Original Research Article

Sex Ratios in the Arctic—Do Man-Made Chemicals Matter?

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Objectives: The objective was to analyze the variation of secondary sex ratios across the Arctic and to estimate the time trend. The rationale for this was claims in news media that, in the Arctic, sex ratios have become reduced due to exposure to anthropogenic contaminants in the environment.

Methods: Data was collected from 27 circumpolar jurisdictions from public websites of the eight Arctic countries. Sex ratios at birth were calculated for each jurisdiction and each available year. Linear regression models of the sex ratios across time were fit within each jurisdiction to estimate the change in sex ratio over time.

Results: All male:female sex ratios were close to 1.05 with time trends close to 0. In a Bayesian hierarchical model overall sex ratio was estimated at 1.054 (95% confidence interval 1.048, 1.058). The estimate for the 10-year slope across all jurisdictions was 0.0010 (95% confidence interval −0.0021, 0.0046). Separate analyses of indigenous populations in Alaska and Greenland gave similar results and similar sex ratios were found among Greenland Inuit in 1900 and today.

Conclusions: The absence of deviation of the secondary sex ratio in any of the Arctic jurisdictions indicates that the contaminants that are present are not disrupting endocrine systems to the extent that sex ratios are being affected. Am. J. Hum. Biol. 24:165–169, 2012.

The Arctic environment is undergoing rapid changes as a result of global warming and resource development, especially in minerals, oil, and gas. It is also affected by long-range transportation by air and ocean currents of contaminants from distant industrial sources. The physical and social environments interact with human biology, lifestyles, and behaviors to influence the health of human populations in the Arctic (Young and Bjerregaard, 2008).

In 2007, the British newspaper *Guardian* declared in a headline that twice as many girls than boys were being born in Greenland and Arctic Russia, and that man-made chemicals were to blame (Brown, 2007). We traced the source of the alarming story to anecdotal information from one village in northern Greenland and a report from the Arctic Monitoring and Assessment Programme on persistent toxic substances among indigenous people of the Russian North (Arctic Monitoring and Assessment Programme, 2004). While we share the increasing concern of many northern residents over environmental pollution in many parts of the Arctic, we believe that concern over health effects should be based on facts. We wanted to analyze this before it became a generally acknowledged truth that man-made chemicals were responsible for changing sex ratios in the Arctic. The first step was to investigate if there had indeed been any deviation from the "normal" secondary sex ratio (i.e., ratio of male to female live births) across 27 Arctic jurisdictions.

The secondary sex ratio is remarkably consistent across human populations, between 1.05 and 1.07, i.e., 105–107 males for every 100 females born (Hesketh and Xing, 2006). In the absence of selective termination of pregnancy favoring one sex over another for sociocultural reasons, substantial deviation of the ratio from this average is suggestive of threats to human reproductive health from the external environment or health conditions in the parents. Trends in declining proportions of male births have been reported from a number of countries (Grech et al., 2003), including those in high latitudes such as Norway (Irgens and Irgens, 2003), Finland (Vartianen et al., 1999), and Canada (Allan et al., 1997), though the magnitude of the decline varies. Among potential explanatory mechanisms proposed, the endocrine disruptive effects of persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs), during conception and pregnancy have received much attention (James, 2006).

In addition to the sources cited above, much of the evidence for the association between pollutants and sex ratio has been based on small community studies or the aftermath of environmental incidents (Hertz-Picciotto et al., 2008; Mackenzie et al., 2005; Mocarelli et al., 1996). Other studies, however, failed to demonstrate an association between sex ratio and exposure to environmental or toxic agents (Karmaus et al., 2002; Taylor et al., 2006; Terrell et al., 2009; Vartianinen et al., 1999; Yoshimura et al., 2001).

The exposure to environmental contaminants and its potential health effects are issues of major concern in the Arctic, especially among its indigenous populations (Arctic Monitoring and Assessment Programme, 2009). Contaminants are transported to the Arctic by ocean and air currents. They are also produced and released by local activities, such as mining or the disposal of waste. Contaminants enter the marine and terrestrial food chains, posing a risk to the animals as well as to humans who consume these animals. For PCBs, it is especially the blubber of marine mammals that contribute to the exposure (Kraemer et al., 2005).

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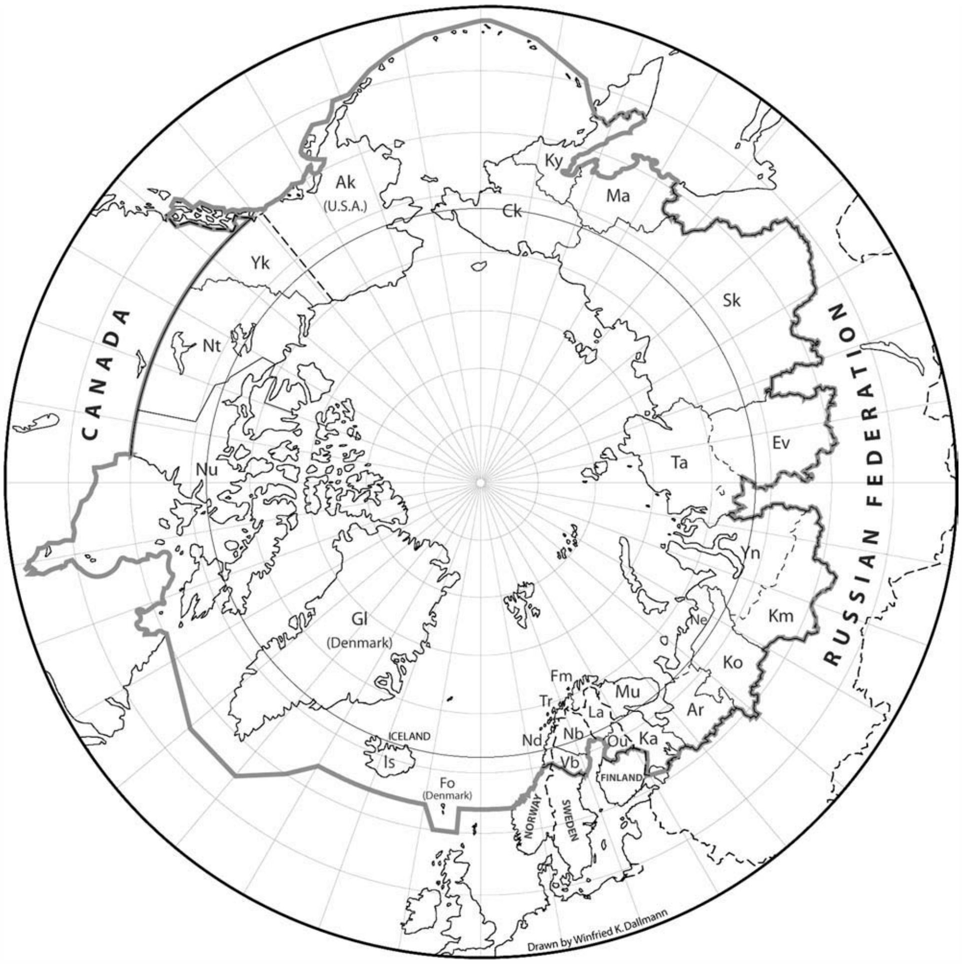

Fig. 1. The Arctic with the 27 jurisdictions studied within eight Arctic countries.

In the circumpolar region, diet is the most important source of contaminant exposure. Indigenous people are at particular risk because traditional or “country” foods, including fish, birds, terrestrial, and marine mammals, continue to constitute an important component of the diet. The harvesting, preparation and consumption of such foods, is an integral part of their culture and important for social and spiritual health. POPs such as PCBs have been found in high levels in the blood, cord blood or milk of pregnant Faroese women (Fangstrom et al., 2002), pregnant Inuit women in Canada (Butler-Walker et al., 2003), Greenlanders (Johansen et al., 2004), and nursing mothers in Arctic and sub-Arctic regions of Russia (Polder et al., 2003).

There is ample evidence for high concentrations of POPs in the serum of Arctic residents from certain regions but only a few studies on time trends. The percentage of women of reproductive age who exceeded the Health Canada level of concern for PCBs (5 μg/L Aroclor 1260) ranged from less than 10% in Iceland and several Russian Arctic regions to more than 70% in Greenland, the eastern Canadian Arctic, and Chukotka (Oostdam et al., 2009). Mean PCB levels of adult women of the Québec City area were reported to be only one-tenth of those of Canadian Inuit (Lebel et al., 1998). Trends of legacy POPs in biota were in general decreasing during about 1970–2006 (Riget et al., 2010). Similarly, data for pregnant women suggested that the serum concentrations of legacy POPs have decreased from 1990 to 2007 (Oostdam et al., 2009). Despite the high concentrations of POPs in some Arctic regions, reports of health effects are few and inconsistent.

We have analyzed secondary sex ratios across the Arctic in 27 jurisdictions that differ among other things with regard to their proportion of indigenous people in the population, the type of traditional diet consumed (marine and terrestrial) and hence exposure to heavily contaminated marine mammals. If there is an association between POPs exposure and secondary sex ratios, we would expect a significant variation in secondary sex ratios among the jurisdictions, as would be evidenced by a non-zero slope for the sex ratio over time.

MATERIAL AND METHODS

Geographical coverage

Because health and demographic data are collected by government agencies, we define the Arctic as consisting of 27 political-administrative divisions (Fig. 1), rather than use geophysical or ecological criteria. These jurisdictions include the state of Alaska, the three Canadian territories of Yukon, Northwest Territories and Nunavut, the self-governing territories of Greenland and the Faroe Islands which are part of the Kingdom of Denmark, Iceland, the northern regions of Norway, Sweden and Finland, and various republics, oblasts, and autonomous okrugs (AO) in the European North and Siberia of the Russian Federation. All or parts of these regions lie above latitude 60°N. These regions vary considerably in area, population size, climate, and socioeconomic conditions.

Data sources

The vital statistics databases of statistical agencies of the various countries and regions were accessed from their public websites to extract the number of live births by sex. A complete list of the data sources is provided in the Appendix A. The number of years of data available varies. Data are generally available from the early 1970s, with the exception of Russian regions, which are available only from the 1990s. For Alaska and Greenland, the vital statistics databases permitted us to create additional data series on Alaska Natives (separate from the Alaska all-race series) and individuals born to mothers who were born in Greenland (separate from the series of all births in Greenland).

Statistical methods

Graphs of the sex ratio over time were prepared for each of the 27 jurisdictions. Within each jurisdiction, a linear regression line was fit to these data. Any deviations of the slopes of these regression lines from 0 would be evidence of a change in the sex ratio over time. Time was measured with the year 2000 as time 0, so that the intercept could be interpreted as the estimated sex ratio in that year.

To combine data from the 27 jurisdictions into an overall estimate, a Bayesian hierarchical model was used. At the first level of this model, the sex ratio data over time for each jurisdiction were assumed to follow a linear regression line, as described above. At the second level of the hierarchy, the intercepts from the first level were assumed to follow a normal density, with a mean representing the overall sex ratio across all regions in the year 2000, and a variance parameter representing the between region variability in sex ratios at that time. The slopes across regions were assumed to follow a separate normal density, with a mean representing the overall estimate of the change in sex ratio over time across regions, and a variance parameter estimating the variability in these slopes across regions. Small variance estimates for the intercepts and slopes at this second level would indicate little differences between regions in terms of sex ratio at the year 2000 and in changes over time, while larger values would indicate higher between region differences. Ninety-five percent intervals are presented throughout.

Aside from the general populations of the 27 jurisdictions, separate analyses were also run for the Alaska Natives and children born to mothers who were born in Greenland as a proxy for the indigenous Inuit in Greenland.

RESULTS

Figure 2 shows 5-year moving averages for the five main regions in the circumpolar area, i.e., Alaska, northern Canada, Greenland, the northern parts of the Nordic countries, and the northern part of the Russian Federation. The overall visual impression is that there is no general trend over time, as indicated by the flat regression slopes, and that all averages cluster around a male:female ratio of 1.05. Separate graphs for individual jurisdictions are shown in Appendix B [available as web extra materials]. There were no obvious deviations from a flat line (slope of zero) within any jurisdiction.

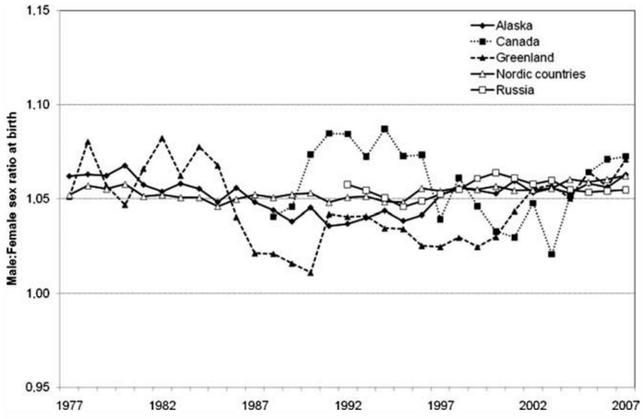

Fig. 2. Five-year moving averages of male:female sex ratios at birth in five Arctic regions, 1997–2007.

This visual conjecture is supported by the estimates of the slopes from each jurisdiction, as presented in Table 1 that shows the ratio and trend estimates from all 27 Arctic jurisdictions. Although slopes for Magadan Oblast and Norrbotten had 95% confidence intervals which excluded 0, the estimated slopes were small, and it can be expected that in calculating 27 intervals that one or two may exclude 0 by chance alone. The sex ratios were all close to 1.05. Only for the Koryak AO did the 95% confidence interval not span 1.05 but this estimate was based on only 7,200 births. Furthermore, in calculating 27 confidence intervals, it is expected that one falls outside 1.05 by chance alone.

To check this, we examined estimates from the hierarchical model. Here all 27 of the intercepts were estimated to be close to 1.05, with overall point estimate from the hierarchical model of 1.054 (95% CI 1.048, 1.058). All the slope estimates included 0 within their range, including those for Magadan Oblast and Norrbotten. The overall estimate for the 10-year slope across the 27 jurisdictions from this model was 0.0010 (95% CI −0.0021, 0.0046).

Results for Alaskan and Greenland native populations were similar, with sex ratios close to 1.05 and slopes close to 0.

DISCUSSION

Our data, which cover the entire Arctic and extend over several decades, fail to confirm media claim or the results of studies on single communities that are limited in time duration, of decreased sex ratios of live births in the Arctic or significant time trends. For a region such as Greenland, the population which is among the most exposed to PCBs, the secondary sex ratio today (1.043) is no different than that in the early 20th century (1.048) as reported by Bertelsen (1935).

The lack of change in sex ratios among 27 Arctic jurisdictions over the period studied provides evidence that the contaminants that are present are not disrupting

TABLE 1. Male:female sex ratio and 10 year increase in ratios in 27 jurisdictions across the Arctic

				Male:female ratio			Increase per 10 year period		
Countries	Region	*N*	Period	Estimate	Lower CL	Upper CL	Estimate	Lower CL	Upper CL
USA	Alaska	363,570	1971–2006	1.051	1.039	1.062	−0.0004	−0.0078	0.0069
Canada	Yukon	9,523	1986–2007	1.069	1.009	1.128	0.0092	−0.0732	0.0916
	Northwest Territories	16,864	1986–2007	1.032	0.983	1.081	0.0092	−0.0584	0.0767
	Nunavut	15,850	1986–2007	1.077	1.029	1.125	0.0008	−0.0649	0.0666
Denmark	Greenland	37,197	1973–2009	1.050	1.025	1.074	−0.0037	−0.0211	0.0137
	Faroe Islands	17,525	1985–2008	1.037	1.001	1.073	0.0000	−0.0460	0.0461
Iceland	Iceland	254,929	1951–2008	1.048	1.035	1.061	−0.0030	−0.0079	0.0019
Norway	Finnmark	42,314	1972–2008	1.056	1.030	1.083	−0.0082	−0.0265	0.0102
	Nordland	114,801	1972–2008	1.066	1.048	1.084	0.0097	−0.0025	0.0220
	Troms	77,330	1972–2008	1.075	1.049	1.102	0.0020	−0.0163	0.0203
Sweden	Norbotten	127,858	1968–2009	1.072	1.056	1.088	0.0098	0.0003	0.0193
	Västerbotten	126,240	1968–2009	1.053	1.037	1.069	0.0041	−0.0054	0.0137
Finland	Lappi	50,573	1987–2009	1.035	1.016	1.054	0.0209	−0.0071	0.0489
	Oulu	144,427	1987–2009	1.051	1.038	1.064	0.0054	−0.0132	0.0239
Russian	Murmansk Oblast	170,147	1990–2008	1.072	1.053	1.091	−0.0089	−0.0424	0.0245
Federation	Kareliya Republic	137,118	1990–2008	1.061	1.050	1.073	−0.0130	−0.0340	0.0079
	Arkhangelsk Oblast	273,484	1990–2008	1.053	1.042	1.064	0.0028	−0.0170	0.0226
	Nenets AO	12,047	1990–2008	1.056	1.001	1.111	−0.0357	−0.1343	0.0630
	Komi Republic	222,706	1990–2008	1.048	1.039	1.056	−0.0084	−0.0234	0.0066
	Yamalo-Nenets AO	127,564	1990–2008	1.057	1.040	1.073	−0.0069	−0.0368	0.0229
	Khanty-Mansi AO	337,655	1990–2008	1.061	1.053	1.069	0.0022	−0.0120	0.0163
	Taymyr AO	11,135	1990–2008	1.033	0.999	1.066	0.0095	−0.0507	0.0697
	Evenkia AO	5,749	1990–2008	1.030	0.961	1.098	0.0255	−0.0980	0.1489
	Sakha Republic	290,227	1990–2008	1.051	1.042	1.060	−0.0028	−0.0192	0.0136
	Magadan Oblast	46,313	1990–2008	1.055	1.037	1.074	0.0486	0.0151	0.0822
	Koryak AO	7,220	1990–2008	1.008	0.972	1.043	−0.0289	−0.0922	0.0343
	Chukotka AO	18,886	1990–2008	1.033	0.992	1.074	0.0253	−0.0486	0.0992
	All regions combined	3,059,252		1.049	1.054	1.058	0.0010	−0.0021	0.0046
Indigenous	Alaska Natives	84,766	1971–2006	1.066	1.045	1.086	0.0127	−0.0007	0.0261
populations	Greenland Inuit	52,323	1956–2005	1.043	1.012	1.074	−0.0077	−0.0204	0.0049

Estimates with 95% confidence intervals.

endocrine systems to the extent that sex ratios are being affected, or widespread enough to be detected at the population level. By analyzing separately data on Alaska Natives and indigenous Greenlanders, populations which have been described to have higher levels of contaminant exposure (Arctic Monitoring and Assessment Programme, 2001), we were still unable to demonstrate any deviation from the global human norm or change in the secondary sex ratios over time.

Our finding is at odds with national studies in several circumpolar countries which have demonstrated a downward trend in secondary sex ratio (Allan et al., 1997; Irgens and Irgens, 2003; Vartianinen et al., 1999), for which the global increase in the use of POPs has been cited as a potential cause. The existing evidence for a causative role of POPs and other environmental contaminants in changing the sex ratio is inconsistent, but the association likely varies based on the type and amount of exposure, the timing during pregnancy and how the exposure is measured. Legacy POPs show a decreasing trend in the Arctic due to legislation banning these widely measured POPs. There are, however, newer POPs that are not studied to the same extent as the legacy POPs (Oostdam et al., 2009) and for which, therefore, we do not have information about time trends.

We recognize that our study is not designed to test the association between environmental contaminants as the exposure and secondary sex ratio as the outcome. It is, however, logical to first determine if an outcome exists at all before finding out what causes it.

While we cannot conclude that PCBs have no effect on the sex ratio at birth in the northern jurisdictions that we have analyzed, we can conclude that the regions studied do not differ from each other with regard to sex ratio at birth, although they differ with regard to contaminant exposure. We can also conclude that there is no trend over time toward a decreasing sex ratio in any of the regions studied or in all of them together.

Many factors have been studied for their effects on the secondary sex ratio—one review listed 30 demographic and environmental factors, including family size, parental age, parental occupation, birth order, race, coital rate, hormonal treatments, exposure to toxins, stress, and several diseases (Hesketh and Xing, 2006). Because of the nature of our data, we were not able to include these variables, but further studies including this information may help understand the stability of the sex ratio in the Arctic.

From a public health monitoring perspective the sex ratio is not of primary interest. Given the fact that the secondary sex ratio has not changed significantly over the past several decades when the Arctic has experienced substantial social, climatic, and environmental change, the ratio is unlikely to be a useful summary indicator to monitor future changes in these areas. Instead, these changes are best monitored directly at the environmental level. Public health responses to social, climatic, and environmental change and the monitoring of human health impacts are more complex and require multidisciplinary responses.

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APPENDIX A: DATA SOURCES

Data was collected from vital statistics repositories, most of which were accessible online.

United States

National Centre for Health Statistics: VitalStats data files (http://www.cdc.gov/nchs/VitalStats.htm) from 1994 to 2006, and earlier data from past volumes of the *Vital Statistics of the United States* annual reports (http://www.cdc.gov/nchs/products/vsus.htm#natab94).

Canada

Statistics Canada: 2000–2006 data available online at http://cansim2.statcan.gc.ca, and 1986–1999 data obtained by special request.

Greenland

Statistics Greenland's Statbank for the years 1973–2009 at bank.stat.gl.

Faroe Islands

Statistics Faroe Islands for the years 1985–2008 at www.hagstova.fo.

Iceland

Statistics Iceland for the years 1951–2008 at www.statice.is.

Norway

Statistics Norway's Statbank for the years 1972–2008, from statbank.ssb.no.

Sweden

Statistics Sweden Database for the years 1968–2009, at www.ssd.scb.se/databaser.

Finland

Statistics Finland data is available at pxweb2.stat.fi/database/StatFin/databasetree_en.asp.

Russian federation

Central Statistical Database available at: www.gks.ru/dbscripts/Cbsd/DBInet.cgi?pl=2401002.

All websites were accessed in February 2011.

APPENDIX B

Graphs of male:female sex ratios over time in individual Arctic jurisdictions. Point estimates and 95% confidence intervals.