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Is Svalbard a pristine ecosystem? Reconstructing 420 years of human presence in an Arctic archipelago.

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ABSTRACT. The Arctic is commonly perceived as a pristine wilderness, yet more than four centuries of human industry have not left Svalbard untouched. This paper explores the historical dimension of human-induced ecosystem change using human presence as a proxy. Its aims are fourfold: to reconstruct and quantify historical human presence, to ascertain if human presence is a suitable indicator of long-term anthropogenic pressure, to deduce trends in anthropogenic pressure on five selected species of game animal, and to postulate trends in their subpopulation sizes. Published sources give rise to 57 datasets dealing with the annual voyages to Svalbard as well as the participants in them. All known archaeological sites are visualised in a distribution map. Despite the large amount of data, the quantification of historical human presence remains biased and partial. Only with the aid of a timeline of known milestones is it possible to make hypotheses about changes in anthropogenic pressure and animal subpopulations over time. The exercise is nonetheless a necessary and instructive one: it confirms that the erroneous view of Svalbard as a pristine ecosystem hinders timely historical-ecological research. Future work must aim at the systematic quantification of past human impact in a holistic approach to environmental conservation and restoration.

Introduction

The Arctic is commonly perceived as a pristine wilderness. Svalbard in particular has known no indigenous people. From a historical point of view, however, references to 'a virtually untouched environment in Svalbard' (Norwegian Government 2001) are as misleading as allusions to 'the rape of Spitsbergen' (McGhee 2006: 173). Both extremes underrepresent and devalue centuries of human commitment and endeavour in the remote archipelago. First documented by Willem Barentsz in 1596, Svalbard now benefits from exceptional archaeological and historical records of subsequent periods of whaling, sealing, and hunting and trapping. Yet, the data have not been analysed sufficiently to offer a pre-arrival baseline of the high Arctic ecosystem or to provide long-term ecological trends. Generalisations such as '[walruses] were hunted virtually to extinction in Svalbard during three and a half centuries of heavy commercial exploitation' (Norwegian Polar Institute, nd) are not based on sound historical knowledge. At worst, they hamper research in this direction.

This paper explores the historical dimension of Svalbard's marine and terrestrial ecosystems. It places focus solely on historical human presence as a proxy of human-induced pressure. Its aims are 1) to reconstruct and quantify historical human presence using only published sources and public databases; 2) to ascertain if human presence is a suitable indicator of long-term anthropogenic pressure on the archipelago; 3) to infer trends in anthropogenic pressure on five species of game animal; and 4) to postulate trends in the subpopulation sizes of these animals.

This study is a first step towards adding time-depth to the current practices of environmental monitoring. Historical ecological data are as of yet not being sought systematically and are therefore lacking from the 'new understanding of the links between different kinds of environmental pressures and their impacts on nature' (MOSJ nd). In the Arctic as elsewhere, historical ecology is a key component in an integral approach to conservation, restoration, and the enhancement of natural and cultural heritage (Crumley 2007).

Concepts, definitions, and delineations

This study uses the interdisciplinary concept of historical ecology, which is defined as 'the study of past ecosystems by charting the change in landscapes over time' (Crumley 1994: 6). Although it centres on Svalbard, it strives to achieve universal applicability by adopting the terminology of the Millennium Ecosystem Assessment (Nelson and others 2005). Hence, an ecosystem must be understood as 'a dynamic complex of plant, animal and microorganism communities and the non-living environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems vary enormously in size; a temporary pond in a tree hollow and an ocean basin can both be ecosystems' (Hassan and others 2005: 27). Current research recognises the need to identify and assess both socio-economic and environmental drivers that affect ecosystems and their services (Anastasopoulou and others 2007). It is not enough to ask how and why environmental change is happening; it is also important to address scale, magnitude, and speed. A common approach does not exist. This study adopts the coupled DPSIR-SES approach as outlined by Anastasopoulou and others (2007).

The DPSIR-SES approach consists of two components. The DPSIR component examines and illustrates

the effects of human activities on ecosystems. It has widely been used by the European Environment Agency (EEA) and by EUROSTAT (Smeets and Weterings 1999; Jessinghaus 1999). 'According to its terminology, social and economic developments (Driving Forces, D) exert Pressures (P) on the environment and, as a consequence, the State (S) of the environment changes. This leads to Impacts (I) on ecosystems, human health, and society, which may elicit a societal Response (R) that feeds back on Driving Forces, on State or on Impacts via various mitigation, adaptation or curative actions' (Maxim and others 2009: 12). The shortcomings of the DPSIR model that have most bearing here are the disregard of environmental drivers, the difficulty in identifying crucial variables, and the lack of spatial and temporal scales.

To remedy these shortcomings, particularly concerning the artificial distinction between human and natural systems, the complementary component of the socio-ecological systems (SES; Berkes and Folke 1998) views the human and natural subsystems as mutually interacting. In addition, SES addresses the issue of scale as it considers subsets of the human and natural subsystems in larger subsystems and their interactions (Anastasopoulou and others 2007). A fjord can thus be an ecosystem, yet it is part of the island of Spitsbergen, which may also be seen as an ecosystem. Similarly, the temporal scale of Svalbard's socio-ecological systems finds expression in interrelated historical records, current research, and future models. In its entirety, a coupled DPSIR-SES approach is therefore a suitable tool with which to investigate the complex dynamics of the spatial and temporal nature of Arctic ecosystems.

In this study, drivers (D) of ecosystem change are occasionally touched on as a means of introducing different historical themes in the living-resource exploitation in the Arctic. The Millennium Ecosystem Assessment (Hassan and others 2005) puts forward the following terms and definitions:

Drivers of environmental change are any natural or human-induced factors that directly or indirectly cause a change in an ecosystem.

Direct drivers are the physical, biological, or chemical processes that tend to directly influence changes in ecosystem goods and services.

Indirect drivers are factors that operate more diffusely than direct drivers, often by altering one of the more direct drivers.

Anastasopoulou and others (2007) identify the following indirect drivers in a literature review: demography, economy, socio-politics, science and technology, and culture and religion. All of these have influenced Svalbard in the past and continue to do so. The authors further list a range of direct drivers, of which harvest and resource consumption, over-exploitation, and species introduction/removal have the greatest relevance here, while climate variability and change, natural, physical, and biological drivers, as well as disease and war will also have played an intermittent role.

The study's primary focus, however, lies on anthropogenic pressure (P) on Svalbard's marine and terrestrial ecosystems over time. Human presence is used as the basic quantitative unit. In Svalbard, human presence has primarily been motivated by economic drivers such as the European demand for the products of polar living resources. These living resources, or simply game animals, included the marine mammals bowhead whale (*Balaena mysticetus*), Atlantic walrus (*Odobenus rosmarus*), and polar bear (*Ursus maritimus*) as well as the terrestrial mammals Arctic fox (*Vulpes lagopus*) and Svalbard reindeer (*Rangifer tarandus platyrhynchus*). Consequently, historical human presence took the form of whalers, sealers, and hunters and trappers, who engaged in activities such as harvest and resource consumption, and over-exploitation, although 'the point at which harvest and resource consumption pass a critical threshold where they are no longer considered sustainable, and are thus categorized as over-exploitation, is not clearly defined' (Anastasopoulou and others 2007: 24). For the purposes of this paper, a fundamental distinction is made between historical human presence and subsequent human activity, that is the hunt. Although some historical catch data is available that would provide a more direct measurement of the hunt, this data has been reserved for a forthcoming publication.

The spatial scale of this study takes both the marine and the terrestrial ecosystems of Svalbard into account. Ideally, it should encompass the former habitats of the five selected species of game animal, where these can be delineated and in which historical human presence, and thus the hunt, will have taken place. As can be seen in Fig. 1, Hacquebord (1999) reconstructed the former annual migration route of the Svalbard subpopulation of the bowhead whale to have led from the southern tip of Greenland via the small volcanic island of Jan Mayen to the very north of Svalbard and back. In this reconstruction, Zemlya Frantsa-Iosifa [Franz Josef Land] and any islands further east were not part of the so-called Greenland Fishery, in which the bowhead whale was once heavily pursued. In addition to the Greenland Fishery, there was also a Davis Strait Fishery to the west of Greenland.

The former habitats of the other four species have not yet been reconstructed, and so their modern distributions are adhered to. The Atlantic walrus can be found from eastern Canada to Novaya Zemlya. Of interest to this study is its Svalbard – Zemlya Frantsa-Iosifa subpopulation, which may be connected to the Eastern Greenland one to its west as well as the Kara Sea – Southern Barents Sea – Novaya Zemlya one to its east (Born and others 1995). Some polar bears are known to roam widely, but based on a female preference for specific denning areas, a Barents Sea subpopulation has been identified, which centres around Svalbard, while Zemlya Frantsa-Iosifa and Novaya Zemlya lie along its eastern edge (Derocher and others 2013). The Arctic fox is a truly circum-Arctic animal. While the

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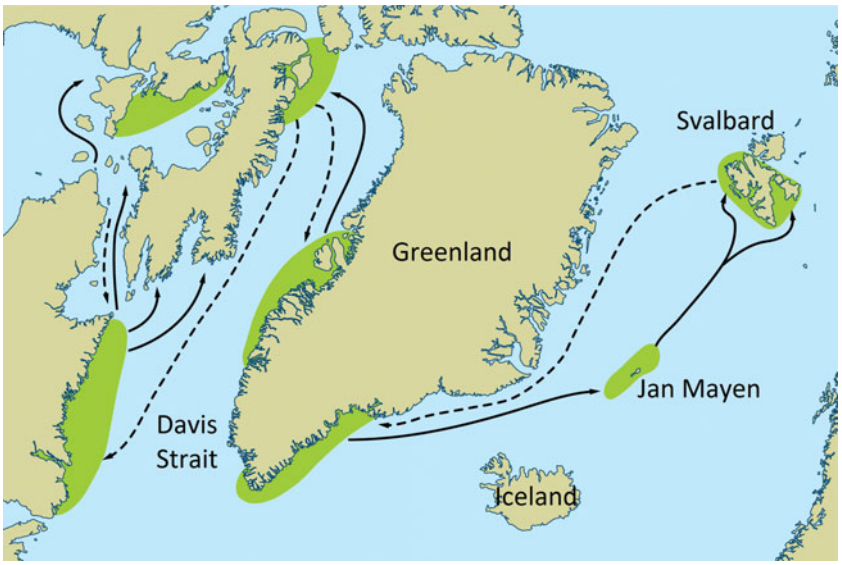

Fig. 1. Reconstruction of former annual migration routes of the bowhead whale in the seventeenth and eighteenth centuries. The Greenland Fishery lay to the east of Greenland, the Davis Strait Fishery to the west. (Courtesy of Frits Steenhuisen.)

lemming-dependent ecotype in Fennoscandia is critically endangered, the Svalbard subpopulation comprises the coastal ecotype that thrives on mixed food sources (Dalén and others 2006). In winter, Arctic foxes are able to leave the main island mass across the frozen sea, which has helped to replenish the stock on Bjørnøya but not on Jan Mayen. The Svalbard reindeer is an endemic species, but it cannot be found everywhere in the island group. The animals are confined to certain biogeographical zones in a few large fjord systems (Rekacewicz 2005). Hence, the diverse ranges of these five species highlight the fact that Svalbard takes a central position in a vast marine ecosystem that is by no means confined to the coastal waters of the archipelago. The terrestrial ecosystem, on the other hand, is largely limited to the islands, but from time to time, extensive sea ice cover may increase species mobility. The species-specific spatial scale of both ecosystems must be treated in its entirety, which adds greatly to the complexity of Svalbard historical ecology.

The temporal scale of this study begins at the arrival of the Barentsz expedition in 1596 and must by definition include the entire historical human presence in Svalbard until the present day. Important milestones that find mention below are the years in which the selected species were protected, with the exception of the Arctic fox. Hunting, trapping, and fishing regulations in Svalbard have become increasingly more strict. In 1997, MOSJ (Miljøovervåkting Svalbard og Jan Mayen [Environmental Monitoring of Svalbard and Jan Mayen]) was established. From then on, there exists comprehensive environmental monitoring data. For easy reading, it is sometimes necessary to refer to 'the whaling period' or 'the mining period'. However, the historical themes overlap, and a conscious effort is made to move away from the traditional temporal segregation in an attempt to portray and treat Svalbard historical ecology as a whole. Collectively, more than four centuries of anthropogenic pressure have given rise to the archipelago as we know it today.

In addition to delineating the spatial and temporal scales of human presence in Svalbard ecosystems, it lies within the scope of this paper to infer the magnitude and speed of anthropogenic pressure on the five indicator species that arose from human activities such as whaling, sealing, and hunting and trapping. This inferred anthropogenic pressure can in turn be used to postulate the subpopulation densities over time. *State* (S) showing the condition of the ecosystem at any given time, *impact* (I) describing the ultimate effects of any changes in state, and *response* (R) demonstrating the efforts of society to solve any problems will also be dealt with in future research.

Materials and methods

Historical sources

Any research into Svalbard's human past benefits from a wealth of historical documents. This study utilises data from easily accessible publications. No additional primary research was carried out. Due to the highly selective and commonly nationalistic nature of previous historical research, the full potential of the available sources has not always been realised, and the data concerning the human presence in Svalbard is very fragmented. Leaning on Arlov (1989, 2003) and Thuesen (2005), a 420-year timeline was initially generated, broadly outlining milestones in human arrival, industry, and ecology. In an effort to organise the various datasets, an extensive informal database was then created. For the

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purposes of this paper, a distinction is made between the number of vessels or voyages and the number of participants.

Vessels are defined here as the seagoing ships that granted people access to Svalbard. They do not include the smaller boats that improved mobility around the islands and on the open water. Vessels commonly functioned as floating bases for early whalers and sealers. While hunting and trapping expeditions initially used their own ships, too, smaller parties or individuals paid for the transfer to the islands in later years. These transfers are not counted as separate voyages under the heading of hunting and trapping, but the vessels involved may well be tallied under tourism, science, or mining. Where a vessel as such could not be identified but an expedition is known to have sailed or where a vessel is known to have made more than one trip in a year, the number of voyages is used. The goal is to create the most complete record to date of the annual number of vessels and voyages to Svalbard as an indication of total historical human presence, regardless of where these vessels were from and what activities they engaged in. Overlapping datasets of a similar theme are not normally added as this is likely to create a yearly total that is too large. Instead, the highest record in such datasets is usually selected. The reason is that where anthropogenic pressure on ecosystems is concerned, it is arguably better to estimate too high a human impact, on which to base an effective remediation strategy, as opposed to too low an impact, risking too little remediation effort.

Participants are all people who participated in the voyages to Svalbard. Again, the most complete record to date of the annual number of participants in the archipelago acts as an indicator of total historical human presence, regardless of gender and age, nationality, or purpose of the visit. Concerning conflicting datasets, the selection once again favoured the higher record.

Due to the fragmented nature of no less than 57 different datasets, it is instructive and informative to outline which sources were consulted and how each was modified before any results could be arrived at. Conway (1906) is a timeless authority on Svalbard history and cartography. Nonetheless, his exemplary research demonstrates the main flaw of many historical works concerning the archipelago: it is published in story-based form, which makes it extremely laborious to extract quantitative data from it. Based on Conway (1906) among others, Holland (1994) has compiled a commendable encyclopaedia on Arctic exploration and development until 1915. Faced with insurmountable information, he summarises the annual whaling voyages to Spitsbergen and selects only the best known or most influential expeditions to the island group in the late nineteenth and early twentieth centuries. Holland's (1994) encyclopaedia, however, is also a catalogue in text-form; here and elsewhere, the time-consuming step of converting the information into tabulated data by reading through every page needed to be undertaken.

The whaling period

The data contained in Holland (1994) contributes to the number of vessels and voyages but not to the number of participants. It covers tentative British expeditions to Bjørnøya and Spitsbergen from 1603 to 1610; annual whaling voyages from 1611, when the first bowhead whale was killed, to 1659; whaling voyages excluding the Dutch very sporadically from 1669 to 1754; London whaling voyages (1725–1732); British whaling voyages (1846–1898, then sporadically to 1911); and combined British whaling and sealing voyages (1857–1885, then sporadically to 1910). In 1719, the diversification of whaling into a new hunting ground in Davis Strait (Fig. 1) occurred, after which historians are frequently faced with the difficulty of distinguishing between the Greenland Fishery and the Davis Strait Fishery. Like Holland (1994), every other source consulted in this study had to make selections. It is outside the scope of this paper to check the reliability of each.

As one of the few sources to work with tabulated data, De Jong (1979) reproduces Bruijn and David's (1975) number of Amsterdam whale-ships from 1640 to 1664. The last four years are superseded by De Jong's (1979) record of all Dutch whaling from 1661 to 1826. From 1719 to 1826, De Jong (1979) distinguishes between vessels to the Greenland Fishery and vessels to the Davis Strait Fishery. He also offers a dataset of Hull whalers to both fisheries (1772–1833), and while it is not ideal to use a dataset that mixes the hunting grounds, this paper utilises the data from 1801 to 1813 as no other information is readily available for this period. With the exception of 1814, De Jong's (1979) data on only the Greenland Fishery from 1814 to 1832 is replaced by Jackson (1978). De Jong's (1979) data on Hamburg whalers (1669–1801), Hamburg sealers (1716–1801), Bremen whalers (1674–1807), and Bremen sealers (1728–1766) is not known to conflict with other published datasets. In this case, whalers and sealers refer to the specialised vessels involved. De Jong (1979) does offer the number of participants in Dutch whaling from 1661 to 1826, again distinguishing between the Greenland and Davis Strait fisheries after 1719, but this number is arrived at by taking an average crew of 42 per voyage. De Jong (1972–1979) focuses on the heyday of Dutch whaling from 1640 to 1803, when the Anglo-Dutch War (1803–1810) and the Napoleonic wars (1803–1815) practically forced the Dutch out of the whaling industry. Nonetheless, some Dutch whalers continued their annual voyages from 1804 to 1873, and these are treated by Schokkenbroek (2008).

A last source on whaling, Jackson (1978) initially distinguishes between English whalers (1733–1800) and Scottish whalers (1750–1800). As mentioned above, De Jong's (1979) data on Hull whalers in mixed fisheries is used to close a gap until Jackson (1978) tallies the British whalers in the Greenland Fishery from 1815 to 1842. From 1904 to 1912, Jackson also provides data on whalers and whales caught off Shetland, the Hebrides, and Ireland, but it is not known if this influenced the

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Svalbard ecosystem at all, and the information has not been taken into account.

The Pomor period

Despite its shortcomings, the data about whaling is much less disjointed than the limited information concerning Russian hunters of the eighteenth and nineteenth centuries. These Pomors from the White Sea region primarily caught walruses, but they also took every opportunity to hunt polar bears, Arctic foxes, and reindeer among a broad spectrum of other animals for subsistence purposes. Kraikovsky and others (2012) refer to a letter which places a Pomor vessel on Spitsbergen in 1709. In 1748, a petition for the departure of a vessel to Spitsbergen was signed, another in 1795. It is assumed that both vessels sailed. The most reliable account of departures for the archipelago is based on customs records in Archangelsk, Onega, Kola and Mezen from 1784 to 1790. These customs records detail both the number of voyages and the number of participants per year, albeit for only seven years. Kraikovsky and others (2012) suggest that Pomor vessels were generally manned by an average crew of between 12 and 20.

Hultgreen (2000) refers to another letter placing the Pomors in Svalbard in 1710. She replicates Belov's (1956) table of Russian vessels that either arrived at or left from Archangel harbour between 1787 and 1802. For the purposes of this paper, only the vessels and crews going to or returning from Svalbard have been considered. Hultgreen's (2000) consultation of a wide range of historical sources resulted in a partially quantified list of Pomor expeditions from 1710 to 1852. Where numbers are not explicitly stated, this study has assigned a vessel to each helmsman or lone winterer and an average crew of 12 (Kraikovsky and others 2012) to every ship.

An article in *Norsk Handels-Tidene* from 1827 (Lønø 1972) supplements this piecemeal record further. It states that an average of six to eight Pomor vessels used to leave for Svalbard annually before 1808, but after the Anglo-Russian War (1808–1812), there were only one to two ships per year. The higher averages are selected spanning a period from 1768, when the monopoly of the Russian whaling companies ended and any Pomor was free to hunt on Spitsbergen (Kraikovsky 2009) to the publication of the article in 1827. Yet, this inexact science does little to better the resolution of the Pomor record.

Norwegian hunting and trapping

Regarding hunting and trapping, Holland (1994) irregularly lists expeditions over the period between 1822 and 1909, but never more than four per year. In this paper, these expeditions are equated with voyages undertaken, noting the highly selective nature of Holland's work as well as a strong bias towards wintering parties. Lønø (1972) refers to both wintering parties and summer expeditions, also tallied as voyages, but this record is sporadic from 1604 to 1860 as his primary focus is on the annual catch of walruses. Kjær (2008) names the vessels in the southern Norwegian sealing fleet and indicates when each was engaged in sealing. From this, the annual number of voyages can be reconstructed for the period from 1863 to 1976. Furthermore, Kjær (2011) provides a table with the annual number of ships of the Tromsø sealing fleet between 1859 and 1909. Lønø (2014) is the primary source for the annual number of participants in hunting and trapping from 1795 to 1973. This catalogue, however, only concerns wintering parties, and as with Holland (1994), it is time-consuming to extract the relevant data. Lønø (1972) adds but little to these figures. Next to nothing is known about the participants in the summer expeditions, that is the sealing.

Scientific expeditions

Despite the fact that the anecdotes of early explorers and scientists on Spitsbergen enjoy great popularity (for example Scoresby 1820; Lottin and others 1842; Rave 1916; Goldberg 2003), there is no comprehensive catalogue of them, let alone a quantitative record. Holland (1994) is again a first port of call for the number of international exploratory and scientific voyages to the archipelago. His encyclopaedia offers intermittent entries between 1758 and 1915, never more than four in any year, which are again highly selective and not representative. To get a better idea, Jones (2008) was consulted, but she bases her study of Swedish scientific expeditions to Spitsbergen from 1758 to 1908 entirely on Holland. Neither take the time to distinguish between the large-scale expeditions during which the scientific staff and crew were based on purpose-built scientific vessels, and the small-scale efforts by small parties or individuals. This makes it very difficult to quantify the exploratory and scientific endeavours of the late nineteenth and early twentieth centuries, let alone their environmental impact.

The mining period

The mining period of the early twentieth century, too, is the subject of many popular narratives (for example Mansfield 1910; Brown 1920; Dole 1922), but an overarching and quantifying synthesis along the lines envisaged by the LASHIPA project (Avango and Hacquebord 2008) is missing. Holland's (1994) record of international expeditions undertaken for mining-related purposes between 1872 and 1913 is very poor, primarily because true to mining-mania fashion, there were so many journeys that it is very difficult to keep count. Hartnell (2009) lists the summer workforce of the American Arctic Coal Company (ACC) from 1905 to 1915. Kruse (2013) provides a record of the British summer workforce from 1901 to 1914, and after a voluntary absence of the British during World War I, from 1918 to 1928, with a last entry in 1948. Rossnes' (1993) outline of seasonal availability of living resources suggests that summer workforces would have hunted different game animals to those hunted in the winter. Yet again, the higher of the two records of historical human presence is selected to

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represent the maximum potential anthropogenic pressure at the time.

The number of annual vessels and voyages undoubtedly increased quite substantially as mining became more commonplace on Spitsbergen, but if a detailed record has been kept, it has not been discovered during the course of this study. As far as the participants in mining are concerned, Statistics Norway (2015) offers historical statistics for Svalbard from 1907 to 2007. The total summer workforce (1917–1951), the total winter workforce (1907–1978), the Norwegian workforce (1938–2005), and the total population (1923–2007) are represented. Notably, between 1907 and 1916, the total winter workforce looks suspiciously like Hartnell's (2009) ACC summer workforce, and the figures have been disregarded. The total population has been refined further into the Norwegian population (1930–2007) and the Russian population (1950–2007). From across these statistics, the highest record for any given year has always been taken to represent the human presence. Generally speaking, the record of the total summer workforce was replaced by that of the total winter workforce and in turn the total population. The record of the Norwegian population was made use of only once, and the Russian population not at all. Besides filling this one gap, the study does not differentiate between nationalities.

Tourism

Another important industry with bearing on this study is tourism, which frequently went hand in hand with trophy hunting prior to the protection of the most prized game animals. Holland (1994) picks several examples of early yachting sportsmen and later holiday cruises between 1856 and 1913, the legacies of which are rich travel accounts now in need of systematic study and quantification (for example Lamont 1861, 1876; Dufferin 1867; Philipps-Wolley 1884). Reilly (2009) introduces the cruise ships that frequented Spitsbergen between 1881 and 1914. From this, the total number of annual voyages has been reconstructed as well as the potential maximum of passengers and crew per year. That is not to say that the voyages were always fully booked, but it offers an upper limit of the human presence through the tourism industry at the time. Between 1915 and 1996, data on tourism is few and far between with Thuesen (2005) providing three readings in the mid-1930s and another six after World War II. In recent decades, the Governor of Svalbard (2014) has been monitoring the annual number of overseas cruise ships (1997–2014), the annual number of overseas cruises, that is voyages made (2002–2014), the annual number of expedition cruise ships (2001–2014), and the annual number of expedition cruises, that is again voyages made (2013–2014). This includes the annual number of passengers and crew on all overseas cruises (1997–2014) and expedition cruises (2001–2014). Unfortunately, there has been no way to monitor the private small boats that visit Svalbard, and the number of their passengers is largely unknown bar two readings in 2012 and 2013.

As a last indicator of the magnitude of human presence in Svalbard over time, the annual number of passengers who access the archipelago through Svalbard Airport in Longyearbyen is available intermittently since 1997 and continuously from 2001 to 2014. This completes the list of published sources consulted and the 57 datasets generated in the process.

Archaeological sources

For Svalbard, the historical and archaeological sources complement each other. The Norwegian database system for cultural heritage known as *Askeladden* (the Ash Lad, after a popular folk tale) provides an indication of the spatial distribution of human presence across Svalbard over time. Using search terms like whaling, walrus hunting, Russian hunting, hunting, (scientific) expeditions, mining, and war, most if not all archaeological sites on the archipelago could be identified. Their geospatial data was exported and plotted in GIS. A base-map of the biogeographical zones of Svalbard (Norwegian Polar Institute 2014) was selected to aid the visualisation of the distribution of the sites. Unfortunately, it was not possible to achieve a greater temporal resolution beyond the division into the crude historical themes suggested by the search terms. None of Svalbard's archaeological sites registered in Askeladden are dated properly. It is unclear if this is an oversight of the database administration or a shortcoming of previous archaeological fieldwork. Another understandable yet regrettable circumstance is that the archaeological cut-off point in Svalbard is the year 1945; later constructions or events of ecological significance are therefore not registered let alone geospatially referenced in Askeladden nor elsewhere.

Results

After combing through the sources outlined above, the 57 datasets arrived at were subdivided into those dealing with vessels and voyages (36) and those pertaining to participants (21). The data of each subset were added and their totals plotted in the form of column charts. No thematic or temporal segregations have been made. The magnitude of human presence in Svalbard over 420 years has for the first time been treated holistically.

Fig. 2 represents historical human presence in Svalbard as the total number of vessels or voyages to the archipelago per year. The phrase 'to the archipelago' must be understood to mean into the marine and/or terrestrial ecosystems previously delineated. The marine ecosystem in particular has been shown to extend far beyond the island group to incorporate at its maximum extent the whole of the former Greenland Fishery. In the chart, there appear to be two main phases of human presence, the first lasting more than two centuries from the early 1600s until approximately 1830, the second from the mid-1840s until the outbreak of World War I. Furthermore, there is a lack

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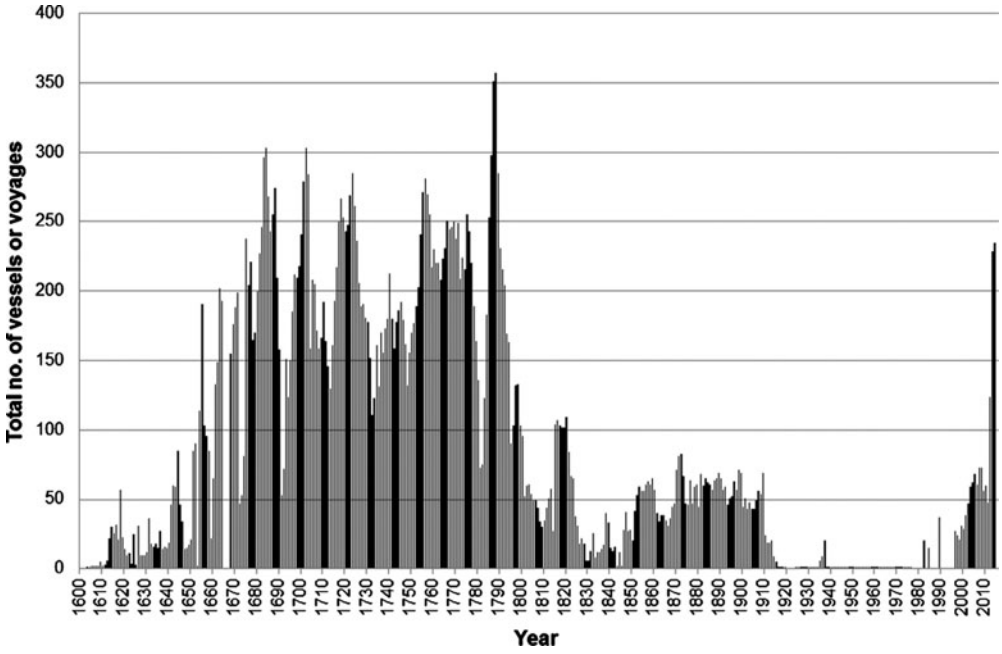

Fig. 2. A column chart of the total number of vessels or voyages to Svalbard per year between 1603 and 2014 as an indication of human presence in the archipelago over time. (From 36 published sources.)

of readings from 1914 until the late 1990s, which mark the beginning of a recent peak.

The first long phase was dominated by whalers in the Greenland Fishery. After an early British participation, the Dutch soon dominated the industry, which they shared with the Germans as of the 1690s. To what extent the Thirty Years War (1618–1648) was to blame for the slow start has not been investigated. The Anglo-Dutch wars were certainly the reason behind the troughs of 1652–1654, 1665–1667, and 1672–1674, but it is outside the scope of this paper to examine every fluctuation in detail. The diversification into the Davis Strait Fishery in 1719 should be noted, around the same time of which the Germans started to also send specialised sealers northwards. This diversification may have been one of the causes of the central depression in the mid-eighteenth century. The Anglo-Dutch wars of 1781–1784 and 1795–1802 made their marks, too. By the start of the Napoleonic wars (1803–1815), the Dutch had effectively left the industry, even if one or two whalers continued until the 1870s. The Germans followed suit. Meanwhile, British whaling had re-established itself after 1725 and first exceeded the number of Dutch whalers in the Greenland Fishery in 1775. The 1790s were the zenith of British whaling. After a slump in the beginning of the nineteenth century, there was another slight peak around the 1820s. This first phase ends with only a sporadic British presence in the 1830s and 1840s.

The second phase from the mid-1840s till 1914 was dominated by Norwegian sealers, again in the marine ecosystem. In the 1840s and 1850s, British whaling was the only large industry to speak of. In 1857, British sealers entered the stage. After a first appearance in 1859, the Tromsø sealing fleet was the main force, closely followed by the sealing fleet from southern Norway. After 1885, British whaling and sealing was practically non-existent, although it did not disappear completely until about 1912. Tromsø sealing came to an abrupt stop in 1909, but the southern fleet continued with a vessel or two each year until 1976. Between 1881 and 1914, tourism added significantly to this second phase. The extreme dominance by whaling and sealing masks the presence of Pomor vessels between 1709 and 1852. Even the high-resolution data from 1784 to 1790 is drowned out by a peak in British whaling at the time. The few recorded voyages for hunting, scientific, and mining purposes are practically inconsequential. Generally speaking, the record of the marine ecosystem overshadows that of the terrestrial ecosystem.

The near-complete lack of data between World War I and the late 1990s is suspicious. It can of course *not* be taken as an absence of people. The outlying spikes are Thuesen's (2005) tourism-related figures. The most recent, rapidly increasing peak of considerable magnitude is caused by the growth in overseas and expedition cruises, and the Governor's careful monitoring thereof.

Fig. 3 represents historical human presence in Svalbard as the total number of participants per year. There again appear to be two main phases of people journeying to the archipelago and the surrounding seas. The first phase between 1661 and 1803 falls within a similar phase in Fig. 2. Since it chiefly consists of De Jong's (1979) average and therefore theoretical crew per Dutch whaling ship, this is not surprising. As before, the fluctuations in the columns frequently reflect armed conflict in Europe while they again tower above a poor record of Pomor

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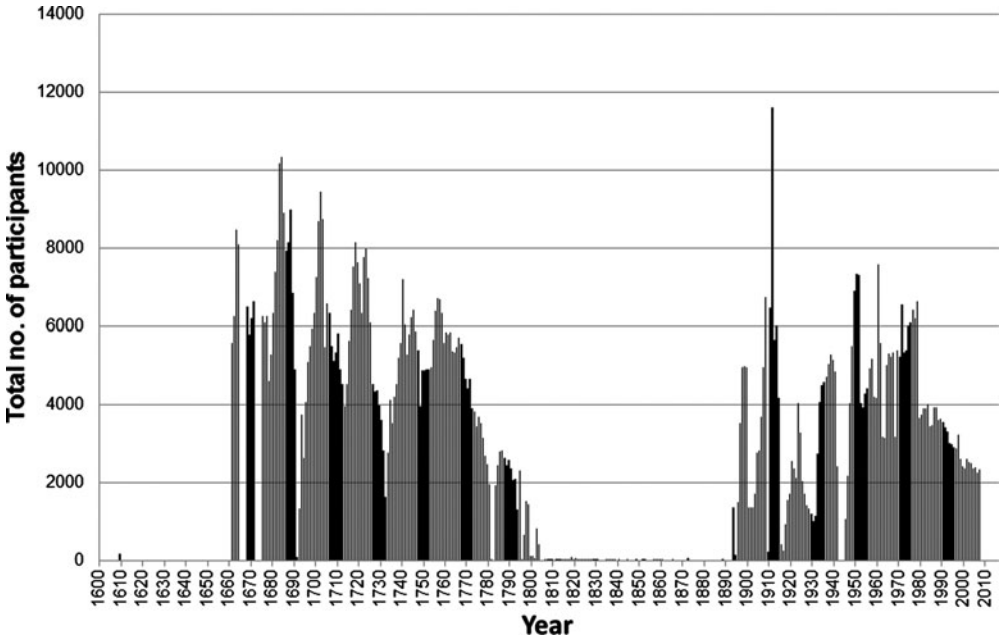

Fig. 3. A column chart of the total number of participants in Svalbard per year between 1603 and 2014 as an indication of human presence in the archipelago over time. (From 21 published sources.)

hunters. At this scale, the small number of wintering trappers in Svalbard throughout the nineteenth century is also barely discernible.

The spike that introduces the second phase at the beginning of the twentieth century is in fact brought about by a change in datasets of early cruise ships' potential maxima for passengers and crew. It also does not show actual figures. This early tourism stopped in 1914. After World War I, the summer workforce of the mining industry increased steadily in size until the total evacuation of Svalbard during World War II. The deceptive slump in the 1950s is in fact brought about by a change in datasets to only the Norwegian summer workforce, which was itself replaced by a count of the total population of Svalbard until 2007.

The most recent 'tourists' peak from 1989 to 2014 was intentionally omitted; it would have been the equivalent of the 'cruises' peak in Fig. 2 with the addition of people also accessing the islands by airplane. In 2014, the total number of tourists reached 213,135. If included in the chart, this peak would dwarf all other records to meaninglessness while at the same time having next to nothing to do with the (over)exploitation of living resources.

The spatial distribution of archaeological sites, based on geospatial data available from Askeladden, is indicated in Fig. 4. Ideally, the figure would have shown the distribution of sites over time, that is the human presence per century or other suitable timescale. However, the Askeladden record is poorly dated. In the absence of absolute dates, the sites are commonly distinguished by type. The types, in turn, give rise to a crude temporal division. As such, land-based whaling occurred in the early seventeenth century; the Pomors are thought to have been present from 1709 to 1852; hunting and trapping, mostly by Norwegians, took place between the beginning of the nineteenth century and 1973; and scientific expeditions, mining, and military action, largely of the early twentieth century, are subject to the archaeological cut-off after 1945. There is great overlap between these 'periods'.

The distribution of archaeological sites suggests a human preference for the west coast of the island of Spitsbergen as well as the south of the island of Edgeøya. Over time, the human presence progressed more northwards and eastwards. This preference can be linked to the presence of the West Spitsbergen Current, the relatively warm waters of which alleviate sea ice conditions here, granting better accessibility to the fjords. The climatic gradient across the islands is manifested in different biogeographical zones. Along the west coast of Spitsbergen and in the south of Edgeøya, the inner fjord zones and middle arctic tundra support the wildlife sought by different waves of hunters. Science, mining, and military were much less dependent on biogeographical zones. However, mining was, and is, largely limited to suitable geology including coal seams on the west coast of Spitsbergen. Scientific expeditions and military activity in the form of gathering weather data also took place in the arctic polar desert shunned by hunters.

Historical human presence being patchy, the aforementioned 420-year timeline based on Arlov (1989, 2003) and Thuesen (2005) was used as the main aid with which to infer long-term trends in anthropogenic pressure on Svalbard ecosystems. It was necessary to treat each selected species of game animal separately in order to

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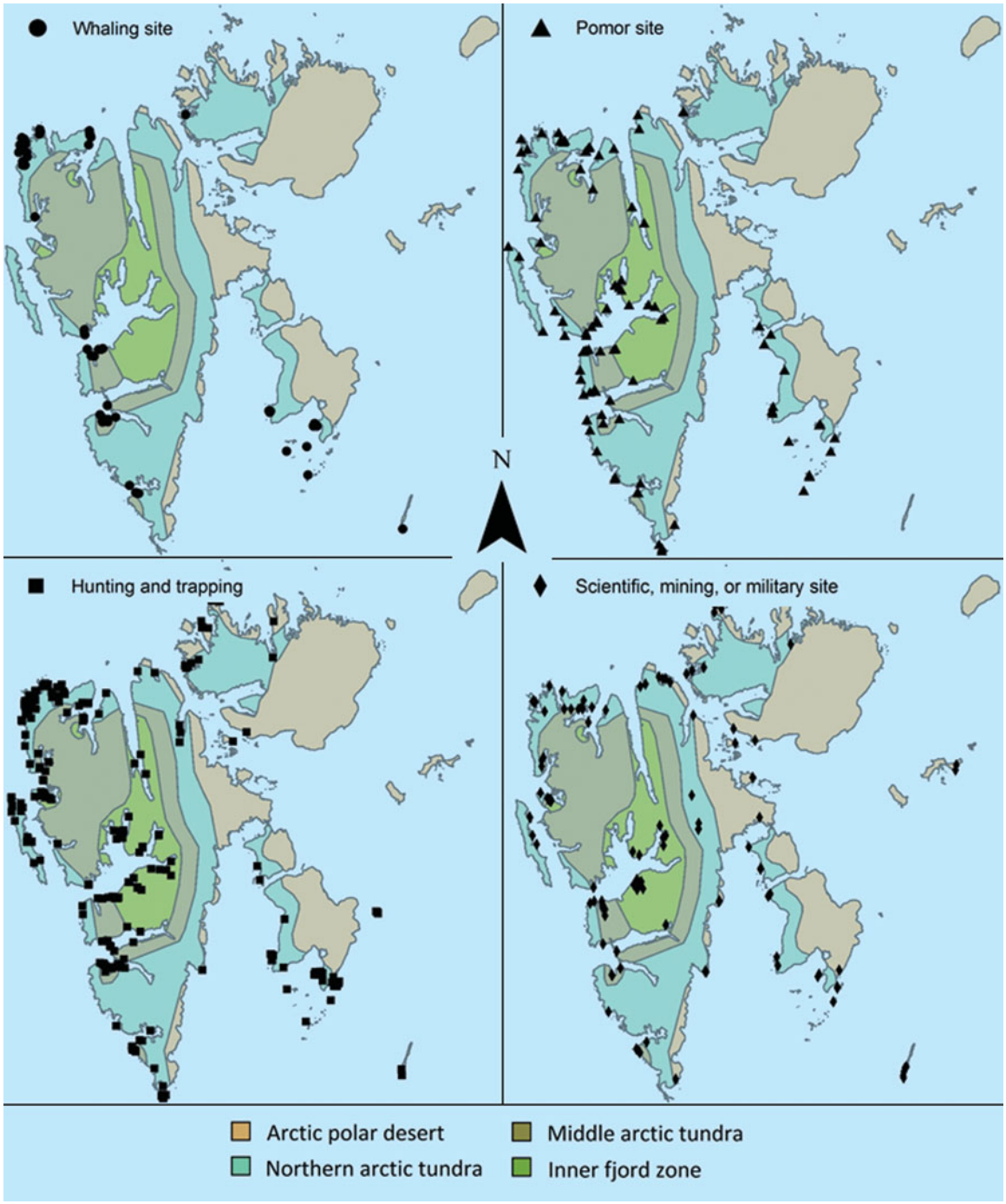

Fig. 4. The spatial distribution of archaeological sites in Svalbard (with the exception of Bjørnøya). The sites have been plotted on a base map of biogeographical zones. (Sources: Askeladden; Norwegian Polar Institute.)

identify occurrences likely to have had bearing on their respective Svalbard subpopulations.

Taking the timeline of hunting into account, Fig. 5 firstly indicates the inferred anthropogenic pressure on the five selected species of game animal in Svalbard over time. Anthropogenic pressure must be understood in relative not absolute terms; the charts are impressionistic and not based on quantitative analysis. Prior to the arrival of the Barentsz expedition in 1596, there was an environmental baseline: environmental fluctuations undoubtedly existed while anthropogenic pressure in the uninhabited archipelago was zero. As a species was subsequently hunted, the pressure it came under could pass through low, medium, and high stages. At low pressure, species reproduction was greater than the catch, and the Svalbard subpopulation could potentially increase. At medium pressure, species reproduction was equal to the catch, and the subpopulation was potentially stable. At high pressure, the catch exceeded species reproduction, and the subpopulation would potentially decline. A critical

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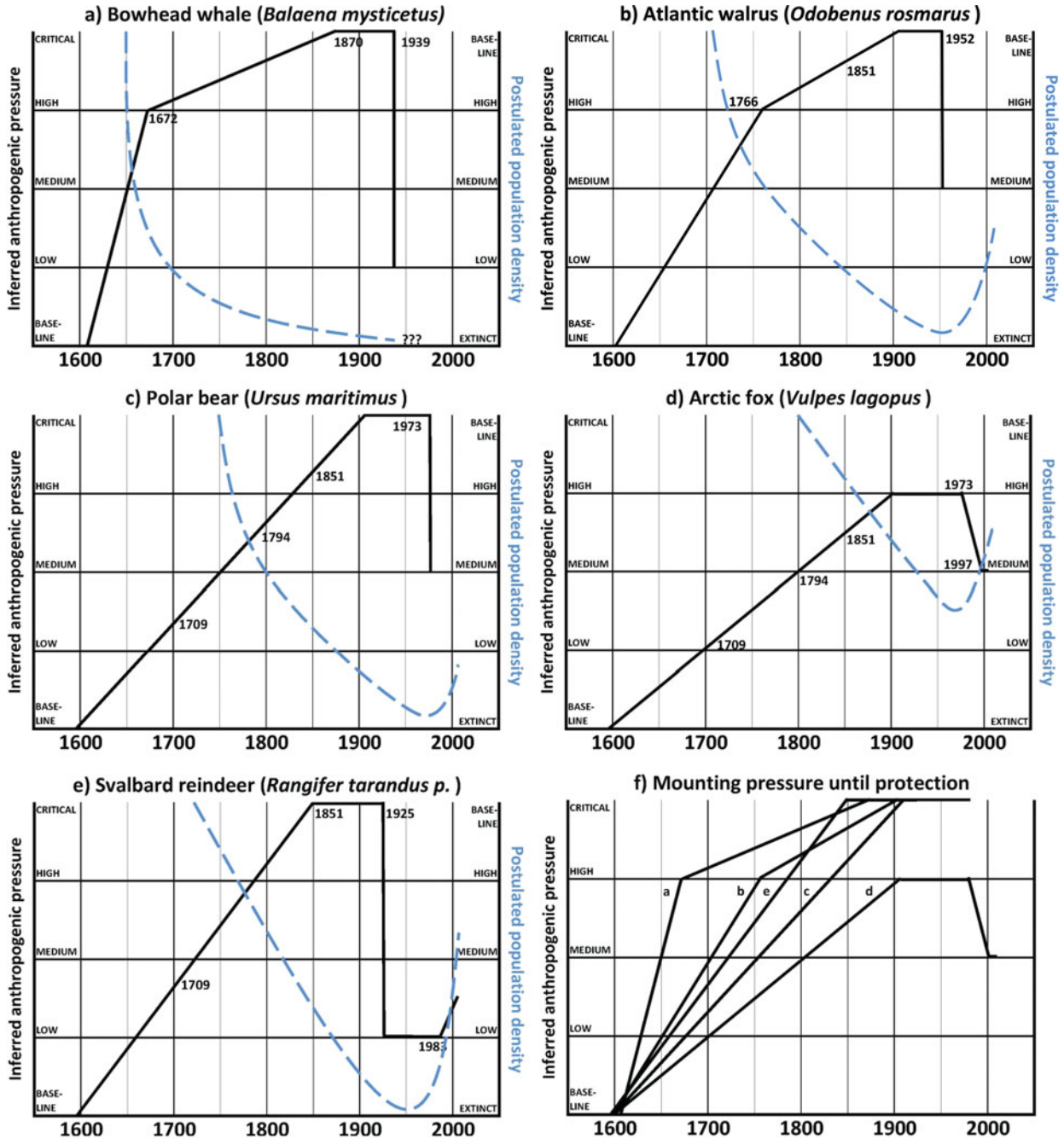

Fig. 5. Inferred anthropogenic pressure (solid line) and postulated subpopulation density (dashed line) of five species of game animal in Svalbard between 1596 and 2015.

stage was reached when high anthropogenic pressure continued for so long that the subpopulation was in danger of becoming extinct. Once the hunting ceased, usually because a species was protected, the anthropogenic pressure from this activity essentially disappeared. In Fig. 5, this disappearance should be indicated by the solid line plunging to low or baseline pressures. In some cases, however, the solid line is shown to only drop to medium pressure: this serves as a reminder that by the time in question, hunting was no longer the only form of anthropogenic pressure. Global human processes were, and are, having an impact in Svalbard. These are now hinted at, but like environmental variations, modern anthropogenic pressure is outside the scope of this paper.

Secondly, Fig. 5 proposes that enduring anthropogenic pressure had a negative effect on the species' subpopulation density. This effect is represented by the dashed line passing from baseline values through high, medium, and low subpopulation densities on route to the worst-case scenario of becoming extinct. Taking some delay into account, baseline numbers may first have been affected at medium pressure. Subpopulation reduction may initially have been rapid until fewer animals over a larger area became more difficult to pursue. Further

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subpopulation reduction probably occurred at a slower rate but with more serious implications for species survival. Species usually faced local extinction by the time they were protected or the hunt was regulated. Once protected, their subpopulations could potentially recover from the intensive hunt. At present, species recovery is not only a function of regulated hunting. Climate change and global human processes play an increasingly important role.

Fig. 5a concerns the bowhead whale (*Balaena mysticetus*). In this case, the environmental baseline extends until 1611, when a first bowhead whale was killed in the bays of Svalbard (Arlov 1989). Dutch whalers from Zaandam were probably the first to extend the hunting ground into open sea in 1626 (Spence 1980), while monopolised whaling of the Netherlands ended in 1642 (Arlov 1989). These events marked the dissipation of pressure into what became the Greenland Fishery and the increasing magnitude as Dutch whaling became free for all. In the figure, these events are not emphasised, but they add to the general upward trend. Rather, the choice has been to highlight 1672 as the year in which the British monopoly was also dissolved, and the whaling industry was now entirely uncontrolled. With time, the unrelenting presence of the whalers as shown in Fig. 2 and Fig. 3 depleted the stock. This depletion is hinted at by the diversification into the Davis Strait Fishery in 1719 (Allen and Keay 2004), the rapid expansion of the British fleet that was only achieved by a high governmental subsidy in 1750 (Allen and Keay 2001), British whalers first substituting poor catches with seals in 1766 (Spence 1980), and the Dutch also needing to offer a high subsidy from 1788 to make the industry attractive (Allen and Keay 2001). Low profitability and war forced the Dutch exit by 1803 (Allen and Keay 2001), while the British, no longer needing to compete, experienced a precarious revival. Although the important British port of Whitby left the industry in 1837 (Spence 1980), suggesting that returns were abysmal, that is the whales were all but gone, the Svalbard subpopulation reached the truly critical stage in 1870 with the introduction of the harpoon gun (Arlov 1989). This technology revolutionised the traditionally labour-intensive industry and made it possible to hunt faster and bigger whale species, in all likelihood finishing off whatever was left of the bowhead stock along the way. In 1904, a ten-year whaling ban in Norway's three northernmost counties meant that unpopular whaling stations were moved to Spitsbergen, renewing the pressure around the islands (Thuesen 2005). Only in 1939 was the bowhead whale protected, and in 1987, commercial whaling was banned entirely (Thuesen 2005). In 1997, MOSJ was established to monitor the wildlife, but over their vast ranges, whales are notoriously difficult to count. In 2000, the Norwegian Polar Institute reported about 100 observations through the public Marine Mammal Sightings (MMS) programme. Despite protection, the Svalbard subpopulation of bowhead whale does not seem to be recovering. It continues to be 'critically endangered' on the Norwegian National Red List. Genetics will tell if this subpopulation is, in fact, extinct and if the rare sightings are visitors from other stocks.

The Atlantic walrus (*Odobenus rosmarus*) is treated in Fig. 5b. In 1604, a British expedition killed a first walrus at Bjørnøya (Arlov 1989), but soon the commercial focus shifted to more lucrative whaling. By 1642, whales were scarce in the bays of Spitsbergen, and as the whalers gradually expanded into new hunting grounds (Arlov 1989), it is possible that they supplemented their catch with walruses at this uncertain time. The Pomors are said to have come to the archipelago in 1709 (Kraikovsky and others 2012). Encouraged by the Tsar, the Russians initially operated a series of monopolistic whaling companies (Kraikovsky 2009). These were unsuccessful, and it is thinkable that the Pomors, already accomplished walrus hunters before they reached Svalbard, abandoned whaling altogether and homed in instead on walruses**.** From 1766, the British were combining whaling and sealing, which undoubtedly included walruses, and once the last Russian whaling company was terminated in 1768 (Kraikovsky 2009), walrus hunting was again free for all. The anthropogenic pressure on the Svalbard subpopulation now crossed the threshold from medium to high. In 1784, a royal subsidy initially failed to stimulate Norwegian whaling and walrus hunting (Thuesen 2005), but by 1824, there were regular Norwegian expeditions both in summer and in winter (Arlov 1989). The Pomors' abandonment of Svalbard after the winter of 1851–1852 has always been taken as a sign that the walrus hunt was no longer profitable to them (Hultgreen 2000). Perhaps the walrus stock was too depleted, but the abandonment may have had additional reasons. The sealing fleets from Tromsø and Hammerfest were in any case only just beginning, closely followed by the fleet from southern Norway. The advent of sport hunting (Reilly 2009), the Norwegian diversification into new sealing and hunting grounds in Zemlya Frantsa-Iosifa and Novaya Zemlya after 1868 (Kjær 2011), and the invention of the harpoon gun in 1870, thus the mounting of pressure on the whales, are all thought to have contributed to the growing pressure on the walruses. The Svalbard subpopulation had most certainly reached the critical stage by 1909, when the Tromsø fleet suddenly crashed out of the sealing industry. As of 1923, the Norwegians were able to reach Zemlya Frantsa-Iosifa more easily on motorised vessels (Lønø 1972), which would have intensified the walrus hunt across the animals' range. After annexing the islands, the Russians expelled the Norwegians again from the territory in 1931 (Lønø 1972), but far from being a much-needed refuge, the Russians probably continued to hunt there themselves. In 1952, when less than 100 animals were thought to remain, the walrus was protected (Thuesen 2005; MOSJ nd). The stock had not improved by 1980, and in 1983, the island of Moffen to the north of Spitsbergen was declared a walrus reserve (Thuesen 2005). Subsequently, approximately 741 animals were estimated in 1993, and an aerial count revealed 2629

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animals in 2006 and 3886 in 2012 (MOSJ nd). The anthropogenic pressure has hence eased off sufficiently to allow for male walruses to recolonise their former haul-outs, but so far, few females with young are sighted. In view of increasing environmental challenges and the questionable effect of growing tourism, the status of the Svalbard subpopulation of the Atlantic walrus remains 'vulnerable'.

The inferred long-term anthropogenic pressure on the polar bear (*Ursus maritimus*) is presented in Fig. 5c. A first polar bear was killed by the Barentsz expedition at Bjørnøya in 1596, an incident after which the island was named (Conway 1906). Since then, the animals were probably prized game on subsequent expeditions, all originating from Europe, where bear hunting had long been a matter of pride and prestige (Zedrosser and others 2001). The arrival of the Pomors in 1709, not only intent on walruses but also on fur-bearing prey, the abandonment of Russian monopolies to free up the hunting ground in 1768, the first successful Norwegian winter in 1794, the establishment of regular Norwegian expeditions from 1824, and the exit of the Pomors in light of dwindling resources and mounting Norwegian competition after the winter of 1851–1852: these are thought to have contributed to the ever increasing anthropogenic pressure on the Svalbard subpopulation. The activities of the Norwegian sealing fleets, not just content with walruses and seals but also heavily exploiting other living resources including polar bears, probably forced the critical stage. The inter-war period from 1918 till 1939 is said to have been golden years for wintering trappers (Arlov 1989). The accessibility of Zemlya Frantsa-Iosifa after 1923, which had intensified the walrus hunt across its range, probably also affected the polar bear. The ratification of the Spitsbergen Treaty in 1925 brought about the first restrictions to the previously uncontrolled hunting practises. As such, the practise of using carrion as bait, commonly poisoned with strychnine and leading to the indiscriminate killing of any scavenger, was banned in 1927, followed by the prohibition of leg-hold traps in 1928 (Thuesen 2005). 1939 saw the restriction of the polar bear hunt in the denning areas of Kong Karls Land (Thuesen 2005). Yet, these measures did little to improve the overall situation, made worse by economic buoyancy after World War I, which witnessed a marked increase in the price for polar bear furs (Arlov 1989), resulting in so-called polar bear safaris for trophy hunters from Tromsø (Thuesen 2005). In the 1960s, between 300 and 400 animals were killed annually, demonstrating a need for more effective restrictions and quotas (Arlov 1989). Despite the killing, the Norwegians strongly identified with the 'king of the Arctic': in 1965, the threatened polar bear became the official postal stamp of Isfjord Radio (Thuesen 2005). In 1970, polar bear safaris and self-shooting traps were banned, followed by the total protection of Kong Karls Land and more hunting regulations (Thuesen 2005). In 1973, the polar bear was finally protected in Norway (Thuesen 2005). Anthropogenic pressure from hunting will invariably have eased off, but with MOSJ (nd) providing a single population estimate of between 1900 and 3600 animals in 2004, it is difficult to recognise any trends. In 2015, the Norwegian Polar Institute (2015) carried out a timely polar bear census. It remains to be seen if the upcoming results will indicate a positive trend for the polar bear currently being listed as 'vulnerable' in the Norwegian National Red List.

Fig. 5d is about the Arctic fox (*Vulpes lagopus*), which caught the attention of hunters with its attractive winter fur. The environmental baseline pressure on the Svalbard subpopulation was superseded by the arrival of the Barentsz expedition in 1596. Once more, the coming of the Pomors in 1709 and the Norwegian dominance after 1851–1852 feature prominently among the other important milestones outlined above. After World War I, Arctic fox furs achieved high prices on the European market (Brown 1919), but it is difficult to discern at which point, if ever, the anthropogenic pressure on the species exceeded the high stage and approached the critical one. While the Arctic fox in Svalbard would on the one hand have benefitted from the ban on carrion bait and leg-hold traps in 1927 and 1928, respectively, its protection in Sweden (1928), mainland Norway (1930), and Finland (1940) may have shifted the location of the hunt to the archipelago, thus turning up the pressure. As the reconstruction of historical human presence has revealed, the annual numbers of wintering trappers was down to only a handful after 1947, and the practise practically ceased in 1970 (Lønø 2014). How many Arctic foxes fell victim to the polar bear safaris between 1952 and 1970 is not known. The protection of the polar bear in 1973 may also have alleviated the stress on them. In its own right, the Svalbard subpopulation of the Arctic fox was never protected but continued to be hunted, albeit under stricter controls. The case of the Arctic fox demonstrates well the pressure that can arise from human activities other than hunting. In 1980, rabies was first documented in Svalbard (Thuesen 2005), and in 2000, Arctic fox cadavers were found to contain the tapeworm *Echinococcus multiocularis* (Thuesen 2005), a parasite that can spread echinococcal disease with a significantly high fatality rate also in humans. The tapeworm was the even more unwanted side effect of the unintentional introduction of the sibling vole, its intermediate host, first described in the archipelago in 1966 (Thuesen 2005). It is thinkable that such diseases quench the enjoyment of hunting whilst at the same time necessitating the culling of infected animals. Since 1997, permanent residents in Svalbard may obtain a season card to hunt and trap Arctic foxes between November 1 and March 15, whereby trapping will have to be undertaken using a body-gripping trap or a dead-fall trap (Governor of Svalbard 2012). Annual catches since 1998 vary greatly but indicate a stable trend around the 120-animals mark (MOSJ nd). The Svalbard subpopulation of Arctic fox is reported to broadly number between 1001 and 10000 individuals (CAFF 2013) and is of 'least concern' on Norway's National Red List, while

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the species is 'critically endangered' in Fennoscandia (Dalén and others 2006). That past human presence and anthropogenic pressure do not provide the full picture of the stress on a species is evident in the fact that the International Union for Conservation of Nature (IUCN) has named the Arctic fox one of ten flagship species to illustrate the impacts of climate change (MOSJ nd).

In Fig. 5e, the probable long-term anthropogenic pressure on the Svalbard reindeer (*Rangifer tarandus platyrynchus*) is shown. From the time of Barentsz, fresh reindeer meat will have been a welcome addition to the provisions of all who visited Svalbard. After 1709, the Pomors may even have been dependent on being able to supplement their diet in this way, but while the anthropogenic pressure seemingly built up gradually at first, its development may need to be seen in conjunction with reindeer hunting and husbandry in Fennoscandia over the same period. The Pomors' abandonment of Svalbard after 1851–1852 may partially have been caused by the overexploitation of reindeer resulting in the loss of a crucial food source. By 1859, the species had in any case become a commercial commodity sought after by the Norwegian sealing fleets (Kjær 2011). Be it hunter, tourist, scientist, or miner, everyone was soon shooting reindeer, if not for sustenance or commercial purposes, then simply for sport. On the eve of World War I, many complained about the near-extinction of the species by 'others', pointing the finger at other stakeholder nationalities. During the conflict surrounding the unsettled legal status of the archipelago, the species, in need of law and order, briefly achieved geopolitical importance (Brown 1912, 1915, 1919a, 1919b, 1927). In fact, following the ratification of the Spitsbergen Treaty, the Svalbard reindeer was the first animal to be protected in 1925, and after a recovery of 40 years, it was chosen to represent Longyearbyen on its official postal stamp (Thuesen 2005). In 1975, research into the state of the reindeer began in earnest, followed by the careful monitoring of three local groups in 1979 (MOSJ nd). 15 Svalbard reindeer were reintroduced to Brøggerhalvøya in 1978, and the stock grew exponentially to 360 animals in 1993, when adverse weather conditions reduced the number to 78 by April 1994. Since then, the annual stock has varied between 85 and 205, with a count of 97 for 2015. In Reindalen, there were between 250 and 650 reindeer per year from 1979 to the mid-1990s. This increased to approximately 800 per year since 2000, which corresponds well with 813 animals in 2015. Since 2000, the annual figures in Adventdalen lay between 700 and 1150 individuals. This was exceeded in 2015 with a census of 1331. As of 1983, the recovering Svalbard reindeer is no longer protected lest it result in overgrazing of the tundra. Presently, permanent residents may procure a hunting licence to shoot reindeer near Longyearbyen between 15 August and 20 September (Governor of Svalbard 2012). The quota is decided anew each year, and as the population has been increasing steadily, so has the bag of reindeer, with a total of 184 in 2014 (MOSJ nd). The current status of Svalbard reindeer is of 'least concern', but the 1993–1994 crash demonstrated how sensitive the species can be to climate change. The working group for the Conservation of Arctic Flora and Fauna (CAFF) thus places priority on circum-Arctic reindeer monitoring (CAFF 2015).

In Fig. 5f, the inferred anthropogenic pressures on the five game animals until their individual years of protection have been plotted together. The Arctic fox was, of course, never protected. This plot enables the direct comparison of magnitude and especially speed. The Svalbard subpopulations of the bowhead whale, the Atlantic walrus, the polar bear, the Arctic fox, and the Svalbard reindeer are presented by lines a to e, respectively.

Discussion

This study of historical human presence in Svalbard ecosystems pursued four lines of enquiry, which generated the results above. The following section highlights the most important findings and discusses additional issues arising from them.

Firstly, it has only partially been possible to reconstruct and quantify historical human presence from published sources and public databases. The published sources generated 57 datasets of greatly varying quality. Although they could be plotted in two column charts, what these charts invariably show is not the total human presence over time but the partial human presence as highlighted by research biases towards certain nationalities, certain industries, and the marine ecosystem. Where do these biases come from and what can be done to counteract them? They originate from past historical and archaeological research agendas as well as the fact that the logbooks of whalers and sealers are the best preserved, the most frequent, and the most easily accessible primary resource on the subject matter. Nonetheless, the wealth of environmental information these logs contain has not been extracted and maximised. Commonly, the focus lies on whales only as opposed to all species encountered, be it animals, plants, and the other kingdoms. To counteract this, the research questions need to be reformulated in line with the current themes concerning societies and ecosystems in integrated Arctic research (IASC 2015). It will be time-consuming, but logs and other primary sources need to be reassessed for their full historical-ecological potential. This data should be made available in a public database.

As far as the spatial distribution of historical human presence in Svalbard ecosystem's is concerned, Fig. 4 provides an initial indication but not the full picture. The temporal scale as well as the magnitude are missing, while the regional bias lies purely on the terrestrial ecosystem. The temporal scale can be improved by a review of Svalbard's archaeological record and the absolute dating of its sites, again a laborious but worthwhile undertaking. Regarding magnitude, Hagen and others (2012) have successfully used graded symbols to visualise the average number of visitors per cruise ship landing site between 2001 and 2010. Something similar should be

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possible for historical human presence, using variables like the total floor space of huts (Reymert and Moen 2015) or the quantity of animal bone per archaeological site. The archaeological record will always favour the terrestrial ecosystem, even if underwater archaeology were to focus on the discovery of Arctic shipwrecks. However, an innovative way to illustrate the unprecedented and enduring yet difficult to grasp intensity of human presence in the Greenland Fishery would be an interactive animation. Whereas traditional animations are passively consumed by the user, this type creates opportunities of interaction with the topic (Dinç 2006). 'In the process of interaction the user can choose which elements to display or which paths to follow, thus generating a unique work. In this way the user becomes the co-author or the work' (Manovich 2001: 55). The use of an interactive animation in historical research has been demonstrated by Kahn and Bouie (2015). Their impressive visualisation of the Atlantic slave trade in two minutes has the subtitle '315 years. 20,528 voyages. Millions of lives.' The Svalbard equivalent of 420 years, 35,579 voyages, and millions of lives could be based on the logs' navigational details and catch figures.

Secondly, the partially quantified historical human presence is *not* a suitable indicator of long-term anthropogenic pressure. This raises the question under which circumstances the data would be suitable. Ideally, human presence could be directly equated with anthropogenic pressure. However, for a number of reasons, this is not the case. Firstly, vessels and voyages became increasingly less directly involved with the marine and terrestrial ecosystems. While the sole purpose of whalers, sealers, and hunting expeditions had been to harvest living resources, thereby impacting on the environment, the remits of later voyages became more diverse, the best example being the current cruise ships that have nothing to do with hunting at all. Secondly, the participants became less involved. Again, the total number of whalers and sealers may be taken into account, but what about hunting parties that consisted of family units including small children? All were tallied because most will have helped with the hunting or the processing of the game, and all benefitted from the income. Besides that, even the smallest children needed to be fed while in Svalbard. This statement touches on the fact that historical human presence, and the subsequent human activities, was primarily concerned with commercial as opposed to subsistence hunting. Hunting to supplement the provisions or simply for sport became increasingly more important with the diversification of activities in the twentieth century. Poaching may have played a role after the protection of game animals. To what extent scientific, mining, and military personnel participated in hunting has not been investigated in the paper, but it is clear that a considerable proportion of them did or were allowed to while their presence in the archipelago was not hunting-related. Indirectly, their influence on the environment may have been of unforeseeable magnitude. Studies such as that of Hagen and others (2012) discuss such indirect anthropogenic pressure in the form of, for instance, present-day tourists repeatedly visiting landing sites around the islands. So while whaling, sealing, and hunting were initially the only form of anthropogenic pressure on Svalbard ecosystems, the lines are less clear now and the picture more complex, to say nothing of environmental pressures. So historical human presence is not a suitable indicator of long-term anthropogenic pressure on its own, but it is an essential point of departure for research into Svalbard's historical ecology. The quest for data leads to an appreciation of the fragmented nature of the available sources, uncovers the existing research gaps, and raises a host of necessary guiding questions. In the attempt to reconstruct historical human presence more fully, other data with bearing on anthropogenic pressure will undoubtedly be revealed.

Thirdly, it has not been possible to infer trends in long-term anthropogenic pressure on the selected animal species using historical human presence alone. Only in combination with a 420-year timeline emphasising species-specific milestones could Fig. 5 be arrived at, expressing the results in relative and admittedly subjective rather than absolute terms. It is noteworthy that the figures include no pre-protection recovery periods, with the exception of the Arctic fox maybe benefitting from the polar bear being protected in 1973. The resolution of the data was not good enough to suggest recovery periods prior to a species being protected. In Fig. 5f, there is a significant difference in steepness between the graphs, which is thought to reflect species depletion and changing demand. The pressure on the bowhead whale, which was the first in great demand, the first to promise great financial returns, rose most steeply and reached the critical stage most quickly. The bowhead whale was superseded by the walrus, the polar bear, and the Arctic fox in accordance to their relative worth. The reindeer stands out. This is perhaps due to its initial role in the subsistence hunt, becoming a commercial resource much later. Once it was pursued commercially, however, it was depleted so noticeably that it became the first to be protected.

Fourthly, the paper postulates that past subpopulation trends were always inversely proportional to the anthropogenic pressure they were under. While all species with the exception of the Arctic fox are thought to have reached the critical stage, that is the threshold of overexploitation and extinction, it is perhaps only the bowhead whale that crossed the mark: despite protection and the ban on commercial whaling, the local stock has not recovered. For the Atlantic walrus, the polar bear, and the Svalbard reindeer, the expected trend could be that the sooner hunting was prohibited, the better the subpopulation would recover. This, however, is difficult to establish since mounting environmental pressure over recent decades is bearing down on all Arctic animals, including the Arctic fox.

As this is only a first attempt to move historical-archaeological research in Svalbard in the direction of

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interdisciplinary historical ecology, the potential for future research and cooperation is great. After historical human presence, the next step will be to investigate historical human activity, that is the hunt itself, as another indicator of long-term anthropogenic pressure. The hunt finds expression in the form of catch data in historical sources and as animal bone assemblages from archaeological sites. This data may help to better define the pressure curves in Fig. 5 and to test the hypothesis about former subpopulation sizes.

To conclude, Svalbard's ecosystem ceased to be pristine during the unrelenting human hunt for living resources over more than four centuries. The archipelago now forms a striking case study of human-induced crashes of animal subpopulations which finds parallels throughout the circum-Arctic (Arctic Studies Centre 2016).

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Conflict of interest

None.

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