in these species is likely to be both revealing and important for establishing management plans.

In conclusion, although the wild commodities indicators presented here are still limited in their utility and reliability, they do show strong potential to be useful indicators of sustainable use. A concerted effort by both researchers and decision makers to enable more data to become available and broaden their scope will only serve to strengthen them as much needed policy and reporting tools.

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Tables

Table 1: Species and population numbers in each index generated. A breakdown of the number of species and populations in each index by system (freshwater, marine, terrestrial), zone (temperate, tropical) and vertebrate class (amphibian, bird, fish, mammal, reptile) are provided in Appendix II.

Index	Description	No. Species	No. Populations
Utilised Species	Based on trends in species that are utilised by humans	**1501**	**6214**
Freshwater Utilised Species	Based on trends in species that are utilised by humans found in a broad range of temperate and tropical freshwater habitats	**446**	**2256**
Marine Utilised Species	Based on trends in species that are utilised by humans found in a broad range of temperate and tropical marine habitats	**388**	**1650**
Terrestrial Utilised Species	Based on trends in species that are utilised by humans found in a broad range of temperate and tropical terrestrial habitats	**795**	**2302**
Species used for food	Based on trends in species that are utilised by humans for food	**892**	**4500**
Species used for	Based on trends in species that are	**514**	**3423**

sport hunting	utilised by humans for sport hunting		
Species used as pets	Based on trends in species that are utilised by humans as pets	**907**	**3624**
Substantially Used Species	Based on trends in species where evidence exists that they are substantially utilised by humans (based on scale of trade or volume of harvest at local, national, regional and international levels)	**187**	**1100**
Arctic Utilised Species	Based on trends in freshwater, marine and terrestrial Arctic species that are utilised by humans	**147**	**663**
Harvest index	Combines population and harvest data to track the sustainability of the harvest of select utilised Arctic species	**20**	**73**

Figure Captions

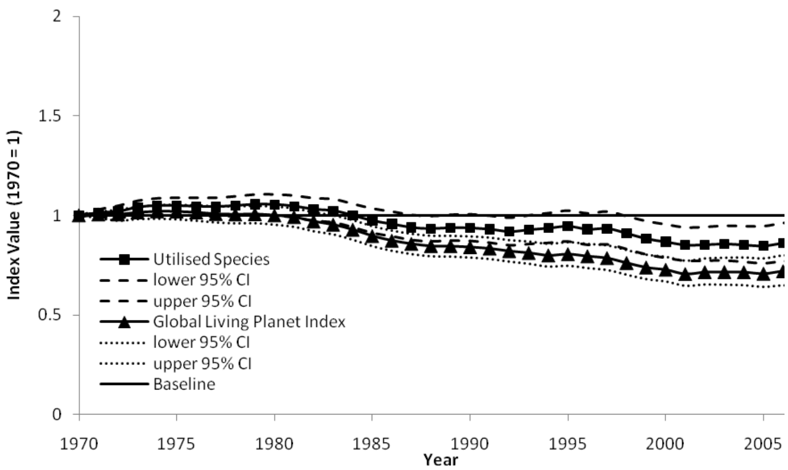
Figure 1: Trends (±95% confidence intervals) in **a)** Utilised Species compared to the Global Living Planet Index (WWF, 2012); **b)** Utilised Freshwater, Marine and Terrestrial Species; **c)** Species used as food for humans, for sport hunting, or as pets; and **d)** Substantially Used Species in evidence categories 3, 4 or 5, between 1970 and 2007. Note confidence intervals not shown for b) and c) to maintain clarity of main trends; these are presented separately in Appendix III.

Figure 2: **a)** Trends (±95% confidence intervals) in Arctic Utilised Species compared to the Arctic Species Trends Index (McRae et al., 2010) between 1970 and 2007; and **b)** Harvest Index of Arctic species between 1970 and 2006. Zones of unsustainable (light grey), cautionary (medium grey) and sustainable (dark grey) harvest levels shown.

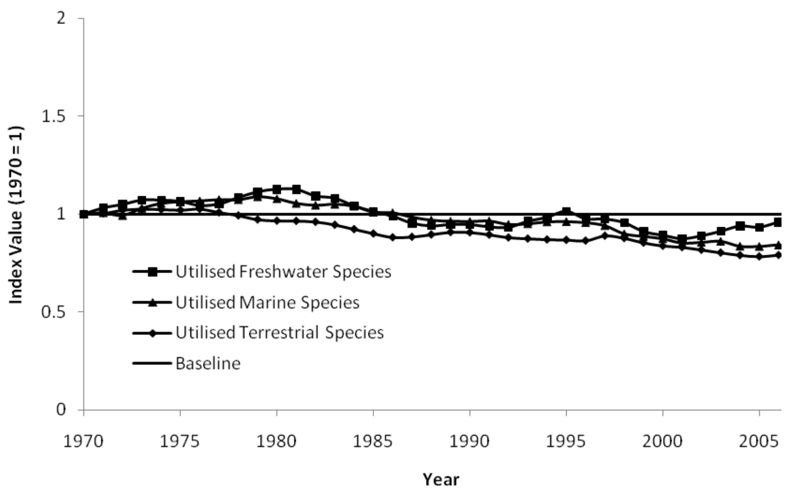
Figures

Figure 1

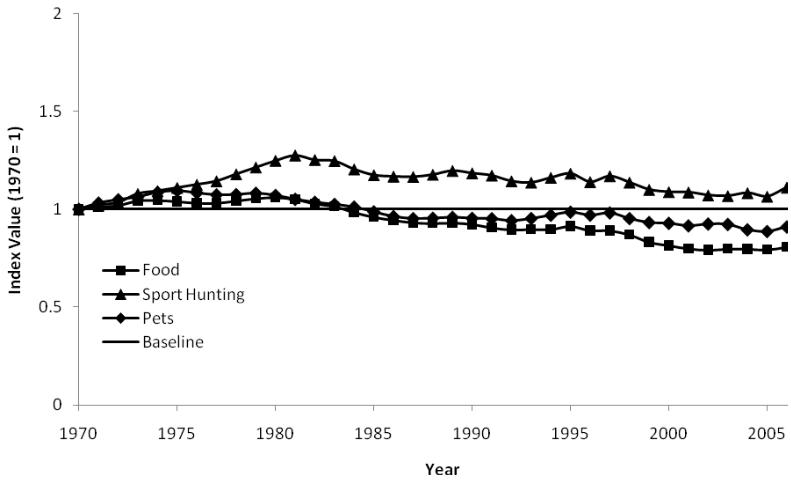
a)



b)

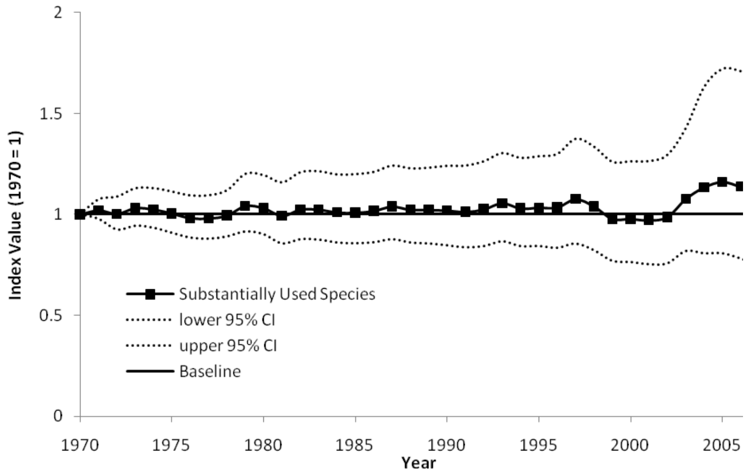


c)



Index Value (1970 = 1)
2
1.5
1
0.5
0
1970
1975
1980
1985
1990
1995
2000
2005
Year
Food
Sport Hunting
Pets
Baseline

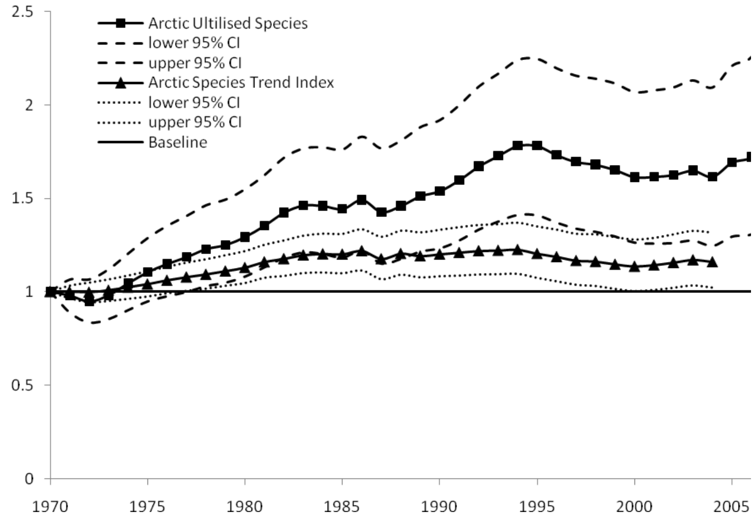
d)



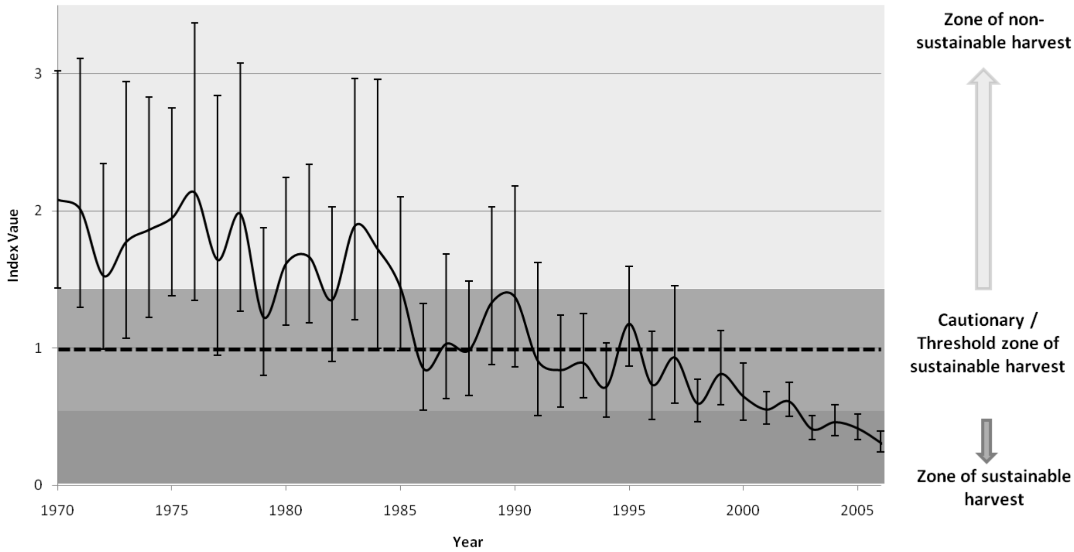
Index Value (1970 = 1)
2
1.5
1
0.5
0
1970
1975
1980
1985
1990
1995
2000
2005
Year
Substantially Used Species
lower 95% CI
upper 95% CI
Baseline

Figure 2

a)


Arctic Ultilised Species
lower 95% CI
upper 95% CI
Arctic Species Trend Index
lower 95% CI
upper 95% CI
Baseline
2.5
2
1.5
1
0.5
0
1970
1975
1980
1985
1990
1995
2000
2005

b)


Zone of non-sustainable harvest
Cautionary / Threshold zone of sustainable harvest
Zone of sustainable harvest
Index Vaue
Year
3
2
1
0
1970
1975
1980
1985
1990
1995
2000
2005

Appendix I

Flow chart used to code whether a species listed in the Living Planet Index (LPI) is utilised.

Datasets used include:

IUCN Red List databases

The IUCN Red List database includes 12,378 species, all classified as in use and/or threatened by use. Includes species in the global bird, mammals and amphibian assessments, the sampled Red List of marine and freshwater fish, plus additional phyla and classes in the Red List classified as being threatened by use, including reptiles, molluscs and plants.

CITES listed species

The CITES trade database, managed by UNEP-WCMC on behalf of the CITES Secretariat, is a unique resource and currently holds 7 million records of trade in wildlife and 50,000 scientific names of taxa listed by CITES. Currently, more than 500,000 records of trade in CITES-listed species of wildlife are reported annually.

Species were classified as ‘used’ if the CITES database recorded permits being issued between 1992 and 2006.

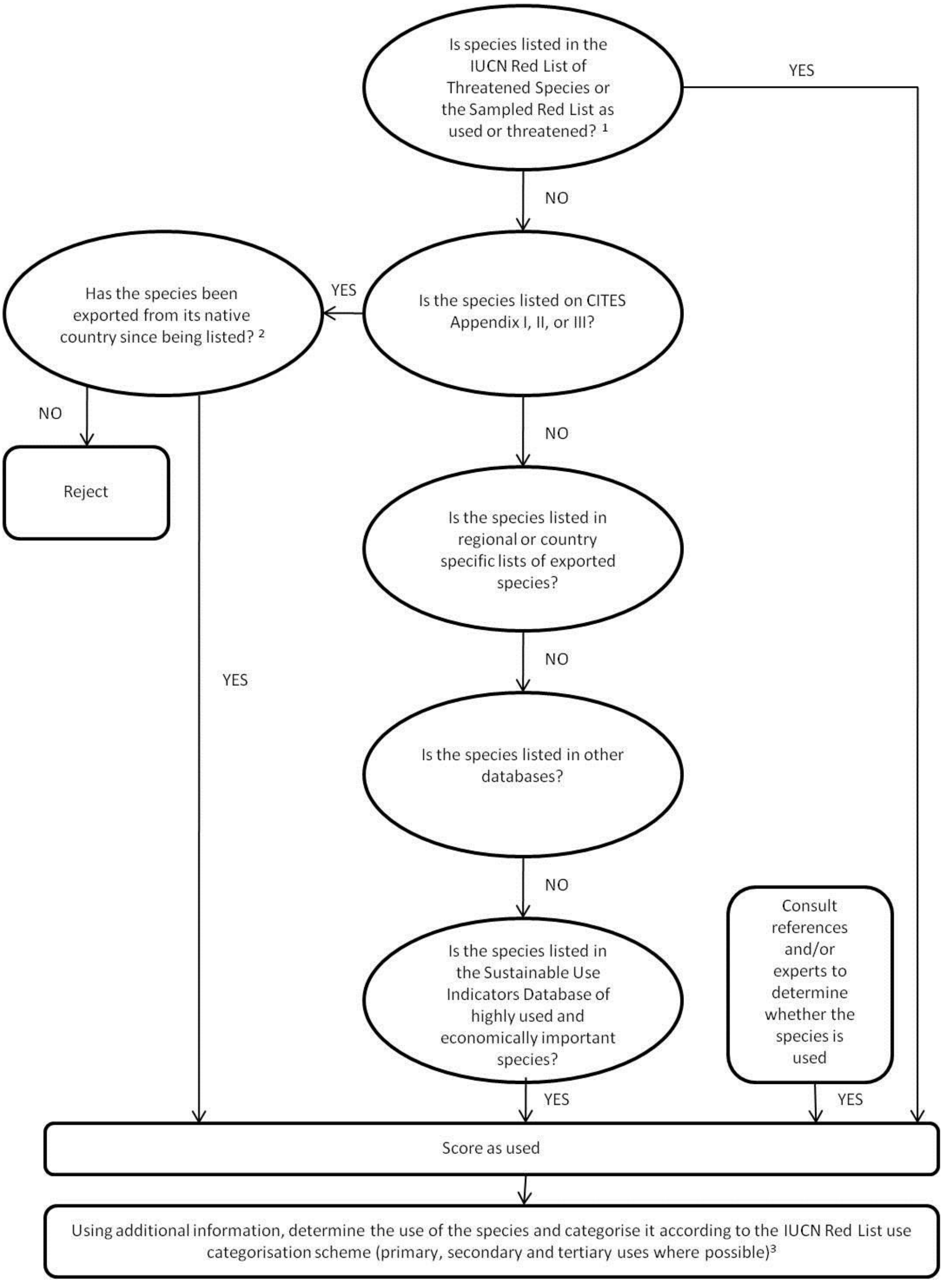
Regional or country specific lists of species:

EU Annex 4 - a list of non-CITES listed species in trade that the EU are actively monitoring

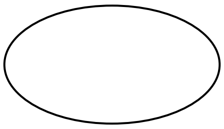
Other

- Avibase (World Bird Database) is an extensive database information system about all birds of the world, containing over 5 million records about 10,000 species and 22,000 subspecies of birds, including distribution information and taxonomy.
- FAO Forestry Country Profiles is a database containing facts and information on forests, forestry and non-wood forest products for some 200 countries and areas in the world.
- International Tropical Timber Organization (ITTO) promotes the conservation and sustainable management, use and trade of tropical forest resources. The annual review statistics database contains information on forest products and trade.
- Centre for International Forestry Research (CIFOR) provides information for decision makers about the use and management of forests in less-developed countries. CIFOR manages an extensive database on the use and trade of forest products.
- Species for whom articles have been published in the FAO publication Non-Wood Forest Product News (NWFP) news - species names extracted from the index of NWFP News from 1994 to 2005.
- The Sea Around Us project (University of British Columbia) collates catch time series starting in 1950 on all fish and crustacean species landed worldwide.
- The Fishbase online database is a global information system with data on nearly all known fish species, including whether they are used by humans.

Flow chart for coding whether a species listed in the Living Planet Index or the Global Population Dynamics Database is in use



Key



Indicates that a list or lists of species known to be in use are matched with the populations in the LPI. If the population refers to a species in one of those lists then it is coded as being used.

Indicates an action - e.g. coding the species as internationally traded or not.

Footnotes

[1] A new version of the Red List utilisation module is being released which will provide more specific and detailed information on the scale and scope of use, and the severity of the threat intentional use poses to the species. These data are already coded as part of the global bird assessment. The assessments for other species provide information on whether the species is used (in the case of birds, mammals, amphibians and some freshwater and marine fish) or threatened by use (for remaining classes) and this information forms the basis of the analysis presented here.

[2] CITES listed species not in trade since being listed are currently coded as being 'not in use' on the precautionary assumption that if a species has a CITES export quota but no permits have been registered, it is unlikely that there is an international market for this species. This does not exclude the possibility of national or local level use or illegal trade, and more information is needed on each of these species before they can be included in the list of 'used' species.

[3] The IUCN Utilisation Classification Scheme consists of 17 categories of end use and was extracted from the report for a use classification workshop held at UNEP-WCMC in June 2008 (http://intranet.iucn.org/webfiles/doc/SSC/RedList/AuthorityF/utilization.rtf).

Appendix II

Species and population numbers in each of the datasets used to generate trends in the Utilised Species and Harvest Indices.

Table A1: Species and population numbers in the Utilised Species database shown by class of vertebrate. Species and population numbers of vertebrates in the Freshwater, Marine and Terrestrial Utilised Species datasets are also displayed, shown by class and zone (Temperate/Tropical). Note, because some species occur in more than one system, the total number of species and populations in the Utilised Species database does not necessarily equal the sum total of species and populations in the Freshwater, Marine and Terrestrial datasets.

Index	Description	Zone	Class	No. Species	No. Populations
Utilised Species	Based on trends in species that are utilised by humans		Amphibian	40	118
			Bird	865	3543
			Fish	303	1177
			Mammal	261	1201
			Reptile	32	175
		Total All		**1501**	**6214**
Freshwater Utilised Species	Based on trends in species that are utilised by humans found in a	Temperate	Amphibian	21	81
			Bird	148	1056

	broad range of temperate and		Fish	83	599
	tropical freshwater habitats		Mammal	10	36
			Reptile	8	21
		Total Temperate		*270*	*1793*
		Tropical	Amphibian	8	17
			Bird	106	316
			Fish	45	68
			Mammal	5	13
			Reptile	12	49
		Total Tropical		*176*	*463*
		Total Freshwater		**446**	**2256**
Marine Utilised Species	Based on trends in species that	Temperate	Amphibian	0	0
	are utilised by humans found in a		Bird	94	737
	broad range of temperate and		Fish	143	400
	tropical marine habitats		Mammal	35	158

			Reptile	3	24
		Total Temperate		*275*	*1319*
		Tropical	Amphibian	0	0
			Bird	44	120
			Fish	55	111
			Mammal	10	29
			Reptile	7	71
		Total Tropical		*116*	*331*
		Total Marine		**388**	**1650**
Terrestrial Utilised Species	Based on trends in species that are utilised by humans found in a broad range of temperate and tropical terrestrial habitats	Temperate	Amphibian	5	7
			Bird	369	879
			Fish	0	0
			Mammal	66	478
			Reptile	3	7
		Total Temperate		*443*	*1371*

Tropical	Amphibian	9	13
	Bird	207	420
	Fish	0	0
	Mammal	135	497
	Reptile	1	1
Total Tropical		*352*	*931*
Total Terrestrial		**795**	**2302**

Table A2: Species and population numbers in the dataset of species that are used as food for humans, that are hunted for sport by humans, or used as pets, shown by class of vertebrate. Species and population numbers of vertebrates in the Freshwater, Marine and Terrestrial Utilised datasets of species that are used for food for humans, that are hunted for sport by humans or used as pets are also displayed, shown by class and zone (Temperate/Tropical). Note, because some species occur in more than one system, the total number of species and populations in the database of all species used for food, sport hunting or as pets does not necessarily equal the sum total of species and populations in the Freshwater, Marine and Terrestrial datasets.

				Food		**Hunting**		**Pets**	
Index	**Description**	**Zone**	**Class**	**No. Species**	**No. Populations**	**No. Species**	**No. Populations**	**No. Species**	**No. Populations**
Species used for specific purposes	Based on trends in species that are utilised by humans for food, hunting or as pets		Amphibian	14	51	5	11	24	77
			Bird	390	2322	285	1867	766	3123
			Fish	279	1091	114	743	73	205
			Mammal	204	913	100	750	39	197
			Reptile	5	123	10	52	5	22
		Total All		**892**	**4500**	**514**	**3423**	**907**	**3624**
Freshwater	Based on trends	Temperate	Amphibian	7	36	3	8	14	57

species	in species that		Bird	100	854	100	900	132	965
used for	are utilised by		Fish	68	538	53	532	28	126
specific	humans for		Mammal	6	25	0	0	0	0
purposes	food, sport		Reptile	4	10	1	1	6	13
	hunting or as	*Total Temperate*		*185*	*1463*	*156*	*1441*	*180*	*1161*
	pets in a broad	Tropical	Amphibian	4	11	32	144	4	6
	range of		Bird	62	220	0	0	95	284
	temperate and		Fish	32	54	20	34	23	28
	tropical		Mammal	4	12	0	0	0	0
	freshwater		Reptile	6	12	1	1	1	2
	habitats	*Total Tropical*		*108*	*309*	*53*	*179*	*123*	*320*
		Total Freshwater		**293**	**1772**	**209**	**1620**	**303**	**1481**
Marine	Based on trends	Temperate	Amphibian	0	0	0	0	0	0
species	in species that		Bird	63	538	34	215	66	593
used for	are utilised by		Fish	138	392	58	144	16	38

specific	humans for		Mammal	32	135	16	68	2	7
purposes	food, sport		Reptile	3	24	2	21	0	0
	hunting or as	*Total Temperate*		*233*	*1089*	*108*	*448*	*84*	*638*
	pets in a broad	Tropical	Amphibian	0	0	0	0	0	0
	range of		Bird	26	68	11	27	33	92
	temperate and		Fish	58	107	17	33	10	13
	tropical marine		Mammal	10	29	2	15	1	1
	habitats		Reptile	7	71	3	29	0	0
		Total Tropical		*94*	*275*	*31*	*104*	*43*	*106*
		Total Marine		**327**	**1364**	**139**	**552**	**127**	**744**
Terrestrial	Based on trends	Temperate	Amphibian	1	1	2	3	3	4
species	in species that		Bird	150	513	154	536	333	792
used for	are utilised by		Fish	0	0	0	0	0	0
specific	humans for		Mammal	37	252	39	379	10	43
purposes	food, sport		Reptile	2	6	0	0	3	7

hunting or as	*Total Temperate*		*190*	*772*	*195*	*918*	*349*	*846*
pets in a broad	Tropical	Amphibian	3	3	16	45	6	10
range of		Bird	61	129	0	0	193	397
temperate and		Fish	0	0	0	0	0	0
tropical		Mammal	117	460	43	288	26	146
terrestrial		Reptile	0	0	0	0	0	0
habitats	*Total Tropical*		*181*	*592*	*59*	*333*	*225*	*553*
	Total Terrestrial		**371**	**1364**	**254**	**1251**	**574**	**1399**

Table A3: Species and population numbers in the Substantially Used Species database shown by class of vertebrate. Species and population numbers of vertebrates in the Freshwater, Marine and Terrestrial Substantially Used Species databsets are also displayed, shown by class and zone (Temperate/Tropical). Note, because some species occur in more than one system, the total number of species and populations in the Substantially Used Species database does not necessarily equal the sum total of species and populations in the Freshwater, Marine and Terrestrial databsets. Only species in evidence categories 3, 4 or 5 are included.

Index	Description	Zone	Class	No. Species	No. Populations
Substantially Used Species	Based on trends in species where evidence exists that they are substantially utilised by humans (based on scale of trade or volume of harvest at local, national, regional and international levels)		Amphibian	0	0
			Bird	27	124
			Fish	77	322
			Mammal	65	508
			Reptile	18	146
		Total All		**187**	**1100**
Freshwater Substantially Used Species	Based on trends in freshwater species found in a broad range of temperate and	Temperate	Amphibian	0	0
			Bird	9	51

	tropical habitats where evidence exists		Fish	2	51
	that they are substantially utilised by		Mammal	2	9
	humans (based on scale of trade or		Reptile	3	9
	volume of harvest at local, national,	*Total Temperate*		*16*	*120*
	regional and international levels)	Tropical	Amphibian	0	0
			Bird	2	13
			Fish	1	2
			Mammal	1	5
			Reptile	11	48
		Total Tropical		*15*	*68*
		Freshwater Total		**31**	**188**
Marine Substantially Used	Based on trends in marine species found	Temperate	Amphibian	0	0
Species	in a broad range of temperate and		Bird	3	26
	tropical habitats where evidence exists		Fish	0	0
	that they are substantially utilised by		Mammal	3	31

	humans (based on scale of trade or volume of harvest at local, national, regional and international levels)		Reptile	3	24
		Total Temperate		*61*	*293*
		Tropical	Amphibian	0	0
			Bird	2	4
			Fish	0	0
			Mammal	1	1
			Reptile	5	65
		Total Tropical		*38*	*127*
		Marine Total		**99**	**420**
Terrestrial Substantially Used Species	Based on trends in terrestrial species found in a broad range of temperate and tropical habitats where evidence exists that they are substantially utilised by humans (based on scale of trade or volume of harvest at local, national,	Temperate	Amphibian	0	0
			Bird	6	13
			Fish	0	0
			Mammal	25	256
			Reptile	0	0
		Total Temperate		*31*	*269*

regional and international levels)	Tropical	Amphibian	0	0
		Bird	8	17
		Fish	0	0
		Mammal	34	206
		Reptile	0	0
	Total Tropical		*42*	*223*
	Terrestrial Total		**73**	**492**

Table A4: Species and population numbers in the Arctic Utilised Species database shown by system (Freshwater, Marine, Terrestrial) and class of vertebrate. There are no amphibian or reptile species in the Arctic Utilised Species database.

Index	Description	System	Class	No. Species	No. Populations
Arctic Utilised Species	Based on trends in freshwater, marine and terrestrial Arctic species that are utilised by humans	Freshwater	Bird	19	34
			Fish	13	72
			Mammal	1	3
		Freshwater Total		*33*	*109*
		Marine	Bird	16	147
			Fish	39	98
			Mammal	15	41
		Marine Total		*70*	*286*
		Terrestrial	Bird	29	110
			Fish	0	0
			Mammal	15	158
		Terrestrial Total		*44*	*268*
		Total All		**147**	**663**

Table A5: Species and population numbers in the Arctic Harvest Index database shown by system (Marine, Terrestrial) and class of vertebrate. No harvest data was available for freshwater species.

Index	Description	System	Class	No. Species	No. Populations
Harvest index	Combines population and harvest data to track the sustainability of the harvest of select utilised Arctic species.	Marine	Fish	6	11
		Marine Total		*6*	*11*
		Terrestrial	Bird	4	17
			Mammal	10	45
		Terrestrial Total		*14*	*62*
		Total All		**20**	**73**

Appendix III

Table A6: Index and 95% confidence intervals (CI) for each of the indices.

Index	Year	1970	1975	1980	1985	1990	1995	2000	2005	2007
Utilised Species	Index	1.00	1.05	1.05	0.97	0.94	0.95	0.87	0.85	0.86
	Lower 95% CI	1.00	1.00	1.00	0.91	0.87	0.87	0.79	0.76	0.77
	Upper 95% CI	1.00	1.09	1.11	1.04	1.01	1.03	0.96	0.95	0.97
Freshwater	Index	1.00	1.06	1.13	1.01	0.95	1.01	0.89	0.93	0.97
Utilised Species	Lower 95% CI	1.00	1.00	1.03	0.90	0.82	0.86	0.74	0.75	0.78
	Upper 95% CI	1.00	1.13	1.23	1.15	1.10	1.20	1.09	1.16	1.23
Marine Utilised	Index	1.00	1.06	1.08	1.01	0.96	0.96	0.87	0.83	0.83
Species	Lower 95% CI	1.00	0.97	0.96	0.88	0.83	0.81	0.72	0.67	0.66
	Upper 95% CI	1.00	1.15	1.19	1.14	1.10	1.13	1.05	1.03	1.04
Terrestrial Utilised	Index	1.00	1.02	0.97	0.90	0.91	0.87	0.84	0.78	0.79

Species	Lower 95% CI	1.00	0.95	0.89	0.83	0.83	0.78	0.75	0.69	0.68
	Upper 95% CI	1.00	1.09	1.04	0.98	0.99	0.96	0.94	0.90	0.93
Species used for	Index	1.00	1.04	1.06	0.96	0.92	0.91	0.82	0.79	0.83
Food	Lower 95% CI	1.00	0.99	0.99	0.89	0.85	0.82	0.72	0.69	0.72
	Upper 95% CI	1.00	1.09	1.13	1.04	1.01	1.01	0.92	0.92	0.97
Species used for	Index	1.00	1.11	1.25	1.17	1.18	1.18	1.09	1.07	1.14
Sport Hunting	Lower 95% CI	1.00	1.05	1.15	1.06	1.05	1.02	0.92	0.89	0.94
	Upper 95% CI	1.00	1.18	1.36	1.30	1.33	1.37	1.31	1.30	1.42
Species used as	Index	1.00	1.09	1.07	0.99	0.95	0.99	0.93	0.89	0.91
Pets	Lower 95% CI	1.00	1.04	0.98	0.88	0.84	0.86	0.80	0.75	0.77
	Upper 95% CI	1.00	1.15	1.17	1.11	1.08	1.13	1.08	1.04	1.08
Substantially Used	Index	1.00	1.00	1.03	1.01	1.02	1.03	0.98	1.16	1.11
Species	Lower 95% CI	1.00	0.91	0.90	0.86	0.85	0.84	0.77	0.81	0.75
	Upper 95% CI	1.00	1.11	1.19	1.20	1.24	1.29	1.26	1.72	1.68
Arctic Utilised	Index	1.00	1.11	1.29	1.44	1.54	1.78	1.61	1.69	1.83

Species	Lower 95% CI	1.00	0.95	1.08	1.18	1.23	1.41	1.26	1.29	1.38
	Upper 95% CI	1.00	1.29	1.55	1.76	1.92	2.25	2.07	2.21	2.44