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Mortality from Smallpox: The 1780s Epidemic in the Hudson Bay Region

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Abstract

The smallpox epidemic of 1781-82 in the Hudson Bay region reportedly devastated the native population, causing mortality of at least 50 percent. We reassess this claim. We total smallpox deaths reported by two trading posts in the path of the epidemic. Next we review mortality from smallpox in other outbreaks. Then the volume of trade is analysed. Finally mortality is inferred from the pre-epidemic population, based on the region's carrying capacity, and the post-epidemic population, from later estimates. Our approaches imply a similar conclusion. Mortality from smallpox was much less than has previously been asserted, likely under 20 percent.

Introduction

Conjectures, assumptions and assertions surround the debate on the size of Native American populations just prior to European contact. Estimates for North America north of the urban civilizations of central Mexico range from 1 million to 18 million (Ramenofsky 1987: 7).[1] More recent work, however, argues for numbers closer to the lower end of this range.[2] Milner and Chaplin (2010) use the spatial distribution of archaeological remains to generate population densities in the eastern half of North America just prior to contact. Extrapolating to the entire continent they suggest a population range of 1.2 million to 6.1 million. While views differ on the size of the native population at the time of European contact, there is little dispute about the number of Native Americans in the nineteenth century, when census counts were taken. At issue is whether the low census figures are a consequence of a very much larger pre-contact population that was decimated by disease and other factors, or whether the native population, even in the pre-contact period, was small. Critical to this question of population size are the timing and impact of diseases brought by the first Europeans and their animals. Widespread epidemics with mortality rates of 90 percent have far different implications than disease outbreaks which were more limited and less severe. As Shepard Kretch (1999: 85) points out: "to decide on a sensible [pre-contact] number, does not mean trivializing the extent of disease nor the extent of biological change introduced by Europeans. But to agree with the highest estimates assumes that diseases arrived early, spread widely and were invariably fatal ... and that diseases can actually be identified."

Native populations before 1500 and in the early contact phase are hard to determine largely because we have so little information.[3] Prior to contact, the main source is the archeological record. This evidence has been used mainly in two ways. First inferences have

been drawn about the size of the population in a region from the area and density of particular sites, as has been done most recently by Milner and Chaplin (2010). Unfortunately, the number of such archeological sites is limited.[4] Second, skeletal remains have been used to shed light on diet, physical activity, and other aspects of native life, as well as on the size of the aboriginal population (Owsley 1992). Such evidence has been used, notably by Richard Steckel, to describe the health of native people before and after contact (Steckel et al. 2002; Steckel 2009).

There is also a literature that tries to infer the size of native populations from the nature of their agricultural and hunting activities, and the types of flora and fauna that were available. This approach, used notably by Dobyns (1983), estimates human population density based on the carrying capacity of the land.[5] In addition, there are, from the early post-contact period, scattered accounts by European travellers and traders on the number of aboriginals they encountered. Over time, with greater interaction between natives and Europeans, such reports increase and become more reliable. Most accurate are the nineteenth-century censuses of native populations. But whatever method has been used, there is a consensus that native populations declined from their pre-contact levels, and these declines were due mainly to disease.[6]

In this paper we explore the impact of the earliest smallpox epidemic to hit natives living in the western drainage basin of Hudson Bay, the epidemic of 1781-82.[7] Although the Hudson's Bay Company erected its first post in 1670, there was limited contact with aboriginals until well into the seventeenth century.[8] Trade provided natives access to new technologies and new commodities; but, over time, traders also carried European diseases, including influenza, measles, whooping cough and smallpox. The expansion of trade from Montreal contributed to the greater exposure of natives in the region to disease. Hackett

(2002; 2006) has documented each outbreak from 1670 to 1846 in *Petit Nord*, the eastern area north of the Great Lakes. Our focus, though, is *Grand Nord*, the region further west where natives were better protected by distance and epidemics were more limited. According to European traders and the natives' own oral history, the epidemic of the 1780s was the first smallpox outbreak to reach this region. Because the impact was severe both on the natives and the fur trade, Company workers have left extensive accounts of what happened. Indeed, this episode provides a rare opportunity to examine the effect of smallpox on a native population that had never been exposed to the pathogen.

We begin by reviewing contemporary descriptions of the epidemic. Both Europeans and natives reported the effect of smallpox on the region, with contemporaries speaking of mortality rates ranging from 60 to 90 percent. We then study the epidemic using four quite different approaches. First, we estimate deaths based on the reports received by two Hudson's Bay Company interior trading posts, Hudson House and Cumberland House, which were in the path of the epidemic. Our estimates include burials at the posts, deaths observed by Company men, and reports by natives of what they witnessed. Second, we summarize the mortality experience associated with other smallpox outbreaks, including mortality among "virgin soil" populations, those with no previous exposure to smallpox. We also discuss the transmission mechanism and the contagiousness of the disease. Third, we place the epidemic in the context of the region's fur trade. Natives in the Hudson's Bay Company's hinterland were the sole trappers of beaver and other furs; and so any serious decline in the native population should have been reflected in the fur returns at Company posts. Finally, we infer the extent of the population decline by estimating the likely pre-epidemic population, which we base on the carrying capacity of the region. We compare that estimate with a population count which was made in the early nineteenth century. Our approaches to the epidemic point

in the same direction, namely to mortality that was much lower than has previously been asserted, likely under 20 percent.

The Smallpox Epidemic of 1781-82

The first smallpox epidemic to affect natives trading in the western drainage basin of Hudson Bay appears to have been transmitted in 1780 and 1781 through the trading villages along the upper Missouri River by the Sioux.[9] By the late fall of 1781 the disease vector had reached Hudson House and Cumberland House, two interior collection points along the North Saskatchewan River that the Hudson's Bay Company had established in the mid 1770s (see Figure 1). These posts helped the Company compete with traders from Montreal for the trade of the Assiniboin, Cree, and other native groups. The furs they received were sent downriver to York Factory, the Company's largest trading post.

All direct knowledge we have of the epidemic comes from the daily journals maintained by the Hudson's Bay Company's post governors and chief traders. They describe the activities at the posts as was required by Company's head office in London. The entries begin with a phrase about the weather and continue with a report. The Cumberland House entries for November 26th and 30th of 1781 are typical:

> November 26th Monday Wind and Weather as Yesterday two Men still lame, sent five Men to the Nets, also fitted out Mr Longmoore and George Hudson and sent them away to trap Martins. 30 Sturgeon and 3 Pike [caught] yesterday.
>
> November 30th Friday Wind E.S.E. a stiff Gale, with Cloudy weather till noon... one man net Making two Hewing timber for the saw, sent others to overhaul the Nets 10 Sturgeon to day (Rich 1952: 221).

In addition to describing the mundane, the journals also report events that were seen as significant, especially to the trade. It is from these entries that we get a picture of the timing

and severity of the smallpox epidemic. In fact, it is possible to track the path of the disease through the region, as has been done by Ray (1974), Hackett (2002) and others (see Figure 1).[10] Hudson House first learned of the epidemic on October 22, 1781, and Cumberland House in early December:

> December 11th Tuesday Wind Westerly, a fresh Breeze Weather for the most part cloudy, with a low Drift... In the Evening three men and four women arrived from the southward with Furs to Trade also one family came across the lake from the Westward, the former has brought the Disagreeable news of many Indians dying, and the latter complain much for want of food. Indeed one of those that came from the southward does not seem to me to live long as she is troubled with violent pain in her back and much inclined to Vomiting, these inform me of seeing several Tents without anybody alive in them and some of the Dead not Buried (Rich 1952: 223-24).[11]

In a letter dated December 4th, William Walker, clerk at Hudson House, wrote: "small pox is rageing all round us with great violence, sparing very few that take it, we have received the News of above 9 tents of Indians within here all dead, ... as for the Stone Indians there are very few if any left alive..." Walker went on to report the impact on the trade: "when the Indians is dying daily and them that has not taken the small pox is frightened to look after any thing for fear of falling with others that is bad" (Rich 1952: 225-26).

The Cumberland House journal notes that as of January 2nd, 1782, four Indians from Le Pas, which was west of the disease vector, "had not heard of the disorder;" but by the 25th of the month "many sick Indians [were] arriving" from there. And a February 19th letter recounts the severe losses suffered by several native groups in the region.[12] The last mention of smallpox by Cumberland House is on March 23rd, when it was reported that all in a group of ten tents in the Swampy River area (to the south) were dead.

Based on the journal entries, it appears that in the area of Hudson House and Cumberland House the epidemic had largely run its course by the spring of 1782. It did not spread further north until later that summer. On March 1st, for example, the post journal notes that five men and three women arriving at Cumberland House from the north had heard nothing of smallpox. Later the disease moved toward York Factory and Fort Churchill. It also moved east, to the area north of Lake Superior, where it was reported among the Ojibwa.

The smallpox epidemic of 1781-82 clearly devastated and dislocated some native settlements.[13] Here, however, we consider its overall impact, particularly on those groups living in the path of the disease. Hudson's Bay Company personnel did not merely describe the event, they also gave estimates of overall mortality, in part because of the likely impact on future trade.[14] Samuel Hearne, who had spent time at Cumberland House in its early years, was at Fort Churchill during the outbreak. He claimed, based on what native traders told him, that 90 percent of the Indians in the Northern Barrens, the area to the west and north of the post, had died (Tyrell 1934: lx). York Factory's journal entry of July 2, 1782 also reports devastation among several tribes in that region: "not one in fifty of those tribes are still living" (HBC, *Post Journals: York Factory*). Four years after the epidemic, David Thompson, who provides one of the first travel narratives, journeyed from York Factory to the Rocky Mountains. Based on conversations with natives, and from discussions with Company employees who had been at Cumberland House or Hudson House during the epidemic, he concluded that "far more than one half had died, and from the number of tents remaining, it appeared that about three fifths had perished." Thompson goes on to assert that "more men died than women and children."[15]

The strength of these reports is their proximity to the event. Indeed, it is from these accounts that researchers have concluded that mortality from smallpox ranged from 50 to 90

percent. In his work on Northern Athapaskan social organization, Kretch (1978: 712), citing Hearne, concludes: " In 1781, smallpox ravaged the Cree and Chipewyan, with losses among some Chipewyan groups estimated up to 90 percent." In *Indians and the Fur Trade*, Ray writes: "lacking any immunity ... the Indians suffered terrible losses" (Ray 1974: 105). While not being specific about actual mortality, Ray cites David Thomson's claim that mortality was one-half to three-fifths. And in his introduction to the *Journals of Samuel Hearne and Philip Turnor*, Glover wrote: "among the natives the scourge swept as murderously as the Black Death through medieval England" (Tyrell 1934: lviii).

In addition to these claims, made after the fact, there are direct accounts from those Europeans and Indians who were in the midst of the epidemic. These are reported in the post journals. William Walker, the chief trader at Hudson House, and William Tomlison, the head of Cumberland House, provide what are arguably the firmest numbers. These are the deaths that they or their men observed.[16] For example, the Hudson House entry of November 1, 1781 includes: "found an Indian man a little distance from the House who died of the aforesaid Distemper;" in the entry of November 3rd: "burying a female Indian that died of the Smallpox." Such reports span the entire period October 1781 through April 1782 and appear to include all the deaths they observed. From the first report of a death in December, through February, Tomlison reported that he had buried thirty Indians, and a summing over all of the later burials gives a total of forty for the entire period of the epidemic in that region. There also are instances of the men seeing bodies at some distance from the post, as in the Cumberland House entry for February 5th: "two men returned after a four day Journey, having found .... eight ....laying Dead at one tent place." Combining the number of natives who died at the posts, were buried at the posts, or whose death was reported by men away from the posts, gives a total of 88 over the six-month period, 25 at Hudson House and 63 at

Cumberland House (see Table 1).

Indians arriving at the posts, generally to trade furs or meat, or to obtain food, also reported on mortality. The first evidence of the epidemic was given by an Indian to William Walker at Hudson House on October 22nd: "One Indian man arrived for tobacco from Seven Tents of Indians. One of their Tents they was obliged to leave standing in the Barren Ground with Seven Indians laying dead." This statement is unusual in that a specific number of deaths is given. In fact, for the cases where actual numbers are reported, deaths total only 15.

Indians more typically reported losses in terms of tents lost, as in the entry for November 27th: "One man and two women arrived. Had left two Tents about 5 days journey...The People belonging to them lying dead inside;" or two days later: "Old man, two Young Boys, and one Young Girl...all that was left alive out of 5 tents." During this period the full complement of a tent would likely have averaged between nine and eleven; but when a tent was hit by smallpox, occupants could abandon those who fell seriously ill.[17] A report that all in a tent were dead would have referred to those left behind.

Harder to interpret still are accounts that do not include specific numbers. The first report of smallpox at Cumberland House was on December 11th: "Three Men and four women arrived from the southward...these Inform me of seeing several Tents without any body alive in them." On January 24th: "five more arrived...The women have got over smallpox. These is all that is alive out of several tents."[18] Combining the Indian accounts received at Hudson House and Cumberland House of mortality in terms of tents suggests deaths of between 344 and 483 (see Table 1). Of these, just over half were reported to Cumberland House. Finally adding estimated deaths, based on losses in term of tents, to the actual counts of deaths, gives total mortality of 447 to 586.

Hudson House and Cumberland House were interior posts for York Factory,

contributing to about half the total trade of that principal post (see Figure 1).[19] Prior to the epidemic, the native population of the entire York Factory hinterland was perhaps 8,600.[20] If we take 4,300 as an approximation of the population in the hinterland of Hudson House and Cumberland House, then the reports of deaths by the men at the posts and the Indians sum to mortality of 10 to 15 percent.

There are, in addition, more general statements in the post journals both from Indians and post traders about mortality. For example, on November 12th: "One Indian man and his family arrived [at Hudson House] ....He informs me the Indians he went in Company with are all bad and a great many dead." On November 24th, it was reported : "Stone Indians arrived with provisions. Small Pox has carried off two of our leaders that used to trade here." Although only these deaths are specifically reported, it is likely that others in the group would also have died. The entry of December 24th also points to an unspecified number of deaths: "Five Indian Men and four women arrived from the Southward...brings the Melancholy News...of the small pox rageing amongst them and but few escape Death that take the Disorder."

The letters from Hudson House and Cumberland House paint a picture of devastation that suggests more deaths than those given in the daily journal entries, but it may be that in a sparsely-occupied land, the numbers they were observing either directly or through the Indian accounts would themselves have been shocking. There were seven accounts, three to Hudson House and four the Cumberland House, that describe mortality beyond the specific reports. For most of these cases, we have assumed a range of 25 to 50 deaths.[21] Recognizing that the numbers we present based on these reports are conjectural, we put deaths from these seven accounts at between 200 and 350. Adding this mortality to the more firmly-based estimates increases overall conjectured mortality to between 15 and 20 percent.

Mortality from Smallpox: A brief review of the evidence

There is a large medical and epidemiological literature on smallpox, a disease with a history of more than three thousand years.[22] Although each outbreak would have had its special characteristics, the experience of other smallpox epidemics can suggest a range of likely outcomes among Native Americans in the region of Hudson Bay, both in terms of the spread and virulence of the disease. The wide-ranging 1988 publication of the World Health Organization by Frank Fenner and his co-authors, *Smallpox and its Eradication*, brings together much of the research on smallpox, and provides an excellent foundation for examining how the disease affected populations that, in some dimensions at least, were similar to the natives of the Hudson Bay basin. Two features of a smallpox epidemic, or indeed any epidemic, are central in assessing its impact on mortality: the case fatality rate and the likelihood someone will contract the disease.

There are well-documented studies of case fatality rates in twentieth-century smallpox outbreaks (see Table 2). These rates, which apply to unvaccinated populations, or to victims who were not vaccinated, are in the range of 15 to 35 percent, with slightly lower rates for adults than children. The highest mortality, 35 percent, is for Madras, India over the period 1961-69. The average, however, is closer to 20 percent. These rates have the advantage of applying to populations who were carefully studied, and are likely more reliable than rates reported in earlier epidemics.[23]

We also have reports on pre-twentieth-century epidemics. An account of a 1795 "virgin-soil" epidemic in a village on the Japanese island of Hachijo-Jima implies a case fatality rate of 38.3 percent (Fenner et al. 1988: 227). During the U.S. Civil War, an outbreak of smallpox among a largely unvaccinated Union army led to case fatality rates of about 35 percent - similar for whites and African Americans; while at the time of the Franco-Prussian

war, French soldiers, who were not vaccinated, had case fatality rates of 18.7 percent. During the late eighteenth century, the case fatality rate at the London Smallpox Hospital was 32 percent; it was somewhat lower earlier in the century (Davenport et al. 2011: 1309). There also are reports of mortality in much earlier epidemics. In 1242, the first smallpox epidemic to hit Iceland is said to have killed 30 percent of the population; and it was reported that, in 1707, another outbreak in Iceland resulted in similar mortality (Fenn 2001: 229; Ramenofsky 1987: 161).

The case fatality rates in these epidemics apply to *variola major* the more severe class of smallpox.[24] Whether someone died after contracting *variola major* depended in large part on the idiosyncratic progress of the disease as reflected in the number and nature of their lesions. A twentieth-century study of an unvaccinated population in rural India found case-fatality rates of 62 percent for *confluent ordinary-type smallpox*, 37 percent for *semi-confluent ordinary-type smallpox*, and 9 percent for *discrete ordinary-type smallpox* The incidence of these three types was 22.8, 23.9 and 42.9 percent, respectively.[25] Thus the weighted case fatality rate over the three severities of smallpox was 30 percent. We, of course, do not know the incidence of these categories of confluence among the Native Americans who contracted smallpox. An entry in the Cumberland House journal for December 27th indicates that at least some experienced the more severe type of reaction: "This morning could observe the small pox coming out *very thick* upon sick lads heads and thighs" (italics added). On January 1st, the boy went blind, and four days later he died.

Given the comparatively low case fatality rates among other populations relative to the mortality rates of 50 to 90 percent reported for natives in the Hudson Bay region, there has been speculation that, because of the thousands of years of isolation, there was less diversity in the Native Americans' immune system antigens which rendered them less able to

survive smallpox and other European-borne infections. However, in her classic work on the continental smallpox epidemic that ultimately reached the Hudson Bay region, Elizabeth Fenn (2001: 26) points out that such lack of diversity was more likely an issue with measles than smallpox; and in other work, scholars have expressed skepticism of a genetic explanation for differential mortality, at least as it relates to ABO blood groups (Crosby 1976: 291-92; Fenner et al. 1988: 166).[26]

Documented mortality rates and case fatality rates in other regions are much lower than the reported experience of Native Americans, but how the disease was treated by Native Americans, as well as the harsh subarctic environment may have raised mortality. Some observers noted that the native sweat lodge would have increased the fever associated with the early stage of the disease, when mortality was greatest. Others noted that some natives responded to their fever by jumping into cold streams which, according to one fur trader, caused "instant death," but in fact the cold water may have reduced fever. As Fenn (2001) points out, it is not at all clear that the treatment Europeans typically received was better than the practices of Natives Americans.

Smallpox, although deadly, has symptoms that last for a relatively brief period; and, although the disease can lead to blindness, such severe consequences are rare. In fatal cases, death typically occurs between the 10th and 16th day of the illness; and among survivors scabs separate by the 22nd to the 27th days (Fenner et al. 1988: 22, 50). Thus, the disease would have seriously limited hunting and other activities for perhaps four weeks. Scabbing left on the soles of feet might have affected mobility for a somewhat longer period, and victims would have taken longer still to regain their full strength. Because the Cree and Assiniboin were migratory hunters, any prolonged period of forced inactivity could have been devastating not just to the adult males, but for their families as well. So, although the

impact of the disease would have largely dissipated after a month, even that period of inactivity could have had serious consequences for the hunters and their families. The post journals reported instances of natives arriving at Company posts not to trade, but for food. At Hudson House and Cumberland House, these cases increased during the smallpox epidemic. For example, it was reported on December 3rd that "One Indian Man and two children arrived recover'd of the Small Pox but almost starved to Death;" and on February 3rd the entry includes: " Those mentioned on Friday arrived starving Some of them in fair way to recover, only are in want of nourishment to keep them alive." As well there are reports that those who contracted smallpox were abandoned, and left to die in their tents. Even though there was evidence of hunger, none of the accounts from either the men at the post or the Indians refer to starvation as a cause of death. Of course, lack of nourishment could have been a contributing factor.

The case fatality rates for documented epidemics are very much lower than the overall mortality of natives that has been claimed in some of the historical accounts; moreover, case fatality rates apply only to those who contracted smallpox. Although deadly, smallpox is a moderately contagious disease; less contagious for example than measles, chicken pox, and whooping cough (Fenner et al. 1988: 200). Humans are the only hosts of variola. The route of infection of smallpox, with rare exceptions, is through the respiratory tract. This requires direct contact with an infected person with transmission of the virus through inhaled liquid droplets or to the nose or mouth by touching. Unlike measles, most patients with smallpox do not have respiratory symptoms such as coughing or sneezing which generate large clouds of infection in the air. This reduces airborne transmission. "Direct and fairly prolonged face-to-face contact is required to spread the disease from one person to another," usually contact within about six to seven feet for a period of a few hours.[27] The disease does not normally

spread as a result of casual or brief encounters. Although droplets or scabs which fall on bedding or clothing remain infectious in principle, laboratory test show that they rarely produce infection because of how they are handled by the respiratory tract. There have been some cases of laundry workers contracting smallpox, but indirect transmission via fomites, including clothing and blankets, is very unusual (Fenner et al. 1988: 188, 194).

The epidemic swept through the region of Hudson House and Cumberland House in the fall and winter, when natives would have been in their winter grounds, occupying wigwams or tepees. Since the living space in the tents was just over 100 square feet for perhaps nine to eleven individuals, the disease, once brought in, would probably have spread to most of the occupants. On the other hand, transmission between tents or from one native group to another was less likely. As we derive below, density over the entire hunting area of the natives in the region was likely no more than one person per 50 km^2, or one tent per 500 km^2. Density in their winter grounds was greater; but a density of one tent per 125 km^2 is at the upper limit of what seems plausible.[28] In sum, the relative difficulty of transmitting smallpox in comparison to other infectious diseases and the low population density in the Hudson Bay region would have mitigated the effect of smallpox on the population.

Mortality in the 1781-82 Smallpox Epidemic and the Trade Records

Given the nature of smallpox and the more recent evidence on how it affected diverse populations, one might be skeptical of mortality rates of 50 percent and higher, as reported by Hudson's Bay Company officials and accepted in the historical literature. As another alternative to these reports, we now approach the epidemic and its impact by focussing on the trade records. Hudson House and Cumberland House, were set up in the mid 1770s by the Hudson's Bay Company to compete with the Montreal traders, who were increasing their presence in the region. The posts, located several hundred kilometers from York Factory,

soon generated trade comparable to the returns at York Factory from the rest of its hinterland. The volume of this trade is potentially revealing of mortality from smallpox, since the hinterlands of the posts were in the path of the epidemic.

Neither Hudson House nor Cumberland House kept separate accounts. Although we do have their journals, these provide no more than a rough indication of their trade. Better are the reports from the main trading post, York Factory. Its records include all the furs received; but, more important are the detailed lists of trade goods sent to Hudson House and Cumberland House both before and after the smallpox outbreak. As shown in Figure 2, the value of trade goods sent in 1777 was a relatively modest 6,060 *made beaver* (*mb*).[29] The low value is not surprising given that the two sites had just been established. Activity, however, increased, reaching 11,770*mb* in the 1781 trading season, which was just before the epidemic.

The smallpox outbreak ruined the 1781-82 trading year. Few natives came to the posts, and those who came brought few furs. The Cumberland House journal comments on the virtual disappearance of the trade, and the York Factory accounts are consistent with the traders' descriptions. Realizing that little additional inventory was needed, York Factory sent just 800*mb* in trade goods that year. There was very little trade the following year as well, although in this case the reason was as much political as environmental. The western hinterlands of Hudson Bay had entirely escaped conflict during the Seven Years' War of 1756 to 1763, but the involvement of the French in the American Revolution spilled over to the Hudson Bay region (Rich, Vol. 2 1960: 84). In 1782, Comte de Lapérouse set out with a 74-gun ship and two frigates to capture the main bay-side posts. On August 8th he took Fort Churchill and two weeks later York Factory. There was no resistance from the English, but both posts were severely damaged and the Company personnel were taken to Europe.[30] It was nearly a year before they returned and reestablished trade at York Factory and Fort

Churchill.

Despite the temporary loss of York Factory, the inland houses continued to trade from their depleted inventory.[31] The Cumberland House journal entry of June 20, 1783 reports that 115 bundles of furs in ten canoes were sent to York Factory. At roughly 50*mb* per bundle, the total value would have been close to 6,000*mb*, an indication the trade was beginning to recover. More revealing, though, is what happened the following years, when York Factory was again operational and resumed sending trade goods to its inland collection points. In 1784 deliveries of trade goods totalled more than 6,850*mb*, and in 1785 the shipment of 9,400*mb* worth of goods was more than in any year other than 1781. The trade continued to increase after 1785, and in 1787 it surpassed *any* previous year. Even recognizing that some of the goods sent from York Factory after 1783 might have been needed to replenish inventories, it seems inescapable that the natives were bringing greater numbers of furs to the post. This level of activity was achieved after an epidemic that was claimed to have decimated the population, not just around these posts, but in the broader region; and was said by some to have especially affected the segment of the population, adult males, who were the main participants in the fur trade.

To highlight the change in trade before and after the epidemic, we compare the trade goods sent from York Factory to Cumberland House in 1781 and 1785 (see Table 3). In 1785, just three years after the epidemic swept through the region and less than three years after York Factory was sacked by the French, trade was recovering. The total value of shipments in 1785 was 9,401*mb*, which is just 20 percent below the 1781 level. Although there is considerable variation by commodity, two goods in particular give a perspective on the yearly volume of the trade, since these would not have been stored for long periods. In 1785, 448 gallons of brandy were sent to Cumberland House as compared to 675 gallons in

1781, a decline of one-third. Meanwhile the shipment of tobacco, an even more important trade good fell by only 15 percent, from 2,348 lbs to 2,007 lbs. Such modest reductions in trade are incompatible with claims that the number of native hunters in the region fell by 50 percent or more. In fact, just three years later, in 1788, York Factory sent 13,856*mb* in trade goods to Cumberland House, or nearly 20 percent *more* than the value of goods sent in 1781.

The adult male population could not have recovered that quickly. That leaves the possibilities of first, rapid in-migration to the region, perhaps to take advantage of the increased availability of resources; second, an increased hinterland served by the outposts, whereby furs were being brought from a greater distance; and third, a larger beaver population which might have allowed for an increased catch despite the decline in hunting effort. We consider each of these.

As documented by Ray (1974: 94-116), there was some movement of the various tribal groups that occupied the Hudson Bay basin during the period 1763-1821. This included the natives' annual migration cycle, as well as more permanent shifts. Ray does identify a westward migration from the eastern part of Manitoba of some Cree groups, who were replaced by Ojibwa; but this took place after 1800. There is, moreover, no indication that native groups from outside the general region were entering the Hudson Bay hinterland at any time from 1763 to 1821. Indeed, it would have been surprising if, in the 1780s, outsiders had moved into an area so recently hit by a serious disease outbreak, especially considering the scope of the epidemic.[32]

The hinterland served by each interior post was determined by the natives' cost of travel and the presence of competing posts. Hudson House and Cumberland House were built to help the Hudson Bay Company compete with the Montreal traders, who as part of the Northwest Company, were increasing their presence in the region.[33] It therefore seems

unlikely that, in the 1780s, a larger hinterland can account for the increasing trade at Hudson House and Cumberland House; indeed a stronger case might be made that the posts were finding it more difficult to attract native traders.

The smallpox epidemic of 1781-82 and the temporary loss of York Factory the following year sharply reduced trade, but the Cumberland House and Hudson House accounts describe the pattern of trade over a more extended period. The value of trade goods sent to Cumberland House prior to the epidemic peaked in 1781 at 11,769 *mb*. In 1782 just 799 *mb* in goods were sent to the post, and the following year Cumberland House received no goods. The trade began to recover in 1784 and by 1788 the post was receiving 13,856 *mb* in trade goods. The years of decline in this largely beaver trade almost certainly had an impact on beaver stocks. To indicate the possible effect, suppose the trade pattern described in Figure 2 corresponded to the size of the beaver harvest.[34] Given beaver population dynamics, the stock in the late 1780s might have been 30 percent greater than in 1781.[35] Assuming a standard harvest function:

$$H = H(E, X), \tag{1}$$

where H is the harvest, X is the population of beaver, and E is harvesting effort, we can infer what the increase in the beaver population and the changing trade implies about harvesting effort. In Carlos and Lewis (1993: 492) we derived harvest elasticities of 2/3 with respect to effort and 1/3 with respect to the beaver stock. The value of trade goods in 1789 was close to the level in 1781. If we assume the beaver population was 30 percent higher in 1789, the implied decline in harvesting effort is 12 percent.[36] Allowing for some recovery of the native population after 1782, the harvesting effort and by extension the native population derived from the pattern of trade, suggests mortality very much along the lines of the 15 to 20 percent rate that we infer from the post journal accounts, and the rates consistent with other smallpox

epidemics.

Carrying Capacity and the Native Population

The approaches we have taken the smallpox epidemic of 1781-1782 appear to belie the view that 50 percent or even 90 percent of natives in the region died. In this section we further address the question of mortality by directly estimating the size of the native population before and immediately after the epidemic. We begin with counts of native groups by contemporaries. In addition to describing native settlements, European travellers sometimes reported the number of tents (lodges). Such accounts span the years preceding and following the smallpox outbreak. In 1776, five years before the epidemic, Alexander Henry the Elder reported 300 tents for the Plains Assiniboin (Ray 1974:105). In 1808, twenty-six years after the epidemic, Alexander Henry the Younger observed 850 tents occupied by ten different groups of Plains Assiniboin (Coues 1897: 522-23). This is nearly three times his uncle's estimate. Even had there been no epidemic, the earlier report of number of tents implies implausibly high population growth rates. Clearly Alexander Henry the Elder's count was incomplete; in fact, elsewhere he wrote: "The Osinipoilles [Assiniboin] have many villages composed of from one to two hundred tents each" (Henry 1969: 303). Henry the Younger's count, by contrast, is regarded as quite accurate. In addition to the tents of the Plains Assiniboin, he reported that a woodland band of Assiniboin had 30 tents. Including these, and assuming nine or eleven persons per tent, gives an Assiniboin population in 1808 of 7,650 to 9,350.[37] These numbers are the basis of our post-epidemic population estimate.

Given the vagueness of the eighteenth-century reports on native settlements, we approach the question of native population prior to the epidemic in a way that relies on evidence that is more firmly based. Our estimate is based on the carrying capacity of the region, namely the population that would likely have been supported by the local food supply.

During the subarctic winter, adult males consumed 4,500 to 5,000 calories per day; and, although fewer calories were needed at other times, the average daily requirement was at least *four* pounds (1.8 kg) of flesh food (Rogers and Smith 1981: 141). Moreover, because a high fat content was needed, the meat had to be from large game rather than small animals such as rabbit. The native population was therefore limited by the population of large ungulates.

The northern boreal forest that covered nearly all the fur trading hinterland of the Hudson's Bay Company was ideal habitat for various large ungulates, including deer, woodland caribou, and moose. In the region of Hudson House and Cumberland House, it was moose that was the native's main food source. The Cumberland journal for 1774/5 is filled with references to moose both as a food for the natives and as a trade good; indeed, no other large game is mentioned. For example, Samuel Hearne wrote on September 9th: "Early in the morning an Indian man came to the tent and informed me of his having killed a moose not far off for which I payed him and sent the people with two canoes to fetch home the meat;" on December 2: "The Indian Man who was sometime since mentioned as starving came in with some of his family brought 4 sledge load of Moose Flesh;" and on February 10th the journal notes: "one Indian man with news that 3 tents of Indians were within 5 hours walk and some had killed 5 moose and coming with most of the meat" (HBC, *Post Journals: Cumberland House*).

Given the vital role played by moose in the native diet, the density of moose and the meat available from a biomass of moose can be used to indicate the human population density. Allowing that some of the flesh requirement was met to a degree from the occasional deer, as well as by small game in winter, and fish and fowl the rest of the year, consumption of moose could hardly have averaged much less than 1.5 kg per day for an adult male, and 5 kg per day for a family of five (Carlos and Lewis 2010: 220-30). Over the year family

consumption would therefore have totalled about 1,800 kg. Moose range throughout the boreal forest, but their density depends on the region. In the period, 1990-1995 the Ontario provincial average was 0.21 moose/km^2, with considerable spatial variation across the roughly 70 wildlife management units (McKenney et al. 1998). Densities varied from 0.05 to 0.79 moose/km^2, and were higher in the northwest part of the province, a region that would have been part of the Hudson's Bay Company's fur trading hinterland. In that region the average density was 0.30 moose/km^2.[38] If we take this density to be consistent with maximum sustained yield management, then density at capacity was roughly 0.5 moose/km^2.[39]

Crête et al. (1981: 609) have estimated potential moose harvesting rates. For a moose population of 1,000 at capacity, they derive a potential harvest of between 62 and 169 animals, depending on the kill ratios of calves, cows, and bulls.[40] The corresponding biomass harvest is 22,000 kg to 50,000 kg per year.[41] Given the limited ability of native hunters to select the kill, a potential harvest of 40,000 kg live weight would seem to be toward the upper end of what would have been possible. Using current dressing techniques, "lean edible tissue" of bull moose is 36.5 percent of their live weight.[42] Assuming natives obtained this percentage, they might have harvested 14,600 kg of meat per year from an area with a capacity of 1,000 moose. At 1,800 kg per family of five, there would have been enough meat to maintain eight families.

The Hudson Bay region that we are considering is one of the better habitats for moose, so capacity would be at the upper end of the Ontario range; we assume 0.5 moose/km^2. At this density, the families, who could have been supported by a standing crop of 1,000 moose (at capacity), needed a hunting ground of 2,000 km^2. Since we estimate that this herd could have supported eight families, or forty individuals, the implied population density is one person per 50 km^2. Our value is well above the high end of the population density estimate

of one person per 130 km^2 given by Rogers and Smith (1981) for all of the northern Canadian shield, but in much of the Canadian shield animal densities are much less than in the areas we are considering.

Our approach to population based on carrying capacity can suggest no more than orders-of-magnitude; nevertheless, the implications are revealing. Ray (1974: 22) puts the tribal region of the Assiniboin prior to the smallpox epidemic at about 246,000 km^2. This area was limited largely to boreal forest and the parkland belt bordering the boreal forest that was their wintering grounds; but the natives also had access to the plains at other times of the year. Caloric demands in the fall and winter were much greater than during the summer, and the mechanisms for storing food were limited. It seems safe to assume that at least two-thirds of their yearly energy requirements, and by extension two-thirds of their meat requirement had to be met during the time they spent in this 246,000 km^2 region. Thus, the potential population density was perhaps 50 percent greater than one person per 50 km^2 calculated above, or one person per 33 km^2.[43] The Assiniboin population prior to the epidemic is therefore estimated to be about 7,400.

The post-epidemic population is based on Alexander Henry the Younger's lodge count made in 1808. Henry reported 880 lodges, which, at an average of ten persons per lodge, implies a population of 8,800. This is perhaps the most firmly based of our estimates. If we assume that, following the epidemic, population was growing at 1 percent per year, which seems close to the upper bound consistent with life expectancies, then at the end of the epidemic in 1782, the Assiniboin population would have been just under 6,800.[44] This estimate is only 10 percent below our pre-epidemic estimate of 7,400 based on carrying capacity.

The calculation of the Assiniboin population based on carrying capacity is subject to a

range of error at each stage, including those involving meat requirements, edible meat per animal, maximum harvest rates, potential animal densities, and available hunting grounds. Our approach has been to err on the side of overestimating the pre-epidemic population. Still, different plausible assumptions could lead to mortality greater than the 10 percent rate that we derive. It is not plausible, however, that mortality was as devastating as 50 percent and higher, the rates suggested in the literature.

Interpreting the Epidemic

Our conclusion that the smallpox epidemic of 1781-82 led to relatively low mortality is contrary to nearly all that has been written, both by contemporary observers and historians.[45] Given that we have no reliable population counts for the pre-epidemic period, such an iconoclastic result might be viewed skeptically. At the same time, it is important to recognize that the generally accepted narrative is based on evidence that is less than firm. Samuel Hearne, who became chief trader at Fort Churchill, reported that nine-tenths of the Indians in the hinterland of the post had died; and this statement, although by no means universally accepted, has entered the historiography.[46] Hearne's estimate was based exclusively on what the natives told him, since Fort Churchill had no inland posts. The entry in the York Factory journal for July 2, 1782: "not one in fifty of those tribes [in the La Pas area] is still living," should also not be taken literally.

Mortality rates of 90 or 95 percent for the overall region can be discounted, but other less extreme values suffer from the same problem in that they are based either on incomplete death counts or on vague comparisons of pre- and post-epidemic native populations. David Thompson traveled widely in the region, but did not arrive until four years after the smallpox outbreak. He reports 60 percent as the likely mortality. This estimate is really Mitchell Omam's. Omam was one of the Hudson Bay Company's interior traders, who accompanied

Thompson in 1786. He told Thompson: "it appeared about three-fifths had perished" (Glover 1962: 236). Omam was recalling what he saw in the area of Eagle Hills, west of Hudson House, when he was there in 1781. Coming five years later, Omam's statement calls for caution; and even more so any conclusion that applies his approximation to the entire region.

Despite the claims of contemporaries and the interpretation of historians, our various approaches to the smallpox epidemic lead to consistent conclusions regarding mortality. The actual counts of deaths reported by the chiefs at Hudson House and Cumberland total 10 to 15 percent of the native population served by the posts. Adding the deaths that we conjecture from the more general accounts raises mortality to perhaps 15 to 20 percent. The epidemiological evidence on the nature of smallpox suggests similar mortality. There is a long history of variola in its various forms, some more virulent than others, but in no case where numbers are reliable do case fatality rates approach the sorts of mortality claims made about the 1781-82 epidemic, and this includes rates for other "virgin soil" outbreaks. The range is on the order of 20 to 35 percent. As well recent work on smallpox finds little or no genetic link, suggesting that the case fatality rates of aboriginals in the region was no greater than that of unvaccinated populations with a long history of the disease. It also appears, given that smallpox is less contagious than other infectious diseases and the aboriginal population was thinly dispersed, that many natives would have been untouched by the epidemic. Thus, if observed case fatality rates are reflective of what Native Americans might have experienced, and recognizing the low population density in the region, it seems plausible that mortality was on the order of 20 percent or less.

Our third approach is to examine trade at two posts, Cumberland House and Hudson House, which were in the path of the epidemic. The furs they received depended on the native trappers and traders in the region; and so a large decline in the native population

should have been reflected in the trade returns. In 1782, the year smallpox passed through the region, trade at these posts did indeed collapse, but this might not because of native mortality. Rather, fearing the effects of the disease, natives redirected their effort from obtaining the luxuries associated with the fur trade to survival. Had a decline in native population been the reason for the loss in the trade, the effects would have been long-lasting. We find instead that, within six years, the trade at the two posts surpassed the pre-epidemic peak. There is the possibility that the vacuum left by the epidemic was filled by other native groups, but evidence on aboriginal migration gives no indication that this happened. Over the period 1780 to 1821, despite some changes within in the region, the Cree, Assiniboin, Ojibwa and Chipewyan were occupying similar territories (Ray 1974, 99-110). Indeed it would have taken courage for natives in areas unaffected by smallpox to move into a region that had so recently been devastated.

Finally we address the issue of high mortality by estimating the carrying capacity of the region. It is unlikely that the large game in the boreal forest characteristic of that part of the Hudson Bay basin could have supported a population density much greater than one person per 50 km^2. Given their hunting grounds, the Assiniboin, one the main native groups, could not have had a population much more than 7,400 prior to the epidemic. Yet in 1808, just twenty-six years after the epidemic, Alexander Henry estimated the Assiniboin at 8,800. Since population growth after 1782 was at most 1 percent per year, the immediate post-epidemic population could not have been much below 7,400.

Natives in the region of Hudson Bay died of smallpox; the contemporary accounts on this score are indisputable. What is in question is how widespread was smallpox in terms of the number contracting the disease, and how lethal was the disease to those infected. We are in no position to extend our finding, that mortality was much lower than has been claimed in

the literature, to other smallpox epidemics, or to outbreaks of other diseases among Native Americans. In 1819 the region suffered a dual epidemic of measles and whooping cough, and there was another smallpox outbreak in 1838 that was mitigated by vaccinations (Ray 1974: 106, 183; Carlos and Lewis 2010: 113). Still, our multi-pronged approach to the smallpox epidemic of 1781-82 may have applications to other episodes, and may ultimately influence our understanding of how European contact affected native populations and native society.

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Endnotes

1. For a review of the debate on the aboriginal population of the Americas at contact, first written in 1964 and then updated, see Borah (1992).

2. The low estimate is based Kroeber's work of the 1920s and 1930s. The high estimate was made in the 1980s by Dobyns (1983). In 1992, Ubelaker estimated the pre-contact population at 1.9 million, but he has since revised the number upward to 2.4 million (Ubelaker 1992: 170; 2006)

3. The timing of the early contact phase depended on the region, and its effect on health depended on whether natives were in physical contact with Europeans or whether they were simply receiving European goods through trade.

4. Two important hurdles are locating sites, and obtaining the permission and funding required for excavation.

5. Although promising, Dobyn's application of this methodology has been seriously questioned. See the references in Thornton et al. (1991: 42-45).

6. As Larsen et al. (1992: 35) report: "a consensus has emerged that disease brought by Europeans to the New World was the prima facie cause for the extinctions of some native populations." They point out, though, that a variety of other factors, among them warfare, may have led to conditions that exacerbated the effect of disease. On the basis of his study of archeological sites and skeletal remains in the Northern Plains, Owsley (1992) attributes population decline to a combination of disease, malnutrition, and tribal warfare. Ramenofsky (1987) also points to war as a significant factor in some population declines.

7. Smallpox affected aboriginals in North America almost from the time of contact. There was an outbreak in the 1730s that reached the Mandan villages in current day North Dakota, but it does not appear to have extended further north. Even if it had, there would have been be few survivors who might have had immunity as late as 1780.

8. Direct contact was restricted to those natives who came to the posts to trade furs, and to the "home guard" Indians, who spent much of the year in the general vicinity of the posts, providing mainly game to the Company men.

9. This outbreak was part of a much larger smallpox epidemic that began five years earlier during the American Revolution. The disease first appeared in Boston in 1775 and had three epicenters along the east coast of the United States. Smallpox spread from the Gulf of Mexico northward through the central plains, reaching the southern edge of the Hudson Bay Company's fur-trading hinterland in the summer of 1781. This same epidemic continued to the Columbia River basin and Puget Sound (Fenn 2001: 7).

10. There are differing views on the paths of transmission. Hackett (2002: 98) suggests that the Shoshane transmitted smallpox to an attacking party of Cree, Assiniboin, and Blackfoot, some of whom carried the disease along the North Saskatchewan River to Hudson House; and Decker (1988: 14) proposes a path of transmission to Cumberland House directly from the south. See also Fenn (2001).

11. The woman mentioned died two days later and was buried by Company men because the natives would not touch her body.

12. The groups mentioned were the U, Basquiau, Pegogemy, and Cowinetou Indians.

13. The disease did not merely result in increased mortality. There was also the longer term impact on morbidity and future fertility (Ramenofsky 1987: 147).

14. A potential agency problem might be noted. Post factors may have exaggerated mortality to help explain a decline in fur returns that was due to other factors, such as their own lack of effort.

15. These observations came from Mitchell Omam, who had been at the posts during 1781/2 (Glover 1952: 236). It should be noted that some statements about mortality were made by European observers several years after the event.

16. The following reports on smallpox are drawn from the Cumberland House and Hudson House journals. The journal entries have been compiled in Rich (1952: 223-56 and 262-91).

17. On numbers per tent see Ray (1974: 105), who suggests eight to ten, and Demollie and Miller (1981: 590), who report an early nineteenth-century estimate of eleven. Note that in the Indians' account of October 22nd, seven were reported dead in one tent, which was likely fewer than the original number of occupants.

18. There is little guidance in the reports on the meaning of "several," which was used occasionally. We take it to mean four to six. In other reports, round numbers of tents tend to be given: 5, 10 or 20. These may have been approximate.

19. In 1781, for example, the value of goods traded at York Factory, 11,605 *mb*, was about equal to the value of trade goods that were sent to Cumberland House, 11,769 *mb* (HBC, *Post Accounts: York Factory*).

20. The figure is from Carlos and Lewis (2010: 72), and is based on the population ranges for different native groups given by Ray (1974: 105, 111). Later in this paper we derive a population estimate for the Assiniboin, but the area covered is not fully comparable.

21. The details are given in Appendix Tables 1A and 1B.

22. Smallpox was present in China in the 4th century AD, while Egyptian mummies show evidence of smallpox as early as 1500 BC (Fenner et al. 1988: 210-11).

23. To the extent that smallpox treatment improved, twentieth-century case fatality rates might understate previous experiences, but the bias is likely to be small. Even in the twentieth century, the treatments for smallpox were largely ineffective. As Fenner et al. (1988: 64, 68) puts it: "No disease better illustrated the adage 'Prevention is better than cure.'" In poorer countries "patients were usually better looked after at home in their village surroundings."

24. The much less virulent, *variola minor* (case fatality rate of about 1 percent), was not seen outside Africa until the late nineteenth century (Fenner et al. 1988:4).

25. Confluence refers to the density of the rash. Occasionally, an individual would present a form of the disease known as haemorrhagic. This occurred rarely but was always fatal. Haemorrhagic-type smallpox was primarily due to defects in the response to infection, and mainly affected patients who were pregnant. See Fenner et al. (1988: 22, 38, 50).

26. Some experimental work on mousepox does find a possible genetic component to resistance; and a small study of Dutch soldiers indicates that the presence of a particular HLA (human leukocyte antigen) group, Cw3, may imply greater susceptibility to smallpox (Fenner et al. 1988: 166). The HLA allele, Cw3, which is present among 30 percent of the Netherlands population, is common among Amerindians (Bernal et al. 1990: 1050) It should be emphasised, though, that the connection between Cw3 and susceptibility to smallpox is tenuous. The impact of a diminished immune response to a virus is ambiguous in terms of clinical outcomes; moreover vaccinia has a somewhat different structure than smallpox. I thank Dr. Roy Ilan, Faculty of Medicine, Queen's University for these observations.

27. Rarely has smallpox been spread in settings where contact is fleeting, including enclosed spaces such as buildings. The incubation period for the disease is normally 12 to 14 days but can range from 7 to 17 days. CDC , "Smallpox Disease Overview," and "What We Learn About Smallpox from Movies - Fact or Fiction."

28. In 1808, for example, the entire hunting area of the various groups of Assiniboin was about 355,000 km^2, while their winter locations totalled 94,000 km^2 (Ray 1974: 95, 101 - hunting area based on the tribal distribution in 1821).

29. The trade goods sent to Cumberland House and Hudson House (the much smaller post) were combined in the York Factory accounts under "Cumberland House." The *made beaver* (*mb*) was the unit of account used by the Hudson's Bay Company at all its trading posts. A prime beaver pelt had a price of 1 *mb* and all other furs and trade goods were assigned prices in terms of that standard.

30. The French attack did more than disrupt trade. Aboriginal traders with smallpox arrived at York Factory in June 1782. The chief factor, Matthew Cocking, had imposed a quarantine to keep native traders in affected regions away from those who had not yet been exposed. This quarantine measure broke down with the capture of the post, contributing to the spread of the disease.

31. Company policy did not allow posts to maintain high inventories; indeed, the London management kept a close watch on inventory levels and on the annual request for new trade goods. Both Cumberland and Hudson Houses would have held inventory to allow trade to proceed in the spring before the rivers to the north were navigable.

32. The smallpox epidemic not only affected areas to the south of the posts, it later mover northward.

33. In the 1790s both the Northwest Company and the Hudson Bay Company set up additional posts some in close proximity (Moodie et al. 1987).

34. The assumption that the deliveries of trade goods corresponds to the beaver harvest almost certainly overstates the fluctuations, in part because beaver were hunted for personal

use as well as for trade, and because the shipments of trade goods fluctuated more than the value of furs received.

35. We assume the change in the beaver population is described by $\triangle X = aX - bX^2 - H$, where X is the beaver stock, H is the harvest, a and b are the parameters of the natural growth function, and $\triangle$ indicates the annual change. We set $a = .3$ and assume that the maximum sustained harvest was 12 thousand, which was about the level in 1781 and over the period 1786 to 1789. The implied maximum sustained yield population is 80 thousand and the value of b is 0.001875. Assuming the beaver population in the Cumberland House and Hudson House hinterland was 80 thousand in 1781 and the beaver harvest corresponded to the volume of trade goods expressed in *made beaver*, we project the beaver population increasing to 103 thousand in 1789 or by 30 percent. See Carlos and Lewis (2010: 192-93).

36. Since $H = E^{\frac{2}{3}} X^{\frac{1}{3}}$ and the harvest was about the same in the two years, E varied according to $X^{-\frac{1}{2}}$.

37. On numbers per tent, see fn. 17.

38. This was the average density in Wildlife Management Units (WMU): 5, 6, 7A, 7B, 8, 9A, 9B, 10, 11A, 11B, 12A, 12B, 15A, 15B (McKenney et al. 1998: 1929). Densities in WMU's to the north and to the east were much lower.

39. Capacity is the animal population that will be reached in the absence of hunting. Crête et al. (1981: 608) estimate the maximum sustained yield population for moose in southwestern Quebec to be between 48 percent and 72 percent of capacity. Their intermediate values are about 0.6.

40. This seemingly wide range is due to differences in the proportions of each category of animal killed. If the harvest is exclusively bulls, only 62 animals can be taken. The number of animals killed and the productivity of the herd, in terms of biomass, is much greater if roughly equal numbers of calves, cows, and bulls are harvested.

41. Jordan et al. (1971: 149) estimate the average biomass of a standing crop of moose of 1,000 on an island off the northern coast of Lake Superior to be 367,000 kg. A harvest of 50,000 kg is 14 percent of that biomass. Moose weights may have differed in the eighteenth century, but given that the values we are using apply to relatively productive areas, we are more likely biasing our harvest estimates upward.

42. This ratio applies to a moose weighing 914 lbs. The field dressed weight is 72.9 percent of live weight, and edible tissue is 50 percent of that (Marchelle and Garden-Robinson 2006: 8).

43. The density of one person per 50 km^2 is based on annual consumption. Assuming 2/3 of annual consumption is met on the winter grounds, it follows that density there would be one person per 33 km^2 (ie. $2/3 \times 50$).

44. Life expectancy at birth of these populations would certainly have been under 30 years. The gross reproduction rate (GRR) that would have allowed an annual population growth of 1 percent is between 3.00 and 3.25 (Wrigley and Schofield 1989: 243). A GRR in this range (roughly 6 to 6.5 births per woman) is close to the upper end of what would have been

possible. On the maximum rate of growth of similar aboriginal populations see Thornton et al. (1991: 32).

45. Ray (1974:111) gives what is perhaps the lowest of the mortality estimates for some groups, one-third to one-half.

46. Hearne's previous posting was at Cumberland House.

Table 1. Number of Smallpox Deaths based on reports to Hudson House and Cumberland House

	Hudson House	Cumberland House	Total
Reported number of deaths by			
Company	25	63	88
Indians	9	6	15
Reported deaths by Indians based on tents			
Low estimate	167	177	344
High estimate	220	263	483
Total reported deaths			
Low estimate	201	246	447
High estimate	254	332	586
Deaths based on general statements			
Low estimate	*115*	*85*	*200*
High estimate	*190*	*160*	*350*
Total deaths			
Low estimate	*316*	*331*	*647*
High estimate	*444*	*492*	*936*

Note: Numbers in italics are conjectures based on general descriptions.

Sources: Rich (1952, Vol.2); Appendix Tables 1A and 1B.

Table 2. Smallpox Case Fatality Rates in Unvaccinated Populations

	Period	Case fatality rate (percent)	
		Adults[a]	All
Liverpool, England	1902-1903	24.0	27.2
Tabriz, Iran	1954-1955		13.8
Madras, India	1961-1969	35.4	35.5
West Pakistan	1966-1967	15.9	15.7
Noakhali, Bangladesh	1972-1973	20.0	21.0
India, 6 States	1974-1975	18.1	26.5

[a] Ages ranges are generally from 15 to 50.

Sources: Fenner et al. (1988: 51, 53, 54, 176); Fredericksen and Motemani (1957: 854); Mack et al. (1970: 483).

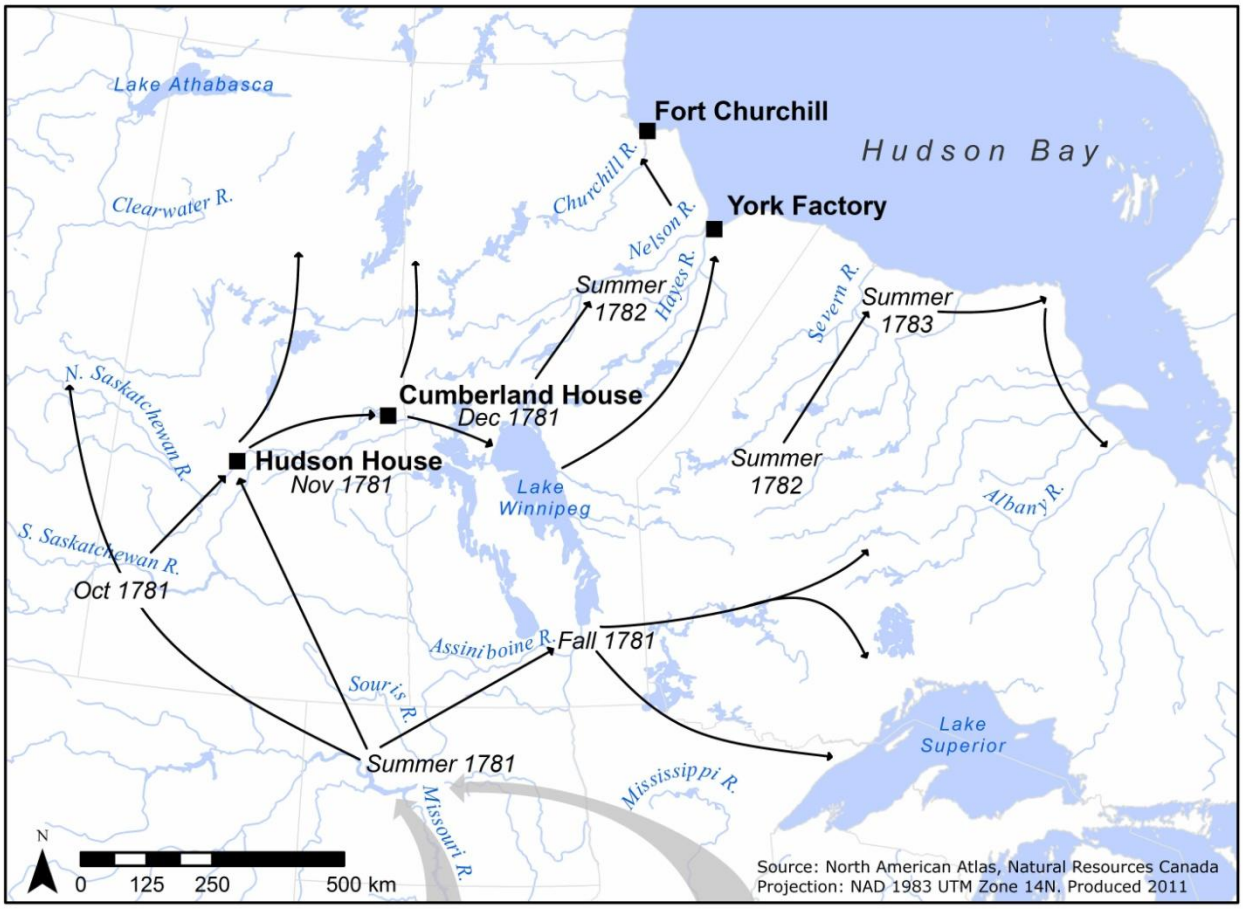
Table 3. Trade Goods Sent from York Factory to Cumberland House, 1781 and 1785

Trade Good	1781	1785		1781	1785
awl blades	288	26	kettles	52	61
baize (yds)	20	71	knives	1,830	1,818
bayonets	204	126	lace (yds)	180	
beads (lbs)	39	28	looking glasses	40	48
blankets	86	43	needles	388	504
brandy (gals)	675	448	net lines	6	12
buttons	24	37	pistols		10
cloth - various (yds)	1,316	761	powder (lbs)	1,308	934
combs	84	100	powder horns	7	9
duffel (yds)	172	48	rings		516
files	66	144	rundlets	31	53
fish hooks	160		scrapers		10
flints	3,000	2,000	shirts	68	125
gartering (yds)		836	shot (lbs)	2,416	1,240
gun worms	144	288	stockings		24
guns	60	99	thimbles		24
hatchets	288	211	thread	3	6
hats	8	21	tobacco (lbs)	2,348	2,007
hawk bells	216	500	tobacco boxes	30	57
ice chisels	202	80	vermilion (lbs)	14	10
Total - *made beaver*				11,769	9,401

Note: Includes trade goods for Hudson House.

Source: HBC, *Post Accounts: York Factory,* 1781,1785.

Figure 1. Hudson House, Cunberland House and the Principal Paths of Diffusion of the Smallpox Epidemic, 1781-1782



Sources: Ray (1974:107); Hackett (2002:98).

Map: Hilary Dugan 2011.

Figure 2. The Value in *Made Beaver* of Trade Goods Sent from York Factory to Cumberland House, 1777 – 1789

Note: Includes trade goods sent to Hudson House.

Source: HBC, *Post Accounts: York Factory*, 1777-89.