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A Survey-Based Assessment of Cattle Producers' Adaptation to Climate Change in British Columbia, Canada☆

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ABSTRACT

A quantitative analysis of the British Columbia, Canada cattle ranching community in light of global climate change provides insight as to how stakeholder needs and observations can be included in future planning. More than 63% of the 239 survey respondents believe that human activities are increasing the rate at which global climate changes occur, and 60% of 231 respondents adapted their management because of climate change. Cattle ranchers operating for less than 20 years were more likely to agree that human activities are increasing the rate of global climate change compared with those operating more than 40 years. This may reflect the fact that the concept of climate change has gained more public acceptance in the past 2 decades and would likely be perceived as a legitimate risk to an operation by those in this category in comparison with those who have been operating for a long period of time and tend to rely on experiential or embedded knowledge. Regional analysis showed that the most northerly region is more likely to have noticed change in climate compared with one of the most southern regions. With respect to operation of scale in terms of head of cattle, those ranches with more than 50 head of cattle identified water availability as a significant challenge to operations. Family succession planning was identified as a greater challenge for those operating their ranch for more than 40 years, compared with those operating less than 20 years. Adaptation to climate change included accessing available forage and providing a water source for cattle. Experiential and scientific knowledge will be crucial to future planning to reduce the vulnerability of the ranching industry and building adaptive capacity.

Introduction

Land classified as agricultural, which includes cropland, managed grassland, and permanent crops, occupies 40–50% of the Earth's land surface (Parry et al., 2007; Smith et al., 2007), with managed grazing systems occupying more than 33 million square kilometers or 25% of the global land surface. Rising global temperatures are expected to create an increase in drought, which will affect forage and crop production, intensifying the process of desertification in these systems and reducing the carrying capacity of rangelands and other livestock systems. This could also increase the prevalence of other risk factors due to the availability and cost of grain (Nardone et al., 2010), making agricultural systems more vulnerable and impairing their relative ability to adapt to changing conditions.

Considering that climate influences forage productivity (Antle, 1996) and that global climate change will likely have a significant effect on plant growth, it is important to predict the effects of global climate change on forage productivity and forage quality and the impact global climate change will have on livestock management (Joyce et al., 2013; Polley et al., 2013). Fluctuation in climate conditions usually results in variation in total yield of available forage and thus cattle production. This variability poses challenges to those depending on grazing land to support livelihoods (Conner, 1994; Joyce et al., 2013; Nardone et al., 2010). Crop and pasture growth in grazing-based livestock systems will be negatively affected by lower rainfall and increased drought conditions and by the effect of higher temperatures and solar radiation on animals (Nardone et al., 2010).

Agriculture is a major economic, social, and cultural activity and remains highly sensitive to climate variations in all its different forms and locations (Howden et al., 2007; Kurukulasuriya and Rosenthal, 2013). Soil, water, terrain, and climate conditions provide both constraints and opportunities for agricultural production (Wall and Smit, 2005), and, as such, environmental conditions are often a dominant source of the annual variability of regional production. Continued fluctuations in climate and weather patterns induced by global climate change will undoubtedly impact the future management of farming operations.

According to Mote and Salathé (2010), the general climate prediction for northwestern North America is for warmer and wetter

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winters and warmer and drier summers. One recent consequence of warmer winters was a mountain pine beetle outbreak in the Pacific Northwest (Carroll et al. 2003), which has indirect positive and negative effects on the ranching industry. A positive effect is the potential for increased forage availability where there are no longer pine forests. A negative effect is the potential loss of income those ranchers may face because they rely on tree-harvest licenses to supplement their income. Drier summers would occur from the combined effect of reduced precipitation and increased evaporation in some areas, resulting in an increased water deficit. The expected impact of climate change varies regionally because of the distinct nature of the climate and characteristics of each area. An increase is expected in annual variation in temperature and precipitation and the probability of extreme weather events (IPCC, 2013), contributing to increased agricultural risk (Weber and Hauer, 2003) and vulnerability (Kurukulasuriya and Rosenthal, 2013; Polley et al., 2013).

Farmers, including ranchers in British Columbia, respond to weather events, which, right or wrong, simultaneously constitutes their adaptation to climate change. Further, weather is but one of a myriad of sources of risk (or opportunity) to which farmers are exposed and respond. Events such as commodity market downturns, changes to government support programs, fluctuations in currency and interest rates, and the loss of export markets due to consumer health concerns may present significant risks to producers at certain times. It is in this rather complex context that adaptations to perceived or real climate change will (or will not) be undertaken. This point has been long recognized in the literature on climate change impacts and adaptation in agriculture (see, e.g., Bradshaw et al., 2004; Brklacich et al., 2000; Bryant et al., 2000; Chiotti and Johnston, 1995; Eakin, 2000; Easterling, 1996; Kandlikar and Risbey, 2000; O'Brien and Leichenko 2000; Timmerman, 1989; Smit et al., 1996; Smit et al., 1999; Smithers and Smit, 1997; Wheaton and McIver,

Fig. 1. Map of British Columbia, Canada, identifying the six major cattle regions in the province. Thompson and Okanagan are referred to as one region.

1999). It is only by understanding the nature of agricultural production decisions and situating climate change in a wider risk management context (i.e., climate as one of many sources of risk) that we can make sense of farmers' adaptation to climate change. There is no academic support for empirical research that assumes a direct relationship between climate and adaptation decisions.

A U.S. and Canadian survey done by Borick et al. (2011) found that climate change believers are divided on the root causes of climate change, citing both human activity and natural causes. Understanding opinions and perceptions about climate change will be a vital component in developing and facilitating effective policy options. Social adaptive capacity can be enhanced or inhibited by the character of decision-making relationships and policy planning as adaptation is influenced by the institutional, social, economic, and political environment in which individuals operate. With two out of three Canadians believing that their province has already felt the effects of climate change (Borick et al., 2011), the social and political climate is supportive of developing mechanisms to increase adaptive capacity.

It is crucial that range management practices are adaptable (as defined in Howden et al., 2007) and are able to address climate change issues that impact all aspects of ranching. Effective range management and associated policies, including incentives, need to consider changes in annual temperature and precipitation patterns. Agriculture and the agricultural land base represent valuable ecosystem services, which suggest that incentives to maintain or increase forage productivity could be an important policy tool for ranchers (de Groot et al., 2010; Power, 2010). Undertaking a survey-based analysis of the ranching industry in light of climate change will provide a more comprehensive assessment of adaptive capacity via the inclusion of stakeholder observation (Coles and Scott, 2009). Scientific research alone cannot effectively contribute to the improvement of adaptive capacity without a comprehensive understanding of the context in which decisions about adaptation are made and the capacity of decision makers to change (IPCC, 2013; Nardone et al., 2010; Thornton et al., 2009). The aim of our study was to assess the degree to which ranchers in British Columbia believe climate change is a fact and whether they are adapting their management as a result of climate change.

A mailed survey was delivered to the British Columbia ranching community. The survey design focused on characterizing cattle producers' present understanding of climate change and the degree to which they have adapted management practices in response to perceived changes in climate. The objectives of the survey were to determine whether 1) ranchers believe that climate change is caused by human activities and if ranchers have experienced changes in annual precipitation, annual temperature, timing of seasons, and frequency of extreme weather events; 2) region, operation size, or establishment time (number of years in the ranching industry) influence if individuals attribute observed changes in weather on rangelands to climate change; and 3) adaptive range management changes made in response to climate change vary by region, operation size, or establishment time.

Adaptation to climate change requires modifications to behavior. It was expected that next to issues related to water quality and availability, feed prices and market prices for beef would be identified by livestock producers as increasing their vulnerability and influencing their relative ability to adapt to changes in climate. We also expected to see regional differences in management adaptations and operational concerns. By assessing adaptive response of the ranching industry to climate change, we can direct better research, education, and policy initiatives to increase the sustainability of the industry.

Methods

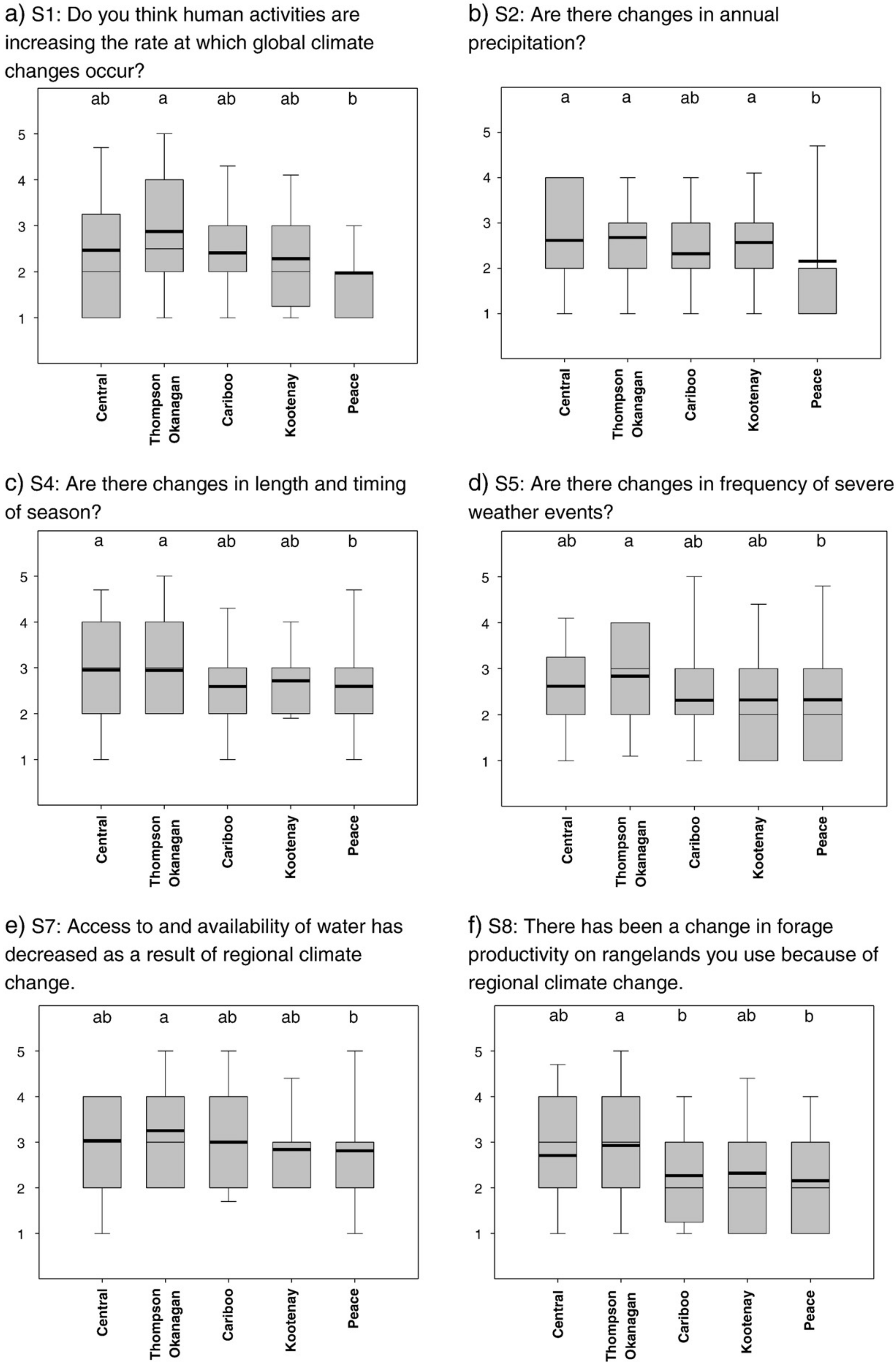
Sample Selection and Survey Delivery

A mailed survey was chosen as the best approach to survey delivery on the basis of a number of factors including economic viability, time, and resource constraints. Although face-to-face interviews conceivably allow for more in-depth discussion of the interview questions and for clarification, this method would have considerably restricted sample size and breadth. The survey was designed in a manner consistent with recommendations by professionals in the field of survey methodology (Dillman, 1983, 2000; Sanchez, 1992; Puffer et al., 2004; Diaz de Rada, 2005).

Many strategies, as described by Dillman (2000), Dillman et al. (2009), Kanuk and Berenson (1975), and Sanchez (1992), were

Table 1
Frequency response to question statements relating to climate change, including Pearson chi-square with *P* value for each statement.

	Statement	Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree	Total	Pearson chi-square	*P* value
S1	Human activities are increasing the rate at which global climate changes occur	50	102	37	28	22	239	86.126	<0.001
S2	Are there changes in annual precipitation?	39	107	46	32	15	239	102.736	<0.001
S3	Are there changes in annual temperature?	30	119	48	25	17	239	143.406	<0.001
S4	Are there changes in length and timing of seasons?	28	76	76	38	23	239	57.255	<0.001
S5	Are there changes in frequency of severe weather events?	43	82	49	26	19	219	55.224	<0.001
S6	Local climate on rangelands is changing because of global climate change	31	93	54	27	27	232	69.379	<0.001
S7	Access to and availability of water has decreased as a result of regional climate change	20	59	79	46	29	233	47.665	<0.001
S8	There has been a change in forage productivity on rangelands you use because of regional climate change	53	76	44	44	17	234	38.350	<0.001
S9	There has been a change in forage quality on rangelands you use because of regional climate change	39	77	59	40	18	233	42.858	<0.001
S10	The destruction of forests caused by the pine beetle has impacted my ranching operation	35	38	84	36	38	231	38.805	0.004


a) S1: Do you think human activities are increasing the rate at which global climate changes occur?
ab a ab ab b
b) S2: Are there changes in annual precipitation?
a a ab a b
c) S4: Are there changes in length and timing of season?
a a ab ab b
d) S5: Are there changes in frequency of severe weather events?
ab a ab ab b
e) S7: Access to and availability of water has decreased as a result of regional climate change.
ab a ab ab b
f) S8: There has been a change in forage productivity on rangelands you use because of regional climate change.
ab a b ab b
1 2 3 4 5
Central
Thompson Okanagan
Cariboo
Kootenay
Peace

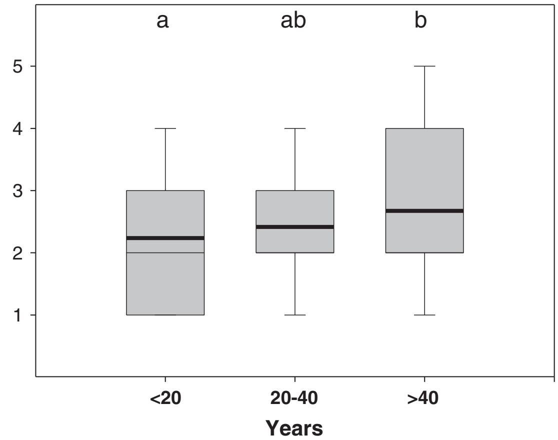


Fig. 3. Response by number of years operating at current location (Age) to the question "Do you think human activities are increasing the rate at which global climate changes occur?" with 1 being "strongly agree" and 5 "strongly disagree." The bold line indicates mean values, thin line indicates median, the box edges are the first and third quartiles, and whiskers show the range of values. Box plots sharing the same letter are not significantly different using Tukey's HSD.

employed to reduce nonresponse survey error. Surveys and cover letters were sent to 581 ranches, representing approximately half of the British Columbia Cattlemen's Association's (BCCA) provincial membership. The surveys and cover letters were mailed out in envelopes containing a postage-paid return envelope stamped with a postage stamp. The membership was categorized into six regions of British Columbia (Fig. 1), and half of the members within each area were randomly selected to receive the survey: 90 to Peace, 176 to Central, 90 to Cariboo, 167 to Thompson-Okanagan, 47 to Kootenay, and 11 to South Coast. Mailworks, a third-party mailing service, was employed to work with the BCCA's membership list and to add codes to the surveys to maintain confidentiality. The BCCA allowed the use of their membership list for distribution on the condition that those selected to receive the survey would be able to maintain anonymity. The concern was that recipients may not otherwise feel comfortable responding or expressing an opinion regarding current government policy. In an attempt to reduce nonresponse error and to address this concern, anonymity was maintained.

Coding was used to determine a recipient list for the reminder postcard and for selecting three prize winners from the pool of respondents. A reward mechanism was employed as an incentive to complete the survey and increase response rates. Two $50 prizes and one $100 prize were available to be won as store credit at a local retailer of choice. Respondents were entered into the contest once completed questionnaires were received. Research suggests employing reward mechanisms can significantly increase response rates (Dillman, 2000; Oppenheim, 2000).

The reminder postcard was mailed 14 days after the initial mailing. The cover letter and postcard also contained direct contact information (phone number and email address) of the researcher. The postcard also included the web address of the online survey. An online version of the survey was also created using SurveyMonkey and distributed to members of the BC cattle ranching community through the BCCA via e-newsletters, BCCA website, and *Beef in BC* magazine. The web address for the online survey was included on the reminder postcards to provide an option for those who wished to complete the survey online. This mixed-mode approach to surveys is still relatively new and has been met with limited success depending on respondent demographics (Dillman et al., 2009).

The codes were also used in statistical analysis to discern regional differences in responses. Full disclosure regarding the coding was made clear to survey recipients on both the cover letter and the surveys.

Survey Design

The survey design focused on characterizing cattle producers' present understanding of climate change and the degree to which they have adapted management practices in response to perceived changes in climate. Several steps were involved in the survey design, including successive drafts and revisions based on recommendations from cattle producers, range management scientists, and experienced survey designers. Once there was agreement that the survey design and content met the goals of the study, the survey was forwarded to the BCCA and select cattle ranchers for review and feedback regarding clarity and readability. Final revisions and changes were made to the survey on the basis of the comments received, keeping the goals and objectives of the survey in mind.

Questions were grouped into four sections (climate change opinions, management adaptations to climate change, perceived challenges to the ranch, and policy incentives), and question response options remained consistent throughout the survey. Possible recency (choosing the last response category) and primacy (choosing the first category) effects and the effects of nonopinion filters (offering a middle alternative on agree/disagree questions) were considered in the design; however, research suggests the overall impact of these effects is overrated and not of concern in mail surveys (Dillman, 1991). Questions in the first section focused on global climate change and attempted to capture how climate change is perceived and defined by cattle producers. An attempt was also made to characterize the perceived nature of climatic changes, global and regional, through the design of the questions in this section.

The second section focused on range management strategies in relation to global climate change and included questions about adaptation in range management strategies in response to perceived changes in climate. The third section included questions relating to the perceived challenges currently facing the ranching industry, and the fourth section identified types of incentives that would be considered in the adaptive management of rangeland. In addition, information on the background of the respondents was collected, which included regional (geographic location) and operational (number of cattle and years of service as a rancher) questions. The background information was used to categorize respondents and to determine if the different categories influenced their response. The respondents were also asked to identify areas and opportunities for further education and information and to elucidate the preferred medium of receiving this information.

Human Ethics Approval

Permission from the Thompson Rivers University Human Ethics Committee was required before making contact with potential survey respondents. Information that could possibly be used to identify respondents was kept in a secure location and accessible only to researchers directly involved in the project (Certificate of Approval # 10-11-S4).

Statistical Analysis

Frequency analyses and Pearson's chi-squared test were generated for all question statements. Significance was set at the standard

Fig. 2. Response by region of operation (Region) to survey questions S1 (a), S2 (b), S4 (c), S5 (e), S7 (f), and S8 (g) relating to global climate change, with 1 being "strongly agree" and 5 "strongly disagree." The bold line indicates mean values, thin line indicates median, the box edges are the first and third quartiles, and whiskers show the range of values. Box plots sharing the same letter are not significantly different using Tukey's HSD.

Table 2
Frequency response to 5 question statements relating to management changes, including Pearson chi-square with *P* value for each statement.

	Statement	Not at all	Slightly changed	Moderately	Significantly changed	Completely changed	Total	Pearson chi-square	*P* value
S11	Changed the way you manage rangelands in response to changes in climate	92	40	52	36	11	231	76.035	<0.001
S12	Developed additional water sources	97	44	37	43	8	229	90.367	<0.001
S13	Changed the way water is used/shared	167	17	18	14	6	222	425.162	<0.001
S14	Changed the way water reaches operation (trucking water in)	172	20	12	8	11	223	456.664	<0.001
S15	Made irrigation/pasture management changes	76	52	47	32	19	226	41.124	<0.001

P value < 0.05, but we also considered $P < 0.10$ for an indicator of trends. Three sets of categorical data were used as dependent variables on questions relating to 1) climate change opinions, 2) management adaptation to climate change, 3) perceived challenges to the ranch, and 4) policy incentives for the ranching community. Region of operation (Region), number of years cattle ranches have been in operation (Age), and number of cattle per ranch (Cattle) were used as dependent variables in one-way ANOVAs on the survey questions. The purpose was to see if there was any effect of location, operation size, or establishment on responses to questions such as those pertaining to water and forage quality/availability, impact of the mountain pine beetle information needs, and preferences. If the test was significant, a Tukey HSD post hoc analysis was done to separate treatment means. All statistical analysis of the survey data was performed using SYSTAT 13 (2009).

Results

A total of 287 surveys were returned (including 23 blank) for a 49% return rate. A number of surveys were excluded due to nonresponse bias (Ornstein, 1998); that is, the survey was returned either incomplete or contained invalid responses. Some surveys were only partially completed but still contained usable data for some questions and that information was included in the results. An additional 22 surveys were excluded from the analysis due to either being improperly completed or the respondents self-identifying they were no longer actively ranching. A total of 242 surveys (42% usable) were used in the final analysis: 32 from Peace, 62 from Central, 56 from Cariboo, 56 from Thompson-Okanagan, 28 from Kootenay, and 2 from South Coast. Because only two surveys were returned from South Coast, these surveys were excluded from regional statistical analysis ($n < 5$).

Only 13 individuals chose to complete the survey online. This was unsurprising and in agreement with the findings of Dillman et al. (2009) that switching to a second mode of data collection (i.e., following up a mailed survey with a different survey mode option) is not an effective means of reducing nonresponse error for mailed surveys. The online survey results were not included in the final analysis in order to maintain consistency in survey response methodology.

Population Background Data

According to the BCCA membership list, the majority of operations are located in Central BC, followed by the Thompson-Okanagan and Cariboo regions. Eighty-four respondents indicated establishment of more than 40 years, with the longest operation being established for 147 years. Seventy-six respondents have been ranching for less than 20 years, and 78 between 20 and 40 years.

Participants were asked to indicate the category that most appropriately reflected their current operation size in terms of number of cattle: 65 selected 0–50 head, 63 were 50–100 head, 48 were 100–200 head, and 62 indicated more than 200 head of cattle, which reflects the fact that the provincial average of cattle per ranch in B.C. is 95 (STATSCAN TABLE 003–0099).

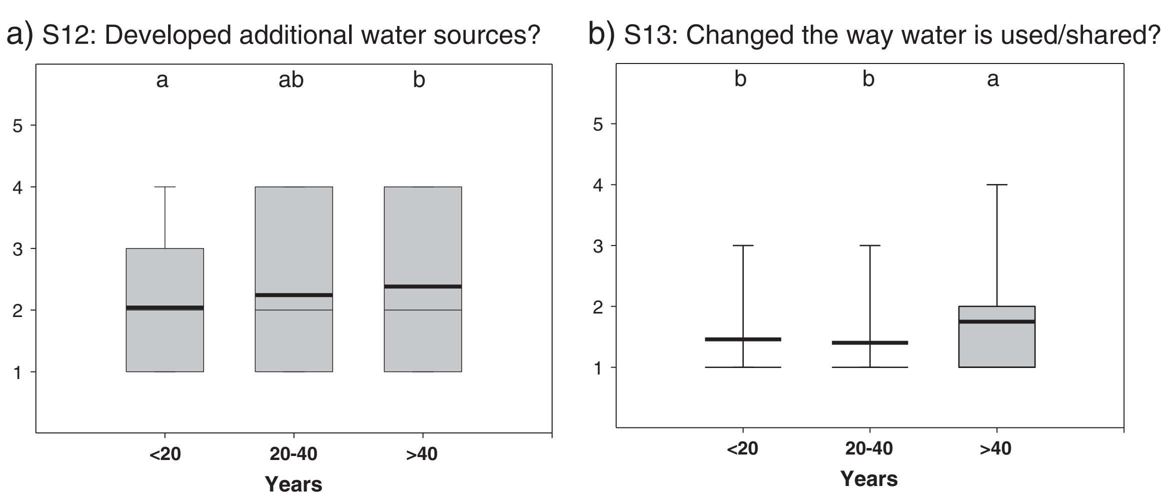


Fig. 4. Response by number of years operating at current location (Age) to survey questions S12 (a) and S13 (b) relating to management changes, with 1 being "not at all," 2 "slightly changed," 3 "moderately," 4 "significantly changed," and 5 "completely changed." The bold line indicates mean values, thin line indicates median, the box edges are the first and third quartiles, and whiskers show the range of values. Box plots sharing the same letter are not significantly different using Tukey's HSD.

Table 3
Frequency response to the question "What are the major challenges currently facing your ranching operation?", with '1' being the least significant, including Pearson chi-square with *P* value for each statement.

	Statement	1 (least)	2	3	4	5 (most)	Total	Pearson chi-square	*P* value
S16	Cattle prices	2	2	9	29	190	232	566.060	<0.001
S17	Fuel costs	3	6	18	59	147	233	313.330	<0.001
S18	Global climate change	82	52	63	16	11	224	83.455	<0.001
S19	Water availability	37	46	54	44	47	228	3.272	0.513
S20	Grain/hay costs	22	33	47	49	78	229	38.838	<0.001
S21	Family involvement/ succession planning	73	34	51	30	39	227	26.458	<0.001

Climate Change Opinions

One of the objectives of the survey was to determine the extent that cattle producers believe in global climate change. This section of the survey focused on trying to characterize that understanding by asking questions regarding what climate change is, asking respondents to identify factors normally associated with global climate change, and determining factors that may affect operations also associated with climate change (i.e., water and forage quality/availability). When asked whether they agreed with statement S1, that "Human activities are increasing the rate at which global climate changes occur," more than 63% of respondents strongly agreed/agreed and 21% strongly disagreed/disagreed (Table 1). There was a significant effect of region ($F_{4,226} = 2.376$, $P = 0.050$) and age ($F_{2,230} = 3.178$, $P = 0.044$) with response to statement S1, but no effect of cattle number. The Thompson-Okanagan region was less likely to agree with statement S1 than the Peace region (Fig. 2a). Ranchers in operation for more than 40 years were less likely to agree with statement S1 than ranchers in operation less than 20 years (Fig. 3).

Sixty-one percent identified changes in annual precipitation as a factor (statement S2), followed by 62% identifying changes in annual temperature and 57% stating a change in frequency of severe weather events (Table 1). Region significantly affected the response to S2 ($F_{4,226} = 3.603$, $P = 0.007$) such that respondents from the Peace region were more likely to agree with the statement compared with those from the Central, Thompson-Okanagan, and the Kootenay regions (Fig. 2b). There was no effect of age or cattle number.

Sixty-two percent of respondents agreed that there are changes in annual temperature (Table 1, S3), but there were no regional, age, or cattle number effects on the response rate. Only 44% agreed with the association between changes in the length and timing of seasons and global climate change (Table 1, S4). A regional effect to statement S4 was found ($F_{4,226} = 3.176$, $P = 0.015$) such that respondents from the Peace region were more likely to agree compared with those from the Central and Thompson-Okanagan regions (Fig. 2c). Fifty-seven percent agreed with the statement that there are changes in the frequency of severe weather events (Table 1, S5). A regional effect to statement S5 was found ($F_{4,208} = 2.872$, $P = 0.024$) such that respondents from the Peace region were more likely to agree compared with those from the Thompson-Okanagan regions (Fig. 2d).

To differentiate between perspectives regarding global climate change and regional changes in climate, participants were asked to select the degree to which they agreed with the statement: Local climate on rangelands is changing because of global climate change (S6). Fifty-three percent of respondents relate changes in local climate on rangelands to global climate change (Table 1). There were no regional, age of operation, or cattle number effects to statement S6.

To ascertain what factors participants associate with regional changes in climate, participants were asked to characterize changes in access to/availability of water and forage quality/productivity on their managed rangelands. This is an important question as restricted access to water or a reduction in forage quality can have a significant impact on the long-term feasibility of an operation. Only 34% agreed that access to and availability of water has decreased regionally while 32% disagreed (Table 1, S7). There was a significant regional response to S7 ($F_{4,221} = 2.545$, $P = 0.040$) such that respondents from the Peace region were more likely to agree compared with those from

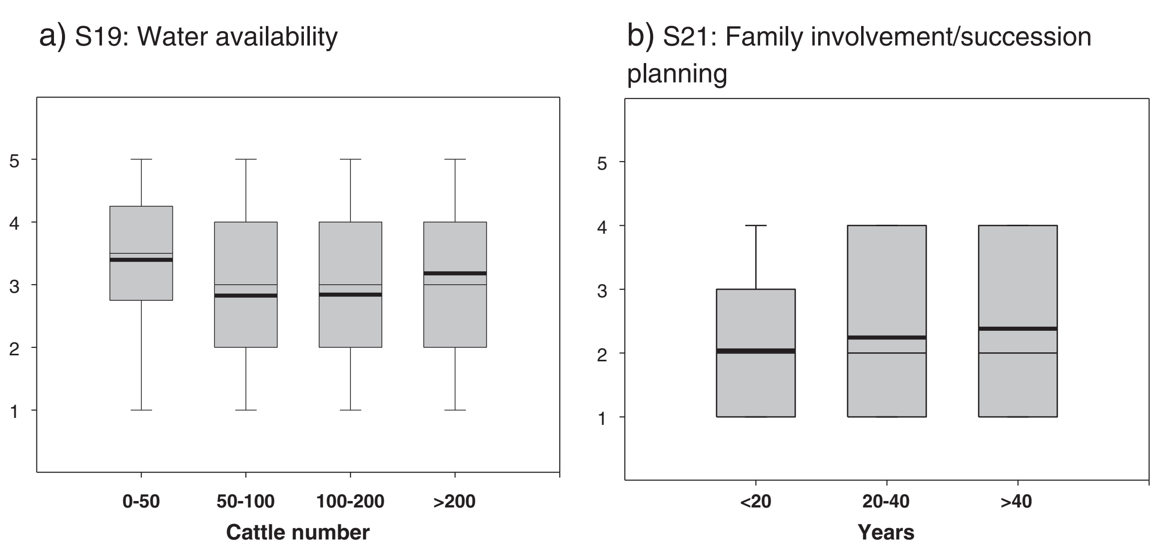


Fig. 5. Response by number of cattle (Cattle number) to survey question S19 (a) and response by number of years operating at current location (Age) to survey question S21 (b) relating to major challenges, with 1 being least significant. The bold line indicates mean values, thin line indicates median, the box edges are the first and third quartiles, and whiskers show the range of values. Box plots sharing the same letter are not significantly different using Tukey's HSD.

Table 4
Frequency response to the statement "Identify what types of incentives you would consider in exchange for sustainably managing private rangelands you use," with '1' being the least significant, including Pearson chi-square with *P* value for each statement.

	Statement	1 (least)	2	3	4	5 (most)	Total	Pearson chi-square	*P* value
S22	Carbon offsets for grazing management	71	36	35	28	42	212	26.443	<0.001
S23	Compensation for water management	22	25	53	42	77	219	46.091	<0.001
S24	Grants	36	24	54	44	63	219	21.936	<0.001
S25	Tax incentive program	30	28	36	44	84	222	47.640	0.513
S26	Rangeland health and monitoring program	73	39	48	28	24	212	35.972	<0.001

the Central and Thompson-Okanagan regions (Fig. 2e). Fifty percent and 55% agreed that there was a change in forage productivity associated with regional changes in climate (S8), and forage quality (S9), respectively (Table 1). A significant regional response was found for S8 ($F_{4,222} = 3.444$, $P = 0.009$), such that respondents from the Peace and Cariboo regions were more likely to agree compared with the Thompson-Okanagan region (Fig. 2f).

Climate change is associated with the spread of the mountain pine beetle throughout BC (Drolet, 2012); therefore we wanted to describe any impact the loss of forest may have had on rangelands as a result of the mountain pine beetle. The response options for this question allowed for the indication of positive, negative, or no impact (neutral). A follow-up question asked respondents to expand on their category selection by briefly stating how their operation was affected. Thirty-six percent of respondents were neutral, while 32% agreed and 32% disagreed with the statement (Table 1, S10). There were no regional, age of operation, or cattle number effects with S10. The following comment encapsulates most of the negative impacts identified in this response section:

> *Value of timber is gone so can't be used as capital for improvements; destruction of fences due to dead trees falling constantly; makes for poorer bush pasture—limits movement of cattle due to downfall.*

Other negative impacts include the loss of natural barriers (resulting in the need for more fences), loss of shelter from the elements, increased wind, faster spring run-off (less water retention), increased soil erosion, increased risk of forest fire, and loss of income source via lower stumpage rates or an inability to harvest and/or market dead/fallen trees.

Management Adaptations to Climate Change

Further details on management changes made in response to factors associated with climate change identified in the first section of the survey were expanded upon in the second section of the survey. To try and determine if management changes were made on the basis of changes in climate (i.e., weather variability), we asked more general questions excluding the term "global climate change."

Forty percent of respondents stated they have not changed the way they manage their rangelands in response to changes in climate, 40% have made slight or moderate changes, and 20% completely or significantly changed management strategies (Table 2, S11). Respondents were instructed to skip the following questions regarding economic costs associated with management changes and the extent/type of changes made if they responded "not at all" to the question: "Have you changed the way you manage rangelands in response to changes in climate?" Approximately 72% cited costs in management relating to global climate change: 45% at < \$25, 15% at \$25–\$50, and 12% at > \$50 per hectare.

Respondents were asked to identify what management changes, if any, they had made, selecting each option separately to reflect the extent of any changes made. Forty-two percent stated they did not develop additional water sources, 35% made slight-moderate changes, 19% made significant changes, and 3% completely developed additional water sources (Table 2, S12). A significant age of operation response was found for S12 ($F_{2,219} = 3.187$, $P = 0.043$), such that ranchers in operation for more than 40 years are more likely to have made management changes compared with ranchers operating less than 20 years (Fig. 4a).

Table 5
A selection of respondents' comments for and against the belief that humans are causing global climate change.

Deniers of global climate change	Believers of global climate change
I don't believe global warming has affected climate change. In the winter of 1930–31 there was no snow; it was a reasonably mild winter. The winter of 1942–43 there was hardly any snow and a very early spring. There has been winter when we haven't had snow until the end of December and been winters when we've had snow in October Through the years there has been wet years and dry years. I don't think things have changed.	*There is a global climate change, no doubt, how much is really man-made? Petty prices for cattle and some appreciated (financial help?) for ranchers would help more than anything else. If a government wants cheap food for all, it must support the producer. The producer is the key for quality of food and environment and life.*
The so called climate change is just a cycle that has not been seen or recorded before. To let government to be involved is going to allow another type of beating stick to use on food producers. It is trumped up hype to allow big business to gain another way of making money for themselves. As for carbon credits, this is a joke—big corporations are allowed to buy credit from someone else and not correct their own pollution.	*Few seem to realize and accept that the immediate future and condition of our rangelands are going to be much different and therefore more challenging to manage than what we have been and are just now experiencing. Livestock access to water will and must change for the overall benefits of both ecosystem and human health.*
Global warming started when the ice age stopped.	*I feel it is too late to change global warming. We have to learn to adapt to the changes. Info on strategies would help.*
Global climate change is a hoax!	*I believe that any policy change should come from people involved in the industry and not the government. I perceive the government to have a biased and limited knowledge of this problem.*

Seventy-five percent of respondents did not start sharing water sources, 16% made slight-moderate changes in sharing resources, 6% made significant changes, and 3% completely changed (Table 2, S13). A significant age of operation response was found for S13 ($F_{2,212}$ = 3.115, $P = 0.046$), such that ranchers in operation for more than 40 years are more likely to have made water use/sharing arrangements compared with ranchers operating less than 40 years (Fig. 4b).

The majority (77%) of respondents did not make any changes in regards to trucking water (Table 2, S14), while 33% made no irrigation/pasture management changes (Table 2, S15). There were no effects by region, age of operation, or cattle number for responses to S14 and S15.

Perceived Challenges to the Ranch

Six categories were identified as posing potential challenges for the ranching operation (Table 3): cattle prices (S16), fuel costs (S17), global climate change (S18), water availability (S19), grain/hay costs (S20), and family involvement/succession planning (S21). In response to the question: "What are the major challenges currently facing your ranching operation?", the top challenge was identified as cattle prices, followed by fuel costs, grain/hay costs, water availability, and family involvement/succession planning (Table 3). The challenge identified as the least significant was global climate change. There was a marginally significant ($P < 0.10$) effect by number of cattle in the operation on the water availability challenge (S19) ($F_{3,221}$ = 2.400, $P = 0.069$), such that ranchers with less than 50 head of cattle view water availability a more significant challenge than ranchers with 50 to 200 (Fig. 5a). The only other significant grouping effect ($P < 0.10$) was by age of operation on family involvement/succession planning (S21) ($F_{2,219}$ = 2.537, $P = 0.081$), such that ranchers in operation more than 40 years are more concerned about succession planning compared with ranchers operating less than 20 years (Fig. 5b).

Policy Incentives

Five policy incentives were identified: carbon offsets for grazing management (S22), compensation for water management (S23), grants (S24), tax incentive program (S25), and a rangeland health and monitoring program (S26). In response to the statement: "Identify what types of incentives you would consider in exchange for sustainably managing rangelands you use," the top incentives listed in order were 1) tax incentive program, 2) compensation for water management, 3) grants, 4) carbon offsets for grazing management, and 5) rangeland health and monitoring (Table 4). Both carbon offsets for grazing management and rangeland health and monitoring program were identified as the least significant incentive. None of the grouping factors, by region, age of operation, and number of cattle, affected response rate for policy incentives.

Information Needs and Preferences

In terms of information needs, when asked if they would benefit from a better understanding of what global climate change is, 38% felt they would not benefit, 38% felt they would somewhat benefit, and 24% felt they would significantly benefit. Of those identifying an interest in further information, the majority preferred mailed educational material with a website being the second choice. No difference was found in a regional analysis, age of operation analysis, or number of cattle analysis of responses regarding future information needs.

Respondent Comments

The final page of the survey provided a blank space to accommodate additional comments regarding the effects of global climate change on the ranching industry. Almost half (49%) of respondents took advantage of the opportunity to provide input and feedback. Additional comments made in the margins of the returned surveys were grouped with the final comment section as all pertained to perspectives about global climate change and the ranching industry. A select sample of these comments is provided here (Table 5). The anecdotal information provided via the comments clearly encapsulates a divided opinion regarding climate change within the BC cattle ranching industry.

Discussion

Objective 1: Do Ranchers Believe That Climate Change Is Caused by Human Activities?

The majority of respondents believe global climate change is occurring and is affecting their livelihoods, reflecting similar results from a broader country-wide survey of Canada and the United States (Borick et al., 2011). This positive result suggests the need for strategies and tools for management adaptation and the desire by the British Columbia ranching industry to adopt such strategies. However, some surveys were returned with comments revealing a need for clarity concerning climate change (Table 5). The comments from the minority of deniers reflect a misconception of weather and climate, where short-term weather effects are used as evidence to counter long-term climate change (Lombardi and Sinatra, 2012). It is critical that effective future range management approaches include the communication and education of important environmental terms. Illumination of the meaning of each term and how they are interrelated factors and not separate entities or "catch phrases" of the time or scientific "fads" is essential for future adaptive capacity.

The following survey comment provides an example of a misperception:

> *Global climate change has been occurring for the last 5 000 000 years. You can't get the weather right three days in advance. What makes you think you know what it's going to be like in the next month much less ten years from now? What happened to global warming?*

The tendency for climate change to be referred to as either global warming or described in terms of changes in weather patterns was also identified by Reid et al. (2007) in their study focusing on vulnerability and adaptation to climate change in agricultural operations in Ontario. They found only 17% associated climate change specifically with a change in variability and extremes, and those respondents also expressed the greatest degree of concern for climate change. In a survey of 622 individuals about perceived environmental, ecological, or societal impacts from climate change in the United States by Semenza et al. (2011), heat waves, average temperature increase, flooding, and more frequent storms were identified by 80–90% of respondents. In the study presented in this paper, the two most common factors respondents associated with global climate change were changes in annual precipitation and temperature, followed closely by a change in frequency of severe weather events.

On the basis of respondent comments, a significant proportion of respondents believe global climate change is a natural cycle, even if they acknowledged the fact that it is occurring. The influence of human activity on the perceived natural cycles was not entirely discounted, nor was it seen as the main or even a significant causal factor. Borick et al. (2011) also found that of those Canadians who believed in climate change, there was division in attributions to anthropogenic or natural causes. Reid et al. (2007) found 21% of producers were skeptical about the issue, maintaining the changes were due to natural cycles. As Antle (1996) points out, this may be because when climate is stable, historical records can be interpreted as static processes, but when the climate is changing, those distributions become nonstationary. Climate changes caused by an accumulation of greenhouse gases are at a slower, imperceptible pace to farmers, and small annual changes would be of little consequence relative to normal climatic variation. This may reflect the fact that the least significant challenge identified on the survey was global climate change. Many range managers may not attribute management changes to annual variability in temperature and precipitation, but these changes equate to climate change adaptation. Adaptations are made to the annual variability and long-term average conditions, including extremes.

Objective 2: Does Region, Operation Size, or Establishment Time Influence Opinions?

Cattle ranchers operating for less than 20 years were more likely to agree with the statement that human activity increases the rate at which global climate changes occur in comparison with those operating for more than 40 years. This may be a reflection of the fact that the concept of climate change has gained more public acceptance in the past 2 decades and would likely be perceived as a legitimate risk to an operation by those in this category in comparison with those who have been operating for a long period of time and tend to rely on experiential or embedded knowledge.

Knapp and Fernandez-Gimenez (2009) studied how ranchers in Colorado gain knowledge and how this information is shared. They found that ranchers consistently relied on embedded and experiential knowledge to inform management decisions. They define embedded knowledge as that which “comes from living on the land and observing natural processes.” They state that this knowledge often includes a limited understanding of “cycles that are longer than a human lifetime, such as erosion processes, changes in hydrology, climate change, and ecosystem resilience.” Although their participants perceived an extended drought period, they were divided whether it was a result of climate change or part of a natural, cyclical process. Maddison (2007) noted that the most important finding was that although experienced farmers were more likely to perceive climate change, it was educated farmers who were more likely to make one change to adapt to it. In our study, the most experienced farmers, those farmers in operation for more than 40 years, made water management changes that most likely reflected changes in climate, but it appears they do not necessarily attribute the need for those changes to global climate change.

Duration of time in industry did not appear to influence any other perceptions about climate change. Therefore we conclude that length of time of cattle ranching does not significantly influence belief in or understanding of what climate change is but instead affects the perception regarding the influence that human activities have on the overall rate at which global climate change occurs. Regional differences were observed in this perception between the Peace and Thompson-Okanagan regions with producers in the Peace region being more likely to agree that human activities are influencing the rate at which global climate changes occur. It is interesting to note that the Peace region is the most northerly region in British Columbia, and the Thompson-Okanagan is the most southerly, as well as being the hottest and driest region. The IPCC (2013) report has documented that northern latitudes experience greater climate change than southern latitudes, which may explain the difference in opinion between the two regions. This fact is reflected in the more positive response of Peace ranchers compared with Thompson-Okanagan ranchers to the question of changes in annual precipitation, changes to length and timing of the growing season, frequency of severe weather events, and decreased access to and availability of water.

Operation scale in terms of head of cattle does not appear to influence perceptions of climate change. Without further demographic information such as revenue, number of employees, operation diversification, or educational attainment, it is difficult to determine conclusively whether operation scale has any effect. However, it is likely that larger operations (>200 head of cattle) are more focused on economic factors that will affect the vulnerability of their operations, whereas smaller operations with 0 to 50 cattle are more sensitive to changes in forage quality and availability. Larger operations often grow their forage crops for silage and feed and do not rely as much on accessing natural grazing areas.

Objective 3: Are Range Management Changes Made in Response to Changes in Climate?

According to the B.C. Ministry of Agriculture the average feedlot has 400 head of cattle, with many using grain for feed and not grazing land. Smaller operations, relying more heavily on available range areas for natural forage, are more vulnerable to variability and availability. Larger operations (≥100 head) have a per-beef cow investment of $9 000 to $12 000, whereas smaller operations (<100 head) have a per-head investment of greater than $15 000 (Henry, 2003), meaning that livelihoods have the potential to be severely impacted by fluctuations in forage quality and quantity.

Although it can be difficult to determine whether management changes are made in response to normal climate variability or the longer-term impacts of climate change, general adaptation strategies that would vary according to local conditions and farming strategies can be summarized as follows (Dolan et al., 2001; Howden et al., 2007; IPCC, 2013): changing the timing of operations such as planting and harvesting; changing the timing of inputs such as irrigation and fertilization; altering tillage, crop selection, or diversifying operations (forage and livestock); changing size and scale of operations by relocating, ceasing operations in some locations, and increasing or decreasing number of livestock; modifying stocking rates and timing of grazing to match pasture conditions; and expanding financial security via crop insurance, bank loans, or available government programs.

Managing for changes in the ability of available forage was identified by respondents as a management change made in response to change in climate with 60% indicating they had made some type of management change. This finding is in contrast to only 15% of 120 southwestern Ontario farm operators surveyed by Smit et al. (1996) over 5 years. Of these operations, changes or diversification of crop and/or enterprise was frequent. Some operators expanded or reduced the size of their operation, adopted new technology, or altered the amount or type of inputs such as feed or fertilizers. We found similar adaptation strategies by B.C. cattle ranchers with the most frequent management change being a change in the timing and movement of cattle and a change in the frequency of movement. Many also reduced stocking rates/decreased operation scale. These strategies were also found by Crawford and MacNair (2012) in their survey of adaptation strategies by cattle ranchers in Central BC.

Regional analysis provided some areas of potential focus for programs that would assist producers in further adapting to changes in climate. Range managers in the Peace region would likely benefit from a program or a government-supported management program focused on developing and maintaining access to sustainable sources of water. Producers in this area were much more likely to agree with the statement that access to and availability of water has decreased as a result of global climate change in comparison with respondents in the Thompson-Okanagan region. This may be a reflection of the linear trend of increasing global temperatures being greater at northern latitudes (IPCC, 2013). So although warmer temperatures in the Peace might mean milder winters and longer growing seasons, they also mean a greater demand on existing water supplies. This conclusion is supported by the findings of Crawford and MacNair (2012) who state "access to water and future water supply is of substantial concern for cattle producers."

Other adaptive strategies include market-based policy options including carbon taxes and cap-and-trade energy policy. Borick et al. (2011) found the majority of Canadians surveyed in their study indicated support of a cap and trade energy policy, even if there was a monthly cost implied. Most Americans opposed cap and trade and carbon tax policy programs in any of the forms presented (i.e., with and without individual costs). Our study indicated little support for carbon offsets for range management practices but did identify tax credits as a popular tax incentive. Much of the opposition to carbon offsets may be due to a lack of understanding of the programs and the general view that the programs are designed to benefit large industry and not private business owners. Further research into the perception of these two policy options would be valuable in informing and implementing effective climate change policy. This would be a useful endeavor as close to 60% of those surveyed hold Crown grazing tenures. Because up to 95% of land used for grazing cattle is Crown tenured, it is important to determine the degree of investment cattle ranchers have in maintaining the health of Crown-tenured rangeland and possible options for incentive programs such as carbon offsets.

Anecdotal information gathered from the open comments section offered further insight to the perspectives and experiences of B.C. cattle ranchers. There is an overall sense of frustration with lack of government policy and programming to address the changing needs of the industry. This illustrates that the sensitivity of systems and relative adaptations are to not only climate but also social, economic, and ecological systems. Ongoing evolution of responses and adaptations and policy responses need to exhibit the same flexibility (Smit et al., 2000). Key areas of focus should include the development of strategies for wildlife management, water storage and management, restoration programs for areas affected by the mountain pine beetle (Crawford and MacNair, 2012; Drolet, 2012), and logging and agroforestry programs.

Formation of a collaborative learning process to support livestock producers will enable the adaptive capacity of producers (Crawford and MacNair, 2012; Thornton et al., 2007) and informed decision making, providing a broader long-term framework for range management planning. The information will be made accessible in ways most desired by the survey respondents and distributed by Thompson Rivers University and the BCCA. Some of the areas of focus for further education and information identified via survey responses include the distinctions among climate change, global warming, weather patterns (local climate), and regional variations in relation to climate change and carbon tax/carbon storage credits.

Movement toward building adaptive capacity must include the cooperative effort and support of members of the ranching community, local government (municipalities and regional districts) and communities, and the provincial and federal government. Such a collaborative effort, including experiential and scientific knowledge and peer-to-peer learning, will be crucial to reducing the vulnerability of this sector and building adaptive capacity. Establishing the capacity to adapt to changing environments and creating management plans reflective of this capacity will be critical in aiding ranchers to inform local and provincial governments of their needs. It will also help governments and local planners to form policy and long-term plans illustrative of both the regional and larger-scale needs of the cattle ranching industry.

Reducing vulnerability is a large component of enabling this capacity and needs to include the development and implementation of educational tools to illuminate complex and abstract concepts such as global climate change. The framework for these tools should be based on communication strategies that draw upon people's experiences and local knowledge of the environment (Crawford and MacNair, 2012; Ruddell et al., 2011). As Walker and Sydneysmith (2008) suggest, delivering information in a manner that resonates with the issues and concerns of those receiving it—those directly responsible for implementing adaptation—is crucial.

The vulnerability of the beef cattle industry and agricultural producers will continue to increase in relation to increasing climate variability on a provincial, national, and global scale. Creating an open dialogue to facilitate management strategies that will enable the capacity of producers to adapt to global climate change will be crucial in addressing future food security issues. The beef cattle industry in B.C. has the opportunity to create the framework for this process, providing a template for producers in all areas of the agricultural sector.

Management Implications

Thorpe (2012) provides a comprehensive overview of recommended adaptations to climate change in grassland management for the management of prairie ecosystems. Just as the effects of climate change extend beyond local or regional scales, adaptation strategies must do the same. Continuous improvements in technology will precipitate this process and the ability to observe and predict climate changes. Brown and Thorpe (2008) provide an example of technology contributing to our knowledge of how the local effects of climate change can have global impacts. They state that reduced precipitation and increased temperatures "can lead to overgrazing, which can cascade into regional desertification [which can] cause increased wind erosion and dust that can be transported by upper atmospheric winds where it can affect global weather patterns and impact human health." However, research and technology alone will be ineffective without a thorough understanding of the decision-making environment and the capacity to effect change.

Local knowledge, experience, and skills in dealing with climate variability and assessing risk provide invaluable information to future planning efforts. Change in perception within the B.C. ranching industry seems to be occurring. The fact that cattle ranchers operating for less than 20 years were more likely to agree that human activities are increasing the rate of global climate change compared with those operating more than 40 years may be because the concept of climate change has gained more public acceptance in the past 2 decades. The rate of climate change differs geographically, and our regional analysis showed that ranchers from the most northerly region are more likely to have noticed change in climate compared with the most southern regions. Capacity-building efforts need to focus on educating producers about the science of climate change and helping producers deal with changes and variability that extend well beyond their current knowledge and experience.

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