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Perspectives of climate change: A comparison of scientific understanding and local interpretations by different Western Siberian communities

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Abstract We present a study of social effects of climate change as experienced by local communities, based on field research and analysis in Western Siberia, from southern taiga to tundra. The results of field anthropological research reveal different attitudes of local residents to climate change. We compare the key trends of climate change with the perspectives of local residents, based on memories, subjective experiences, and local environmental knowledge. Our results highlight a significant divergence of the subjective assessments of residents from objective data on the dynamics of changes in certain environmental elements. We explore how the human subjective perception of natural processes, their consequences and impacts, are influenced by such factors as: type of settlement, age, gender, level of education and how collective stereotypes and judgments merge information in attitude formation. We also address the need to reconcile observed climate change impacts and perceptions to enable decision-makers to engage more constructively with the local population to develop and implement adaptation.

Keywords Climate change · Local communities · Indigenous peoples · Local perceptions · Environmental and ecological trends · Western Siberia

INTRODUCTION

The last three decades are the warmest period in the history of observation in Eurasia, with a warming rate several times higher than the global average, and the highest rate of temperature increase at high latitudes (Chernokulsky et al. 2019). During the twenty-first century, the warming processes covered almost the entire the territory of Western Siberia (Kharyutkina et al. 2019; Gorbatenko et al. 2020). An understanding of how society perceives these processes, requiring a synthesis of climatological and socio-anthropological knowledge, can help climate change mitigation (Leiserowitz 2006). Awareness of public opinion and local climate change perspectives is critically important to influence adaptation policies (Pietsch and McAllister 2010; Callaghan et al. 2020).

Public opinion on climate change is currently undergoing extensive research in the United States (e.g., Smith and Leiserowitz 2012; Egan and Mullin 2017), in Europe (e.g., Hagen et al. 2016; Sousa-Silva 2016), Asia (e.g., Esham and Garforth 2013), Africa (e.g., Ayal and Filho 2017), and Australia (e.g., Pietsch and McAllister 2010). The most comprehensive global analysis of this topic is presented in the survey of UNDP-Oxford (Flynn et al. 2021). In contrast, the topic has been discussed much less in Russia. However, the main studies were focused on Yakutia (Anisimov et al. 2017; Takakura 2018; Anisimov and Orttung 2019; Takakura et al. 2020), the North-Western part of Russia (Anisimov and Orttung 2019; Shcherbakova 2019), and the Arkhangelsk region (Varakina and Trifonova 2017), while single surveys were conducted on Vaigach Island (Davydov and Mikhailova 2013). In Western Siberia, there has been no large-scale research of public perceptions of climate change so far. In this work, we present the results of a survey of the vast territory of Western Siberia from the southern taiga to the northern tundra. We focus on individual settlements, allowing us to be immersed into the reality of a certain settlement, with maximum detachment from the regional and global contexts. This has its advantages, allowing us to see through

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anthropological research the smallest details and nuances of feelings in the perceptions of local people (Rakhmanova and Kirpotinfv 2019). This immersion also allows us to establish on a micro-level the causal links between climatic and environmental change and behavior, particularly economic, infrastructural, psychophysiological, historical, social, and political.

Overall, the purpose of this study is to enhance the future mitigation of climate and environmental change challenges by exploring a wide range of perceptions and explaining the gaps, contradictions and counter translations of facts, and subjective interpretations of climate processes. We use interviews along an extensive environmental gradient and compare the varying personal perceptions of change to meteorological observations. This work contributes to a range of studies on Siberian Environmental Change presented by Callaghan et al. (2021).

MATERIALS AND METHODS

Research locations and societies

A number of rural settlements and regional centers in different climatic zones of Western Siberia were selected for the study. Details of survey points are presented in Table 1 and Fig. 1. The city of Tomsk was selected as a an example of an urban area with well-developed infrastructure to compare the perceptions of climate change between urban and rural populations: it represents the classical urban community of the southern part of Western Siberia, explored since seventeenth century, but not the Arctic urban livelihood of the Soviet era.

The sampling points reflect diversity of cultural and social contexts, the degree of urbanization and state of infrastructure. The selection, briefly described in Appendix S1 included (1) mono-ethnic settlements formed in late Soviet times (Agan, Seyakha) and influenced by gas extraction and technological hubs; (2) multi-ethnic communities and families (Tarko-Sale, Aksarka, Harsaim), combining work at various enterprises with traditional environmental management; (3) descendants of 'special-purpose settlers' interconnected with local ethnic groups and formed in the context of resettling operations of the 1930s–1940s. This latter category represents the first wave of resettlement. The second wave was by forest industry and collective farm workers while, the third wave is connected with gas extraction, geological exploration and maintenance of gas pipelines in Western Siberia (in the settlements Vertikos, Vata, Vyngapurovsky and Khanymey).

Our sampling scheme included the socio-economic factor represented by transport possibilities and social infrastructure and the performance of life support services, i.e., medicine, food availability and communal services. We assume that the sensitivity to natural phenomena is much higher in those communities where the majority of the population uses natural resources while the infrastructure facilities are inherited from the Soviet period and require reconstruction. Transport infrastructure in Western Siberia is strongly influenced by major rivers such as the Ob, Pur and Tom. Rivers are a source of uncertainty such as timing of floods, but also a source of stability for example ice roads and necessary resources such as fish. Based on these assumptions, we have divided data on perceptions into three equal clusters ("isolated", "far", "near") according to the state of the transport infrastructure and community interactions within a large river regime (Table 1). Thus we obtained a representative distribution of respondents, covering the strong influences of social, economic, transport and historical factors on the direct perception and subjective assessment of climate change.

Obtaining meteorological characteristics

Weather data were obtained from meteorological stations with locations corresponding to the three subgroups of sampling site localities (Table 1**).** The weather data were extracted from the Global Basic Observing Network (http://meteo.ru), with records by long-term representative stations with a full program of observations. The compilation of these databases containing weather information, statistical principles of data processing and calculations of climatic characteristics, are regulated by guiding documents (Guide to Climatological Practice 2014; Technical Regulations 2019). The calculation of weather and bioclimatic characteristics followed recommendations by Kusch (Kusch et al. 2004) and Gosling (Gosling et al. 2014). To develop the sociological questionnaires, we identified the most variable environmental parameters (Table 2), according to long-term dynamics. The environmental parameters have been translated into a set of indicators that can be calculated from meteorological data and more easily compared with the questions.

Our approach recognizes that human beings are not only biosystems that function in current conditions and adapt to them, but also evaluates their environment through the comfort of its living and working conditions. This correlation of social and environmental parameters reflected in meteorological data are therefore taken forward in this article for a broader further discussion and represents an experimental and interdisciplinary development.

Table 1 Relationships among survey points their coordinates and weather stations selected for data analysis (distribution according to socio-economic and infrastructure)

		Settlemnent/ survey point	No of people surveyed	No of people in the settlement (thousands)	Geographical coordinates of each settlement	Weather station/year of opening: note that data from one station may cover several settlements	Region/district
Type A "isolated"	Seasonally isolated settlements dependent on the regime of a big river	Seyakha	12	2.8	70°10′00″ N, 72°30′30″ E	Noviy Port/1961	Yamalo-Nenets Autonomous District
		Urengoy	34	9.9	65°57′55″ N, 78°22′30″ E	Nadym/1959	
		Lukashkin Yar	24	0.4	60°19′50″ N, 78°23′50″ E	Aleksandrovskoe/1932	Tomsk Region [Tomskaya Oblast']
		Nazino	26	0.4	60°08′12″ N, 78°57′07″ E		
		Novonikol'skoe	32	0.2	59°45′43″ N, 79°13′07″ E		
		Narym	41	0.9	58°55′40″ N, 81°35′46″ E	Kargasok/1934	
		Shpalozavod	8	0.7	58°56′11″ N, 81°32′58″ E		
		Ust'-Tym	24	0.4	59°26′25″ N, 80°01′10″ E		
Type B "far"	Settlements away from major rivers, accessible all year round	Pangody	36	11.4	65°50′53″ N, 74°29′06″ E	Nadym/1959	Yamalo-Nenets Autonomous District
		Khanymey	31	4.2	63°43′25″ N, 75°57′42″ E	Tarko-Sale/1843	
		Agan	28	0.6	62°08′45″ N, 78°44′17″ E	Laryak/1937	Khanty-Mansiysk Autonomous District
		Vata	30	0.4	61°05′18″ N, 75°48′56″ E		
		Vyngapurovskiy	30	6.5	62°58′59″ N, 76°59′21″ E		
		Russkinskaya	45	1.6	62°09′15″ N, 73°35′55″ E		
		Cherdaty	23	0.8	56°57′01″ N, 86°56′05″ E	Pervomayskoe/1940	Tomsk Region [Tomskaya Oblast']
Type C "near"	Cities and villages on a bank of a large river with a year-round road	Aksarka	19	3.1	66°33′32″ N, 67°48′13″ E	Salekhard/1882	Yamalo-Nenets Autonomous District
		Kharsaim	21	0.6	66°35′25″ N, 67°19′15″ E		
		Tarko-Sale	29	21.6	64°54′53″ N, 77°46′22″ E	Tarko-Sale/1843	
		Kargasok	31	7.4	59°03′28″ N, 80°52′16″ E	Kargasok/1934	Tomsk Region [Tomskaya Oblast']
		Parabel'	24	6.1	58°43' N, 81°30' E		
		Tomsk	90	568.5	56°29′19″ N 84°57′08″ E	Tomsk/1837	
		Seversk	10	105.8	56°36′ N, 84°51′ E		

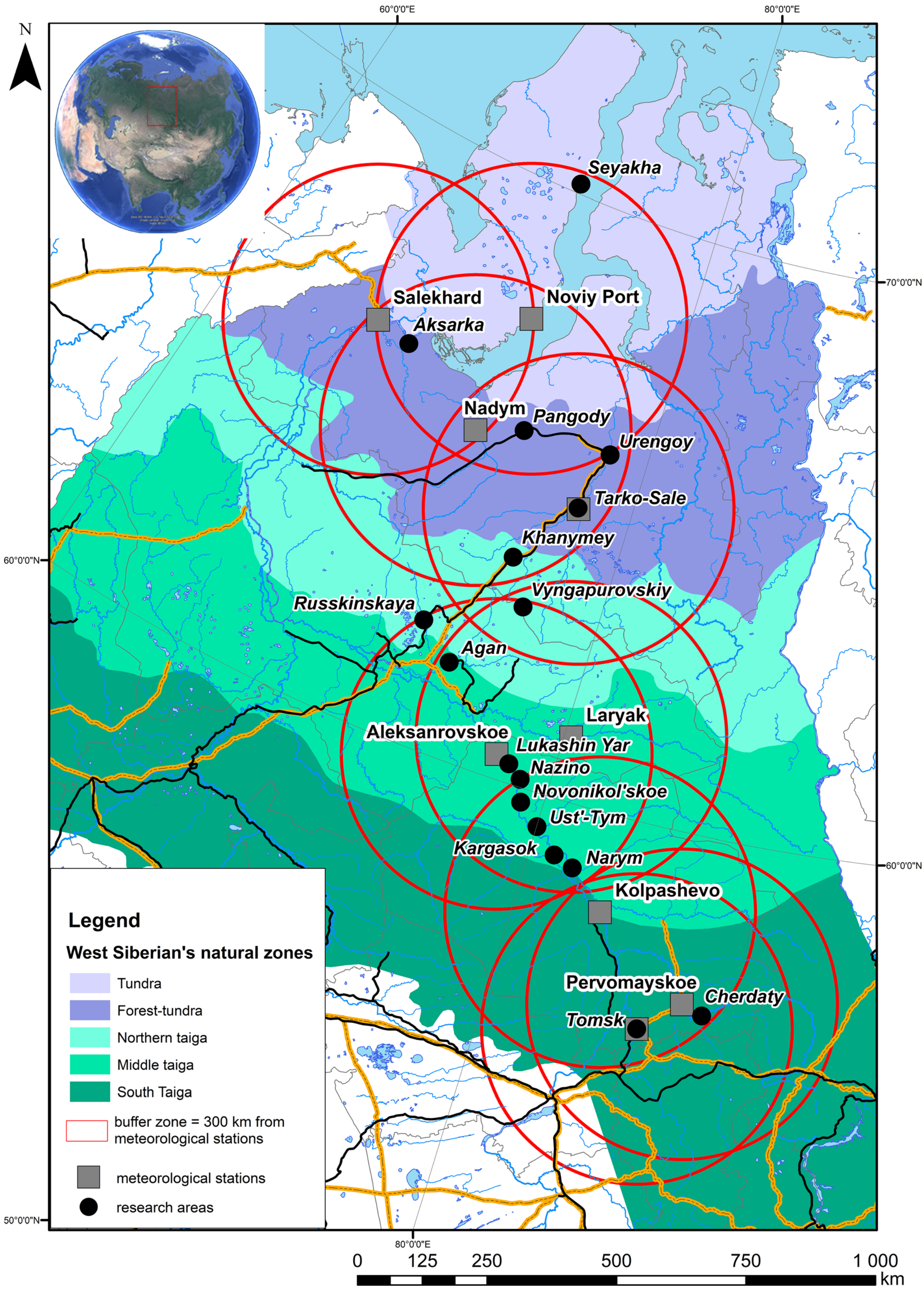

Fig. 1 Research sites, location of weather stations

Table 2 Climatic and bioclimatic indicators correlated with the answers from the sociological survey

Sociological survey questions	Climatic and bioclimatic indicators
Opinion on duration of summer and winter periods	• Number of days per year with average air temperatures above + 10 °C
	• Number of days per year with average air temperatures below 0 °C
Local residents' opinions on whether the season has become warmer or colder (summer, winter, autumn and spring)	• The average temperature of the days in the year with an average daily temperature of > 10 °C
	• Average temperature of days per year with an average daily temperature of < 0 °C
	• Average temperature in April and May
	• Average air temperature for September and October
Opinion on the frequency of extreme weather events	
Number of unusually hot days in summer	• Number of days per year with a maximum temperature above + 35 °C
Number of unusually frosty days in winter	• Number of days per year with minimum air temperature below − 40 °C
Number of unusually warm days in winter	• Average number of days with temperatures above 0 °C in winter period
Opinion on changes in the amount of precipitation in summer	• Amount of precipitation for June–August
	• Precipitation amount for the period with temperatures < 0 °C
Opinion on changes in the amount of snow observed as depth	• Snow cover depth (m)
Opinion on the frequency of sudden air temperature fluctuations	• Number of days per year with a difference of consecutive average daily temperature > 8 °C
	• Daily air temperature amplitude (°C)
Opinion on wind speed variation through past decades	• Wind speed (m/s)

Recording perceptions, data processing and analysis

Over two field seasons (2018 and 2019), we obtained a detailed picture of opinions and views of 640 people with different types of employment and history of migration and adaptation to local climatic conditions (Appendix S1). Taking into account a number of common indicators implying regional specifics, we prepared a research toolkit using closed-ended and open-ended questions. This toolkit was used in three questionnaires. The first questionnaire aimed at identifying the specifics of personal biographical contexts, professional background, and respondents' perceptions of climate change (Appendix S2).The second questionnaire (Appendix S3) aimed to clearly identify lifestyle changes adapting to environmental change. The third questionnaire (Appendix S4) aimed to allow a comparison of opinions with climatic and meteorological data (Table 2). The tools for the third questionnaire were designed and tested in field studies in Yakutia (Anisimov et al. 2017).

In addition to the three questionnaires, 60 semi-structured and biographical interviews were conducted to broaden the context for local interpretations of climate change captured in the questionnaires. In some cases, interviews continued in an in-depth form, providing biographical context on perceptions of climate change. Specifics of peoples' fishing and labor activities, availability of subsidiary farms, length of residence, family structure and health, age, type of education—all these aspects established a link between climate data and the lifestyles of respondents and thus helped to aid the interpretation of questionnaire data.

Statistical methods

Results were analyzed using the Statistica 6.0 software package, in particular, the methods of nonparametric statistics (Kruskal–Wallis ANOVA and Median tests, Mann–Whitney *U* Test) and Principal Component Analysis (PCA). Aggregated meteorological indices were calculated with Python 3.7 using the pandas package and custom parser for www.meteorf.ru database files. We used authoring software scripts to collect data and process them based on weather stations' database from the site "All-Russia Research Institute of Hydrometeorological Information—World Data Center" (https://meteoinfo.ru/en/).

RESULTS

Socio-economic factors that affect perceptions of climate change

There is a lack of unity in the perceptions of climate change and its social consequences. Principal Component Analysis (PCA) showed that the structure of factors varies significantly among different groups of respondents (Table 3). In different samples, values greater than one have eight to ten individual factors (See the results of PCA analysis, groupings of factors in Appendix S4), which were used for the analysis.

The PCA revealed that the gender factor influenced perceptions of climate change significantly. For example, for the male respondents, the first factor included all indicators of changes in the wild-food yield, and changes in the harvest from cultivated plots; the positive correlation values mean that men are interested in this issue. The second component describes male attitudes towards changes in winter and the third, attitude towards extreme phenomena. For women, the first factor (explaining 19.4% dispersion) expresses their attitude to changes in the summer period, the second wild-food harvests, and the third, the transition periods between seasons (Table 3, Appendix S5).

Perceptions are influenced by the level of education: respondents with higher education pay more attention to transitional changes (23.6% of the variance). Perceptions also depend on the type of locality in which respondents live. (Table 3, Appendix S5, S6). For example, residents of seasonally isolated settlements are primarily concerned about changes occurring in the autumn period, including the duration of river freezing (20.7% of variance); they also attribute great importance to changes in extreme weather events, including increased strong winds (11.3% variance). Urban dwellers combine extreme events into a fourth factor, which explains only 6.1% of the variance, and they are primarily concerned about changes in wild crop yields and changes occurring in the summer. The dependence of the perception of climate change on geographic location and bio-climatic zones is presented in Table 4. Notably, the opinions of northernmost settlement (Seyakha) residents most accurately reflect changes in meteorological parameters.

The variability among respondents' perceptions reflects the professional specificity of the different communities (Table 4). Fishermen are acutely experiencing early melting of ice, which brings closer the restrictions on the spawning period. At the same time early warming of the land and snow melting leads to a longer vegetation period and early harvest. Locals working in the sphere of municipal administration and education, culture and services perceive these changes more indirectly than those who are involved in natural resources management.

Do people in Western Siberia believe that climate change is underway?

The general assessment of perceptions of climate change are combined in a separate PCA factor in the majority of the groups of respondents (Appendix S5). The summary data on the observations and experience of climate changes (Fig. 2) shows that local people are more likely to notice minor climate change (41%), and surprisingly, a slightly smaller proportion of respondents notice significant climate change (36%). Thus, 77% of respondents believe that

Table 3 Explained cumulative dispersion (total %) for groups surveyed

	No. of factors with a value greater than "1"	A—Explained cumulative dispersion of initial individual values (total %)									
		1	2	3	4	5	6	7	8	9	10
Gender											
Male	9	24.8	33.4	39.5	45.0	50.1	55.1	59.5	63.4	67.0	
Female	10	19.4	28.0	34.5	40.3	45.3	50.0	54.2	58.1	61.9	65.5
Level of education											
No education and incomplete secondary education	8	21.8	41.0	52.6	62.5	71.1	77.3	82.8	87.0		
Undergraduate professional or specialized education	10	19.0	27.6	34.2	40.6	46.6	51.4	55.8	60.2	64.1	67.9
Incomplete higher and higher education	9	23.6	31.7	38.6	44.0	48.5	53.1	57.3	61.1	64.9	
Type of the settlement											
Seasonally isolated small settlements ("Isolated")	10	20.7	32.1	40.9	48.1	54.4	60.2	65.1	69.6	73.9	77.6
Small settlements with year-round transport availability ("Far")	9	24.1	31.5	38.5	44.2	49.3	54.3	58.7	62.8	66.9	
Town/City ("Near")	10	20.9	29.6	36.8	43.1	48.4	53.1	58.0	62.0	65.8	69.6

Table 4 Percentage of respondents whose opinion coincides with changes in weather

Meteorological stations	Noviy Port	Salek-hard	Nadym	Tarko-Sale	Lryak	Aleksan-drov-skoye	Kolpa-shevo	Tomsk	Pervo-may-skoye
Winter temperature	**58**	**61**	**50**	**45**	**37**	**51**	**52**	**52**	*30*
Spring temperature	**42**	*36*	*14*	*25*	*15*	*9*	*16*	*19*	*4*
Summer temperature	**75**	**39**	**40**	*27*	*18*	*13*	*15*	*32*	*13*
Autumn temperature	**50**	**41**	*21*	*16*	*10*	*9*	**34**	**36**	**35**
Duration of winter	**33**	*31*	*8*	*23*	*16*	*20*	**35**	*21*	*13*
Duration of summer	**64**	*28*	*21*	*24*	*11*	*10*	**9**	**22**	*9*
Winter precipitation	**42**	**36**	**36**	**35**	*25*	**45**	**35**	*26*	*26*
Summer precipitation	**33**	*29*	*11*	**36**	**39**	*29*	**57**	**33**	**52**
Average wind	*8*	*14*	*3*	*7*	*10*	*5*	*2*	*12*	*4*
Extreme wind	**75**	**36**	**46**	**57**	**45**	**45**	**77**	**50**	**70**

Bold—The opinions of respondents coincide with the meteorological data

Italic—The opinions of respondents do not match the meteorological data

climate change is a real phenomenon. Only 14% do not notice changes at all, and 7–9% find it difficult to answer the question unambiguously.

There are differences in the answer to the question above according to the level of education and the duration of residence in the locality and settlement type. Figure 2 shows that 86% of the inhabitants of seasonally isolated localities perceive climate changes. Differences in views on climate changes depending on the type of settlement are statistically confirmed (Appendix S6).This heightened sensitivity and concern about climate change of respondents of seasonally isolated settlements implies that the social and economic vulnerability of the population is related to transport accessibility and daily interaction with the large river ecosystem.

According to the data, 84% of men and 85% of women perceive climate change. However, different percentages of respondents considered the changes to be significant (35% and 42%, respectively), and homogeneity of the answer depends on the level of education, the age of residence in the territory, and type of settlement (Appendix S7).The differences in the views of women and men on the scale of climate change processes are statistically significant (Appendix S6). Interestingly, men are more critical of their own levels of awareness, but neutrality is more characteristic for women.

We found a significant difference in attitudes to climate change as a global problem between the proportion of respondents with a school level of education and with an accomplished higher or college education. 72% of people without a degree believe it is a global problem, while people with college and university education tend to be more skeptical in their judgments: only 46% and 44%, respectively rank climate change as a global problem (Appendix S7).

The local population's perception of temperature trends and changes in the duration of the seasons

Since the beginning of the twenty-first century, warming has been recorded practically throughout the entire territory of Western Siberia (Alekseev et al. 2014; Kharyutkina et al. 2019; Gorbatenko et al. 2020). According to data from Siberian weather stations, the number of days with temperatures below 10° C has greatly decreased while the average winter temperatures have increased (Fig. 3c, d, Appendix S7).

Respondents' answers were consistent with changes in winter temperatures. 48% of respondents say there is a reduction in unusually frosty days, 53% of respondents believe that winters have become considerably warmer, especially those residents of seasonally isolated villages (57%). From a socio-economic and infrastructure perspective, stable frosty weather in winter is preferable for life support and environmental management, and therefore this aspect is quite unanimously reported by residents of remote settlements. It should be noted that in the North-Western Federal District and Yakutia, the population also perceives the warming of climate in winter more than other climatic changes (Anisimov and Orttung 2019; Scherbakova 2019).

Ambiguous answers were received to the question about the length of the winter period. Those that believe winters have become longer (33%) are not significantly different from those with the opposite opinion about shortening of winter (24%). Many respondents either answered that they do not know exactly how to formulate the answer, or did

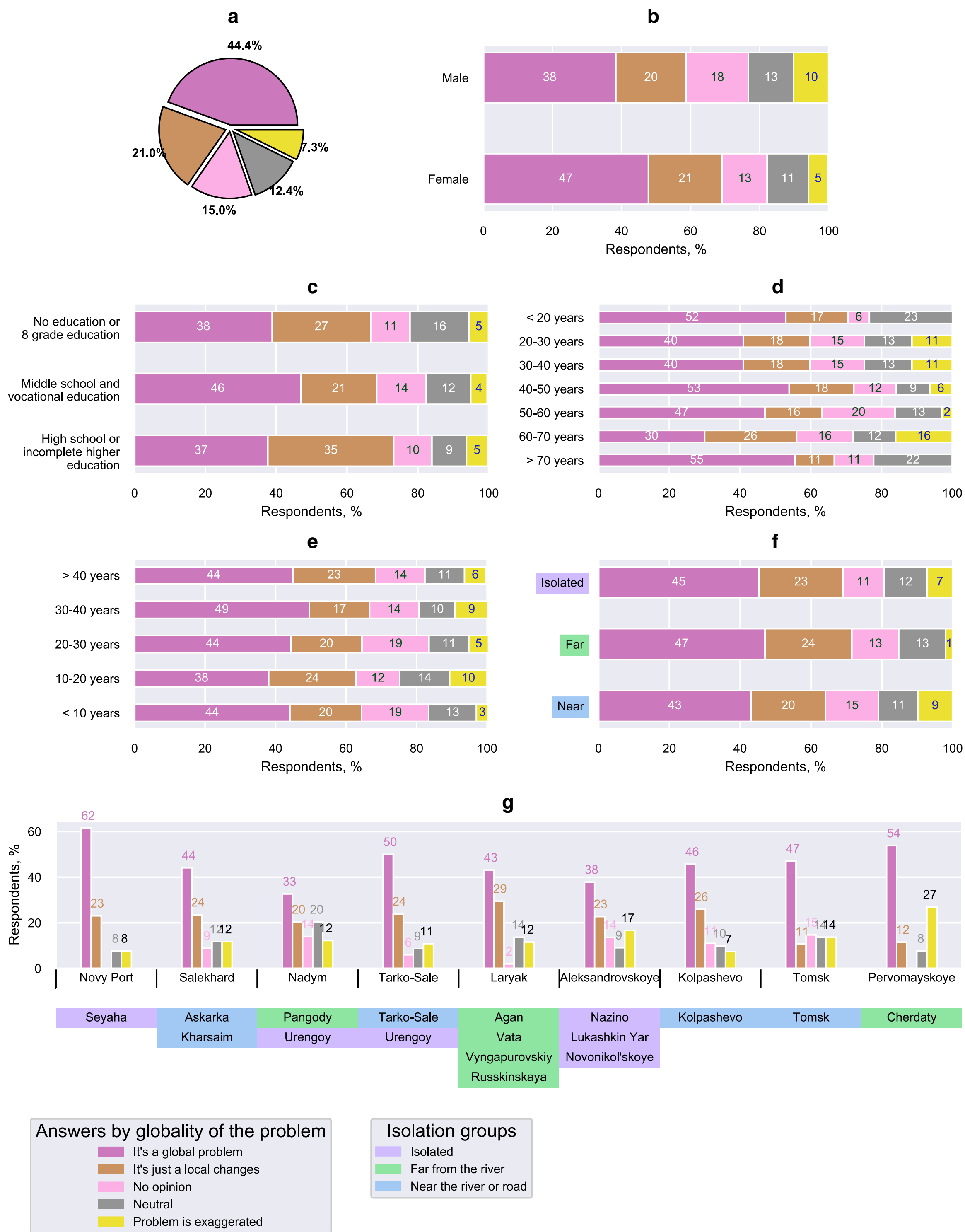

Fig. 2 An overall summary of the respondents' perceptions of climate change in Western Siberia: general statistics of (**a**), views depending on the respondent's age (**b**), level of education (**c**), age of residence in the territory (**d**), gender (**e**), type of settlement (**f**), and geographical location (**g**)

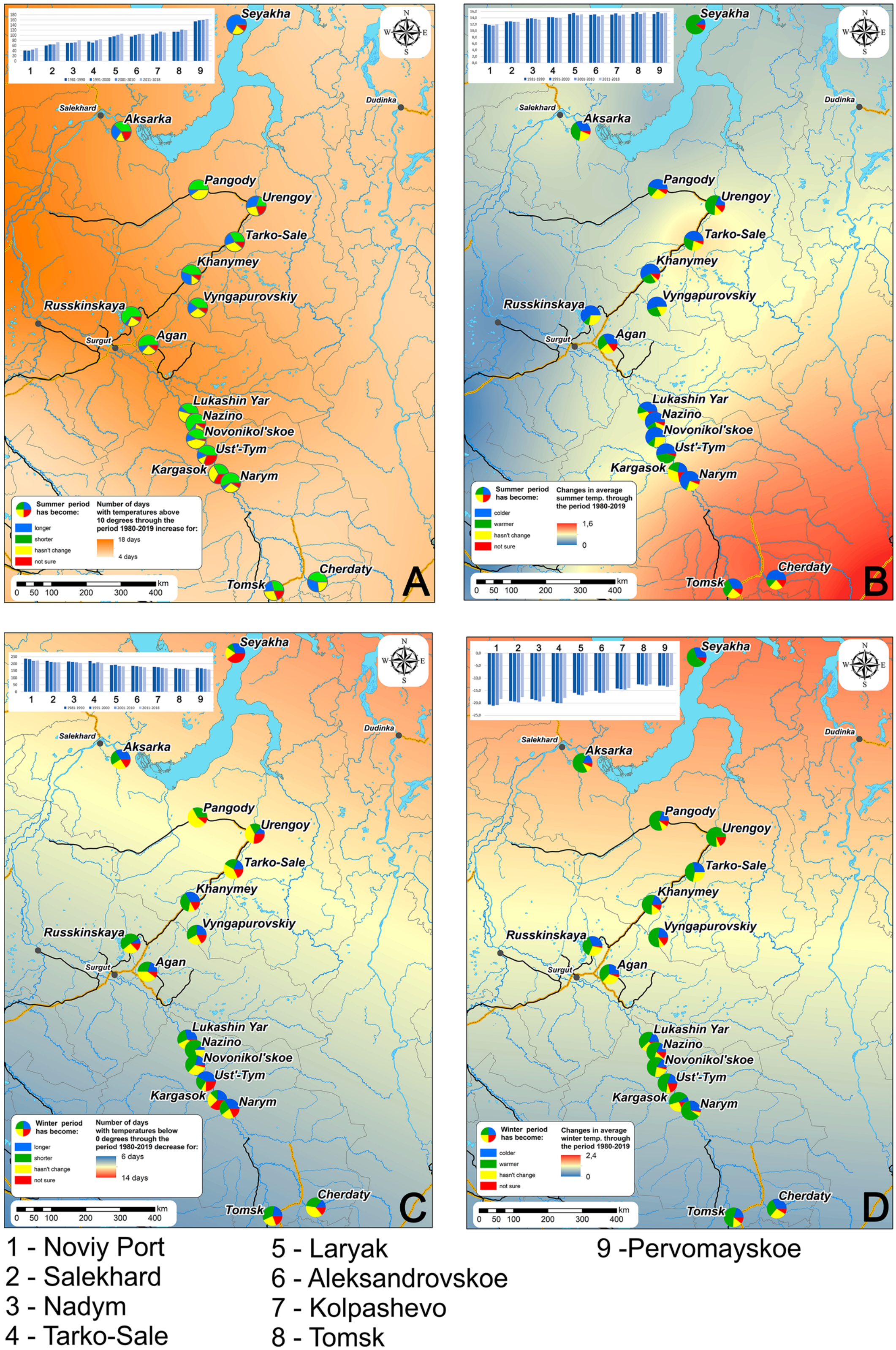

Fig. 3 Western Siberians' perceptions of changes (pie charts) in the duration of the summer periods (**a**), summer temperatures (**b**), duration of the winter period (**c**) and winter temperatures (**d**). Meteorological data are included as bar charts

not see any change. At the same time, residents of seasonally isolated locations were more likely to be aware of a reduction in days with temperatures below zero degrees than residents of small settlements with year-round access. They are also more likely to notice a decrease in the period of frozen rivers (Appendix S6).

The number of days per year with temperatures above 10 degrees has increased significantly throughout the territory of Western Siberia, but if we focus on a single micro-region, and analyze the trend reflected in the data from one weather station we see that the evidence for summer temperature changes is not as clear and straight forward as the general trend for Western Siberia as whole. (Appendix S8, Fig. 3).

In the absence of clear temperature trends, the opinions on summer temperature changes are more or less equally divided: 44% believe that the summer has become colder. At the same time, the number of women who believe that summer has become shorter is higher than the number of men (Appendix S6). In small communities—isolated and away from large rivers—half of respondents believe that summer has become colder (50% women and 51% men).

There is no unanimity among all groups of respondents regarding the length of the spring season (about one-third of respondents perceive shorter, longer and unchanged spring length). In the general sample, 30% believe that spring is longer and 22% believe that spring is shorter, while in the isolated villages the gap was 3% (27% vs. 24%). Local residents perceive that the spring period has become colder overall (35%), but a significant percentage (27%) state that the spring temperature has not changed. Lower temperatures are experienced more in settlements away from major rivers (38%), while residents of seasonally isolated remote villages are less aware of spring temperatures in general.

Meteorological data shows a steady warming of September and October i.e., autumn. However, the views on the temperature regime changes in autumn differ between residents of coastal river villages and those who live far away from major rivers. The perception of warmer autumns may be due to delayed ice freezing, which prolongs the seasonal isolation of these villages and affects unstable river embankments in villages with year-round availability. Warmer and longer autumns are noted by residents of both isolated villages (26%) and year-round accessible riverside villages (36%). Meanwhile, 41% of those living far away from the river, who depend on reindeer herding and collection of mushrooms and berries for their livelihood, report a cold autumn season (in contrast to the data), which may be particularly acute due to perceived shorter harvest times. Due to the blurring of the autumn and winter seasons, residents have no clear opinion on the length of the season.

To create a two-dimensional map (Fig. 4) reflecting sociological analysis of respondents' opinions on changes in the duration and temperature regimes of the 4 seasons, the ratio was calculated between the percentage of respondents who chose the answer options "The season has become longer"/"… has become shorter" and "The season has become warmer"/"… has become colder". In this method of analysis, the options "no change" and "can't answer" were not taken into account to estimate the statistical shift.

The coordinates of each point (the season icon, which has a specific color and shape) are the differences between the two values (duration and temperature regime).Interestingly, the answers of residents of villages remote from rivers about the winter and summer season are almost symmetrical (the icons on Fig. 4 are located in two-dimensional space diagonally- Fig. 4): in their opinions, winters have become as warmer and longer as the summer has become colder and shorter. Moreover, the subgroup of respondents living in settlements far away from the rivers is more inclined to perceive cooling not only of the summer but also of the autumn, while residents of coastal areas feel that the autumn is getting warmer.

Also, according to the general sociological statistics (Fig. 4, the field with "overall" data in the upper-left corner), the majority of respondents believe that the spring has become colder (35%), and an equally significant proportion of residents do not see changes in spring temperatures (27%). Apparently, villages with year-round transport accessibility are more likely to perceive the coldness of the spring season (37–38%) than residents of isolated villages (31%), for whom a warm spring means a rapid destruction of the winter ice crossing for winter vehicles, extending the isolation period.

Typical temperature fluctuations in the transition from cold to warm periods, during the late calendar spring and early calendar summer are reflected in our map of answers (Fig. 4) through perceptions on the lengthening and cooling of spring and the shortening and cooling of summer. The transitions between seasons and their general instability leads to a discrepancy with the data on fluctuations of average temperatures, the latter, according to statistics, increase steadily.

The local assessment and perception of extreme weather events and intra-day temperature fluctuations

It is important to note, that here we consider extreme weather events to be sudden, but not long-lasting events, on a timescale of one day. Since the mid-1990s, there has been a significant increase in the number of hazardous weather events in Russia, and in Western Siberia in particular,

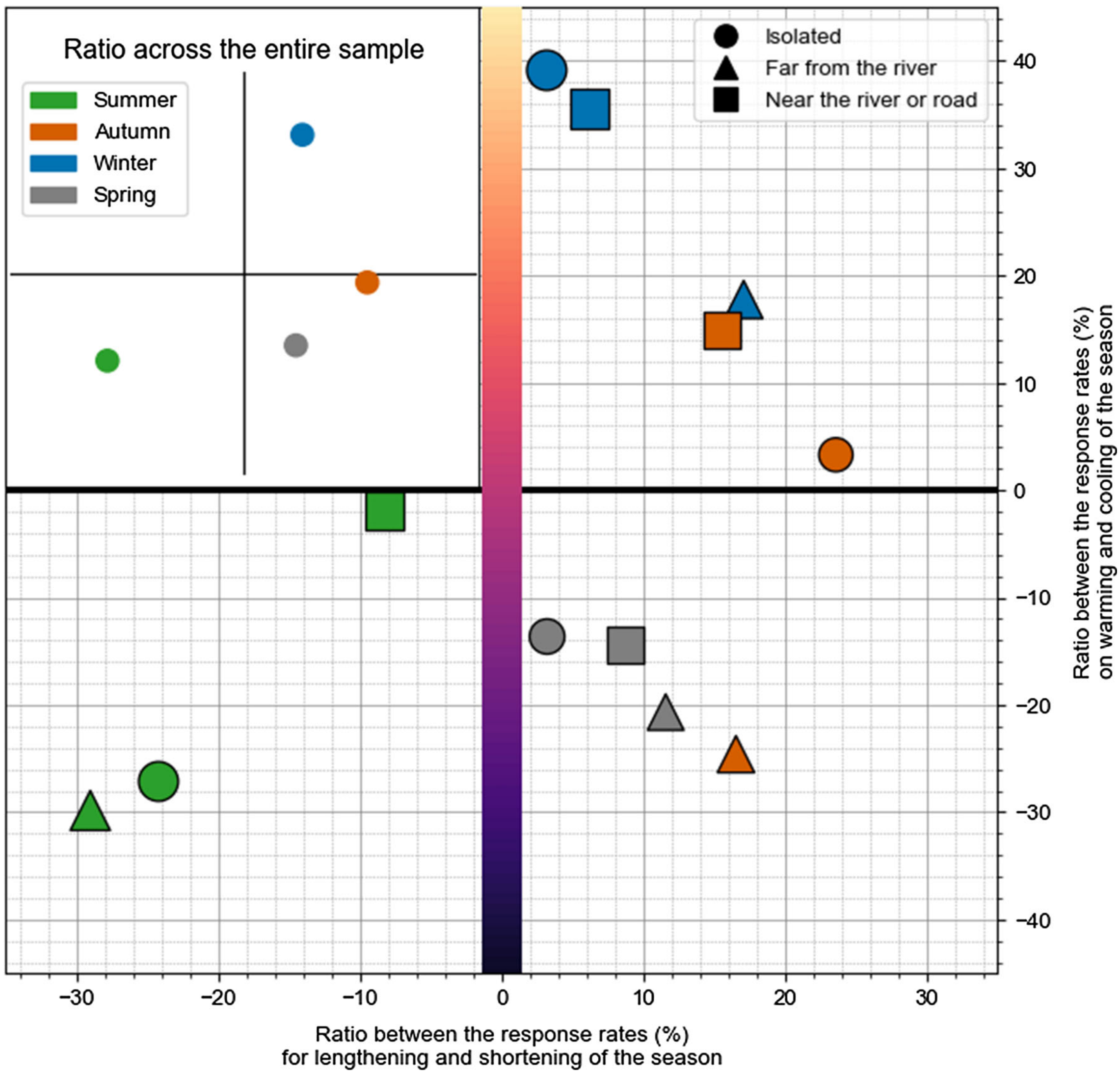

Fig. 4 Residents' perceptions of changes in climatic seasons and temperatures in different types of Western Siberian communities and settlements. The coordinates of each point (the season icon, which has a specific color and shape) are the differences between the two values (duration and temperature regime)

which caused significant damage to the economy and population (Alekseev et al. 2014; Kharyutkina et al. 2019). Emergencies resulting from the development of deep mesoscale convection, such as thunderstorms, hail, squalls and tornados, have been more frequent than before 2000, and increased convective atmospheric instability has been recorded (Gorbatenko et al. 2020). In addition, dangerous meteorological phenomena that are not associated with convection, such as periods of abnormally cold and warm weather, are increasing (Volkova et al. 2019). In contrast to an "event", an extremely 'low temperature' is defined as a period when the minimum air temperature is − 30 °C and less for any duration; an extremely 'high temperature' is characterized by maximum air temperature equal to 30 °C or more. The study of Kharyutkina and colleagues (Kharyutkina et al. 2019) shows that the frequency of 'low temperature' between 1998 and 2016 has decreased over most of Western Siberia (south of 60° N) compared to 1960–1990 by 1–2% days during the period November–April. Extreme low temperatures are specific for cold seasons in the southern part of Western Siberia. In most of the study area, periods with extremely low temperatures were observed every year. At all of the stations considered, "high temperature" events during the warm half of the year 1998–2016 have become more frequent by 1–2% of days during the period May–October.

Extreme weather events in previous decades during the first half of the warm season have threatened the harvests from food plots. Unstable periods of flooding or even a 'second flood' have occurred in the spring–summer period, potentially destroying crops for the entire year.

The perception of changes in sudden temperature fluctuations was analyzed from the questionnaires and interviews. While in quantitative data there are substantial differences in statistics among different settlements, the semi-structured interviews gave an absolutely unambiguous result: more than 80% of informants perceived that intra-day sudden temperature fluctuations (one type of extreme weather events) have become more pronounced. The overall statistics also show that 59% believe that the differences are more pronounced but the ratio of answers in each village and settlement show 4 contrasting types (Appendix S9).

Residents of seasonally isolated settlements are more likely to perceive an increase in the number of extreme weather events than residents of small settlements with year-round access (Appendix S6). For example, residents of one of the most remote settlements in our sample - Lukashkin Yar- unanimously believe that the conditions are stable (60% of answers). One third of residents believe that the fluctuations have become less pronounced, and not a single respondent found it "difficult to answer". The opposite opinion was expressed by residents of Vyngapurovsky, now a remote neighborhood of Noyabrsk. 85% believe that temperature fluctuations are a critical problem that threaten health and working conditions in the north and lead to cardiovascular diseases, deaths and a more severe climate (Unpublished data of field expedition, July 2018). However, residents of two other settlements remote from major rivers with good transport accessibility (Pangody, Nadym) are not so sure that temperature fluctuations have become more pronounced in recent decades. Although one half of the surveyed people think that this is true, 20% of them think that the temperature changes have smoothened out, and 30% are inclined to see the situation as quite stable. Finally, if we compare two coastal, seasonally isolated villages—Lukashkin Yar and Urengoy-, their views are opposed to each other: in Urengoy 60% believe that the differences have become more frequent and 27% -that nothing has changed (L. Yar—60% no changes, 33%—extremes became more frequent).

The local assessment and perception of changes in wind speed

According to the data from weather stations, the average speed has become much lower over the past 40 years (Bulygina et al. 2013, Appendix S10). The most distinct trends are observed near Tarko-Sale, Tomsk, Alexandrovskoe and Kolpashevo (settlements on the banks of large rivers). However, wind speed is reflected not only through the 'average speed' indicator, but also through the amount of short-term gusts which may occur locally and may not be recorded by the nearest weather station. We have taken an indicator such as the number of days with a peak wind gust of more than 12 m/s. which showed that the number of days with strong winds is also decreasing throughout the study area.

Nevertheless, according to the sociological survey, residents of all investigated regions answer that wind speed is increasing according to their experiences (Appendix S11). The respondents perceived strong wind gusts grasping short-term phenomena. With the observed decrease in average wind speeds (Appendix S10), strong winds, which form the wind load on buildings and structures, do not decrease in most of Russia (Alekseev et al. 2014). Thus, for the period 1985–2009, the number of hazard events associated with strong winds amounted to 87% of the total number of meteorological hazards in Western Siberia (Luchitskaya and Belaya 2011). In addition, average wind speed can be important for them in the long perspective e.g., during fishing, moving around the tundra when inhabitants notice long-lasting environmental phenomena, which are closer to weather station data of average wind speed.

The residents of seasonally isolated villages have a more intense perception of increasing extreme weather (Appendix S6) e.g., Narym residents (88%), Ust'-Tym (73%) and Seyakha (70%) as they suffer the most from stronger winds. These settlements (except Seyakha which has recently benefitted from the gas and oil industry) are in a period of socio-economic decline: supply of essentials is irregular, there are few jobs and the housing stock is often in a state of emergency. In contrast to villages located in active oil and gas production areas, where large companies invest in social infrastructure, the respondents of the abovementioned villages assess wind speed not only by objective indicators, but also by monitoring the stability of architectural structures: warehouses, stores and residential buildings. Building standards in the USSR led to construction of buildings that were more resistant to winds than today when lack of budget leads to local entrepreneurs building "light" temporary constructions and trading pavilions that are seriously damaged during storms.

Public perceptions of changes that affect their livelihoods.

Each locality has its own configuration of key biological natural resources, some of which are prioritised and others lacking. In the tundra zone, instead of cones and mushrooms and willow-herb, locals actively harvest berries. Thus, the composition of the resources they have in mind when answering the questionnaire or interview questions is different, but the place of resources as such in the family and village livelihood system is similar. The complex of wild plants, for example, is seen as a cluster that has social significance for the community, rather than being a biological unit (as in ecological and botanical studies). Such questions directly related to the livelihoods of local communities (harvest of berries, mushrooms, fish and animal stocks, number of mosquitoes) were the most resonant among respondents, and answers to them show clear trends. In most of the areas surveyed, respondents complain about a decrease in the yield of berries, mushrooms and pine nuts (Fig. 5).

A decrease in the number of fish stocks is noted almost everywhere but this problem is of greater concern to residents of the Ob basin (52 to 95% of respondents noted a decrease of fish stocks). The experience of fishermen is largely consistent with that of ichthyologists (Interesova et al. 2020), but researchers distinguish between a reduction in the number of fish of a particular species, a reduction in species diversity and a reduction in the size range of commercial fish species.

In the Pur river basin the problem is not as significant. Residents of small communities with incomplete secondary and secondary education living in small communities are more concerned about these problems (Table 5). In cities, a significant number of respondents have difficulty answering this question.

DISCUSSION

The idea of comparing climate change trends and their perceptions among members of local communities is not new. Surveys on perceptions of climate change have been conducted regularly around the world since the 1980s, and public awareness has increased significantly since then: in the first surveys, only about 40% considered climate change to be a serious problem (Capstick et al. 2015).

Current climate change studies answer three basic questions: (1) what changes are actually occurring? (2) to what extent do we understand past and present climate changes identified by observations? and (3) what will be climate changes in the future? In contrast, residents' awareness, their accumulated personal experience and their livelihood priorities characterize their assessment of weather conditions. Weather conditions are formed in the context of ongoing climate change, and a catastrophic event in a particular season may affect a person and his/her perception of the climate as a whole, although within the climate system context it can be simple short-term variability. Our study showed a significant semantic gap between the answers to the question, "Do you perceive climate change and do you notice it?" and "What kinds of climate change are occurring and how are they manifested?" We established that the majority of Western Siberians in the study believe that climate change is taking place, but many of the changes in nature are not visible to them or they do not understand the specifics of trends and processes. It should be noted that analytical work by European and American sociologists has also recorded a high level of doubt on the hazards of climate change in a number of communities (Smith and Leiserowitz 2012; Spence et al. 2012; Hagen et al. 2016). We did not rely much on climate assessments per se, but rather on detailed local knowledge and experience, which showed much more clearly, through indirect questions, whether or not the concern was real.

Our research showed a fairly high level of concern among residents of Western Siberia about climate change, which is similar to earlier studies conducted on the territory of Russia (e.g., Anisimov et al. 2017). However, most respondents judge the changes not by their own perceptions, but by information coming from outside (e.g., from media reports). Consequently, answers to general questions about climate change and to questions about changes in specific climatic parameters based on local experience are poorly correlated (Appendix S6–Table S11). Some of the data is indeed surprising: the survey showed that people with higher education, are skeptical about climate change itself. This shows the importance of factors such as access to different sources of information and not only the level of education, but also intergenerational standards of education, to which adjustments must be made. In turn, this leads us to the crucial conclusion that the policy of informing local residents in rural areas must be sensitive and nuanced, and take into account both information deficit and the ground for skepticism of young people, who tend to deny the threats associated with climate change rather than show anxiety.

Many of the variables and factors that we have tried to consider are in conflict with each other: length of residence and adaptation to an area may decrease sensitivity to climatic changes and their effects, while in contrast, as people get older their sensitivity to environmental changes may increase. Some of the variables conflict between measurements and perceptions. For example, wind speed data are generalized across the entire Ob River valley (Evseeva and Romashova 2011), whereas our analysis relies on micro-regional specificity and respondents' answers from different localities. Kharyutkina et al. (2019) provide data only for winter wind speeds; our respondents, on the other hand, often talked about summer and spring winds, periods when their work is associated with outdoor work and fishing. By analyzing very different traditions and estimation methods, we can show the delicate boundary between wind trends as one of the regular indicators and changes in

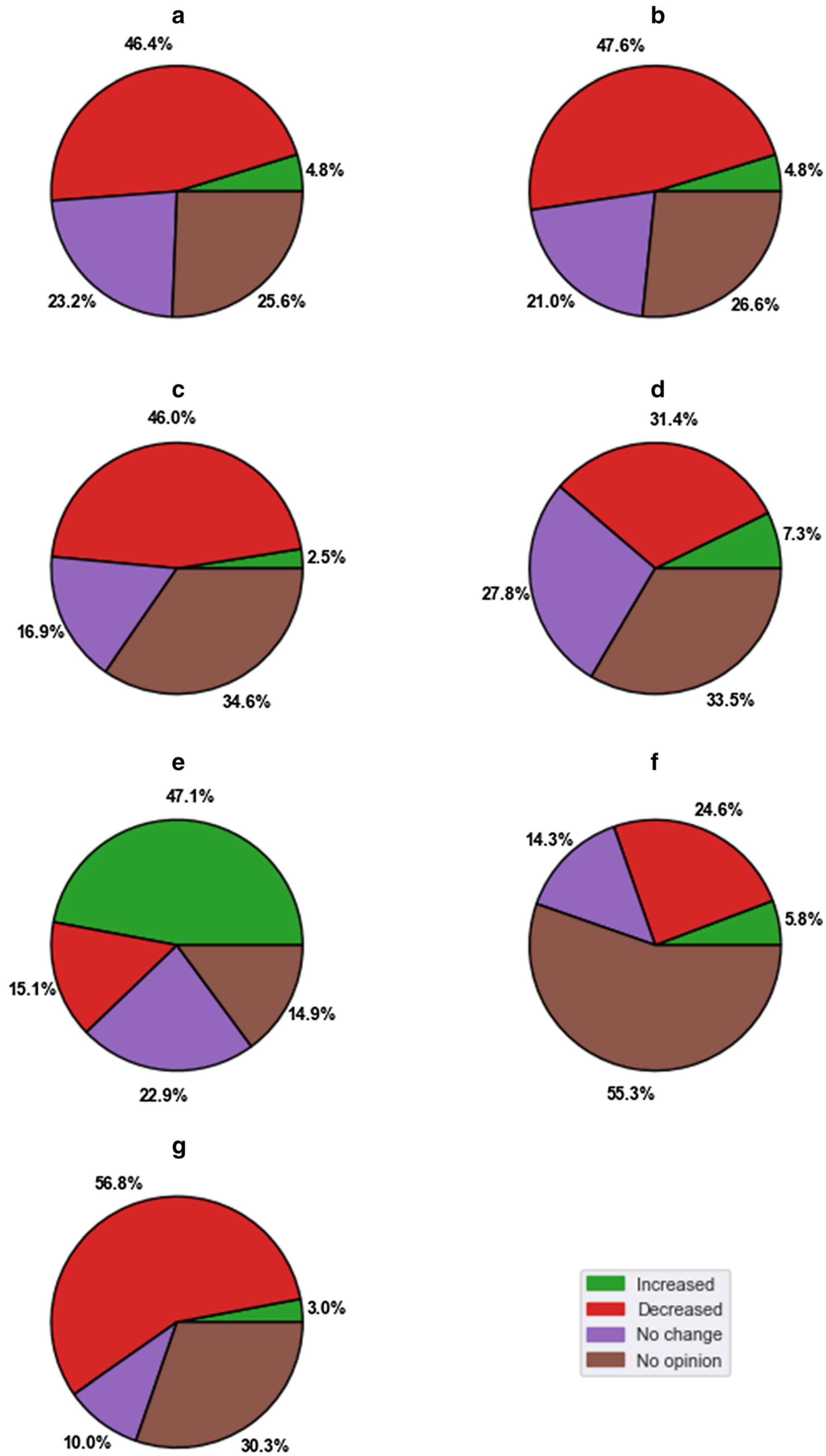

Fig. 5 Public perceptions of changes that affect their livelihoods: **a** berries, **b** mushrooms, **c** pine nuts, **d** mosquitoes, **e** hunting animals, **f** fish

Table 5 The statistical significance of the relationship between the respondents' perception of changes affecting their life support and their level of education and the type of settlement

	Kruskal–Wallis test		Median test (df = 2)	
	H	*p*	Chi-square	*p*
The statistical significance of correlation between the environmental and climate changes perception and the respondent's educational level				
Changes in berry harvest	8.1	0.02	7.9	0.01
Changes in mushroom yield	8.5	0.01	7.7	0.02
Changes in the amount of the river fish stocks	11.9	0.003	11.6	0.003
Change in the amount of mosquitoes	17.8	< 0.001	7.5	0.02
The statistical significance of correlation between the environmental and climate changes perception and the type of settlement in which the respondent lives (village/district center/city)				
Changes in berry harvest	15.8	0.0004	13.0	0.002
Changes in mushroom yield	15.8	< 0.001	10.75	0.005
Changes in the amount of the river fish stocks	62.6	< 0.001	61.2	< 0.001
Change in the amount of mosquitoes	28.2	< 0.001	9.0	0.01
The statistical significance of correlation between the environmental and climate changes perception and the type of the settlement (rural/urban; isolatedl/non-isolated)				
Changes in berry harvest				
Changes in mushroom yield	14.21402	< 0.001	21.8	< 0.001
Changes in the amount of the river fish stocks	16.6	< 0.001	21.6	< 0.001
Change in the amount of mosquitoes	6.6	0.01	7.7	0.005

wind speeds as a source of extreme events. So, our study shows that it is the wind that is perceived as a disaster that is reflected in local perceptions, which is why its perception can be so inconsistent with meteorological data. (Appendix S9, Appendix S10).

The general climate change perception trends in Western Siberia do not differ from the perceptions of residents of other Russian regions, in which respondents also note a decrease in winter temperatures, an increase in extreme weather events and do not notice warming in summer and a decrease in average wind speeds (Anisimov et al. 2017; 2019, 2020). However, we identified important and detailed local differences as well. For example, degree of awareness as well as the level of transport accessibility shows specific basic "settings" that need to be taken into account specifically for material from Siberia. Also, a decrease in the icy period is primarily noted by residents of seasonally isolated settlements and the perceptions of changes in wind speed, climatic conditions of the autumn and spring periods, and extreme weather events depend on the type of settlement. Many of the current climatic transformations are not as important to local populations as impacts of changes that have a direct effect on livelihoods, for example, the number of fish and amount of mushroom and berry crops. Several other areas of life that affect perceptions have been identified through interviews and parallel questionnaires. For example, the perceptions of "normal" or "typical" summer, winter, and autumn periods are formed by experiences of weather patterns that are not easily converted to meteorological indicators. Perceptions are influenced by the duration of dry and hot periods, followed by cold and cloudy days with precipitation and high humidity. In addition, an important indicator is the freezing that occurs after a stable warm period with average daily temperatures above 10 °C.

The dependence of the perception of climate change on a number of social factors has also been noted repeatedly by a number of authors (e.g., Anisimov and Orttung 2019). For example, studies of the influence of gender on the perception of natural phenomena have shown that men and women have different adaptation strategies and spatial perceptions, which reflect their social position (e.g., Villamor et al. 2015; Dah-gbeto and Villamor 2016). A number of authors (e.g., Arıkan and Defne 2020) note that women are more concerned about the environment and tend to overestimate risks. The data on the influence of age on the perceptions of change is not uniform, some researchers reporting that young people are more concerned (Arıkan and Defne 2020) while others, like us, have found the opposite point of view. In addition, we noted that residents of Western Siberia with higher education are more skeptical about climate change, mostly believing that change is insignificant and local in nature, which is not consistent with global trends (Arıkan and Defne 2020).

Our study raises three key questions. (1) As meteorological and sociological data have different standards of verification, how can qualitative data be integrated in a transdisciplinary project? (2) As Arctic ecosystems and human communities are more vulnerable and specific in terms of their study than mid-latitude communities because of hard-to-reach settlements, nomadic communities in the tundra, and localized perceptions of climate change, how do we make sampling adjustments? (3) As knowledge of climate trends is mediated by media information flows and the educational basis that local people have, how can we separate perceptions formed by external media and personal experiences?

The transdisciplinary approach brings several "challenges" to both investigation process and language of description. Firstly, it raises the question of whether sociological data can be superimposed on climatological data to identify matches and conflicts of interpretation. Secondly, we are dealing with the challenge of the reality under study itself: the way it is cognized, perceived, and described is so much included in the life worlds of experts, fishermen, reindeer herders, laboratory assistants, journalists and decision-makers themselves that the problem of interpretation conflict turns out to be much broader than the opposition of "different ways of knowing", i.e., science knowledge and local knowledge. Consequently, the divergence of sociological and meteorological data requires particular interpretation and further study.

However, the problem we would like to highlight in this article is broader than the problem of "correct interpretation" or "representative" measurements. The inconsistency of the data leads us to gaps in the coherent multifactorial model that is eluding us. This model is currently incomplete and only comes close to mapping the full range of influences that intellectual, political, infrastructural, and economic contexts have on local perceptions.

CONCLUSIONS

The study shows that 77% of 640 respondents believe that climate change is a real phenomenon. Only 14% do not notice changes at all, and 7–9% find it difficult to answer the question unambiguously. However, perceptions of details of climate change are influenced by time in a settlement, nature of the settlement, gender, age and education level. Agreement between perception of change and weather/climate differ according to the various statistical classes of respondents and the weather/climate variable. These differences show that the understanding of changes by people needs to be improved but also, sometimes measurements by weather stations are not specific enough for local settings. This complexity of variation in perceptions and their causes leads us to the understanding that a new field of research is forming, which lacks relevant elements and units of comparison, having inherited certain parameters and procedures from the social sciences and the history of meteorological observations. It is necessary to continue improving the parameters for comparing meteorological and sociological data on more extensive statistical material, to include the context of awareness, knowledge sources, engagement, and the difference between climate change as an immediate experience and reflection on climate change within a particular political and social agenda. Completing this task is extremely important because incorrect perceptions that underestimate climate change, whatever their causes, can hinder mitigation and adaption with severe sociological consequences. Although making policy recommendations is outside the scope of this study, we perceive the need to (a) change incorrect perceptions of climate change through education, (b) to respond to causes of perceptions of climate change by providing additional and more relevant weather observations, specifically oriented to the needs of different communities and the people that belong to them and (c) improving local weather forecasts, particularly of extreme weather events.

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