Pirineos.Revista de Ecología de Montaña
Vol. 167, 143-163
Jaca, Enero-Diciembre, 2012
ISSN: 0373-2568
eISSN: 1988-4281
doi: 10.3989/Pirineos.2012.167007

PYRENEAN PASTORALISTS'OBSERVATIONS OF ENVIRONMENTAL CHANGE: AN EXPLORATORY STUDY IN LOS VALLES OCCIDENTALES OF ARAGÓN

Observaciones del cambio ambiental del pastoralismo pirenaico: un estudio exploratorio en los Valles Occidentales de Aragón

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ABSTRACT.– Observations of environmental change by local resource users may be an important source of information about past and current environmental conditions to complement scientific studies and monitoring. In this exploratory, qualitative study, we documented observations of environmental change made by 27 stockmen in the two westernmost valleys of the Central Western Pyrenees of Spain. Pastoralists reported changes in weather, corresponding declines in the flow of mountain springs, and an increase in shrub and tree cover in the mountains. Explanations for the increase in woody plant cover differed in the two valleys; however, the majority of stockmen from both villages believed that the lack of human presence in the mountains contributes to shrub encroachment. Stockmen's observations of environmental change suggest additional research needs regarding climate and vegetation change in the Pyrenees, and highlight the potential contributions of Pyrenean pastoralists' local knowledge to environmental monitoring, research and management.

Keywords: Indigenous knowledge, local knowledge, traditional ecological knowledge, climate change, rangelands, adaptation, resilience.

RESUMEN.– Las observaciones sobre el cambio medioambiental realizadas por usuarios locales pueden ser una importante fuente de información sobre las caracte-

Recibido: 12, 19, 2011. Aceptado: 02, 21, 2012.

rísticas medioambientales del pasado y del presente para complementar los estudios científicos y el monitoreo. En este estudio cualitativo documentamos observaciones sobre el cambio medioambiental realizadas por 27 ganaderos en los dos valles más occidentales de los Pirineos centro occidentales españoles. Resumen cambios climáticos relativos a la disminución del caudal de las fuentes de montaña y al aumento de la cubierta vegetal de matorrales y arbolado en las montañas. Las explicaciones sobre el aumento de arbolado difieren en los dos valles; sin embargo la mayoría de los ganaderos de ambos pueblos pensaban que la falta de presencia humana en las montañas contribuye a la invasión del matorral. Las observaciones de los ganaderos sobre los cambios medioambientales sugieren la necesidad de investigaciones adicionales sobre los cambios climáticos y de vegetación en los Pirineos y evidencian las potenciales contribuciones del conocimiento local de los ganaderos para el monitoreo medioambiental, la investigación y la gestión.

Palabras clave: Conocimiento autóctono, conocimiento local, conocimiento ecológico tradicional, cambio climático, pastos, adaptación, resiliencia.

1. Introduction

The defining characteristic of resilient social-ecological systems (SES) is the ability to live with and adapt to change, including both environmental change and other types of changes (economic, social, political) that affect the environment (Walker and Salt, 2006). Resilience theory also advances the concept of coupled social-ecological systems, the idea that natural and human systems must be considered as an interacting and interdependent whole, rather than discrete and separable domains (Berkes *et al.*, 2003). A resilience-oriented approach to natural resource management strives to understand, maintain and manage within the natural range of variability an ecosystem, given its historic disturbance regimes, climate, and land use, and recognizes that attempts to limit or over-control natural variation may lead to unintended loss of resilience and vulnerability to catastrophic events, such as severe floods or wildfires (Holling and Meffe, 1996). However, in order to respond or adapt to change, we must first observe it. Because of the logistical and financial challenges of carrying out formal monitoring across the many and varied landscapes on Earth, it is important to seek alternative and complementary sources of information about environmental change. Traditional ecological knowledge (TEK) and local knowledge (LK) are two such sources of information that may help to overcome the constraints to detecting environmental change of broad spatial extents and long time periods.

TEK and LK both encompass knowledge about the natural world including biophysical observations, management practices and technologies, values, customs and taboos, and norms of resource use. TEK and LK are specif-

ic to a particular place, group of people and time, and are acquired through direct experience and interactions with the environment, and through observation and oral traditions within a community or local region. Many studies have documented the traditional knowledge of indigenous groups regarding soils, plants, animals, water, ice and other ecosystem elements and their management (e.g. (Berkes, 1999, Menzies, 2006, Ross *et al.*, 2011)). The majority of studies have focused on farmers, hunters and fishers, although a growing body of literature has documented the TEK of pastoralists and ranchers in Africa, Eurasia, the US and Australia (Calvo-Iglesias *et al.*, 2006, Garden *et al.*, 2000, Gemedo *et al.*, 2006, Knapp and Fernandez-Giménez, 2009, Muller *et al.*, 2007, Niamir, 1995, Riseth *etal.*, 2011, Roturier and Roue, 2009). Although often some aspects of traditional knowledge are widely shared among a particular local group (Fernandez-Giménez, 2000), knowledge may vary depending on the age, experience, gender and social role of an individual and cannot assumed to be homogeneous within even a small community (Ayantunde *et al.*, 2008, Rocheleau, 1991, Davis and Wagner, 2005).

Given the rapid rates of anthropogenic environmental change now being experienced on Earth, and the complex cross-scale dynamics involved in how these changes play out in any particular place on the ground, it may be especially important to document local observations of environmental changes, as well as local beliefs about the causes of these changes. We identify four rationales for seeking local and traditional knowledge of environmental change. First, local observations may provide more fine-resolution spatial information about the nature and magnitude of environmental change, which could be valuable to support more coarse grained quantitative assessments or identify potential variability that may be obscured by coarser resolution assessments. Second, and similarly, local observations may provide finer-resolution temporal observations than some formal monitoring. In some cases, TEK may also provide information about environmental conditions before the period of record for formal environmental monitoring. Third, in some cases, local resource users may detect direct impacts on their livelihoods from environmental changes before statistically detectable changes have occurred. Finally, mounting evidence shows that traditional-knowledge-based resource management systems often have a strong record of sustainability and are highly adapted to local conditions, including temporal and spatial variability in those conditions (Fernandez-Giménez, 2000, Forman, 1995), and that involving local people and their knowledge in ecological monitoring and management increases the likelihood that monitoring information will be acted upon and applied to future decision-making (Danielsen *et al.*, 2010, Reed *et al.*, 2008).

There are relatively few studies as yet of pastoralists' observations of climate change. Those that exist are primarily from regions where climate change is expected to have (or has already had) a fairly dramatic effect on resources, such as forage and water, that directly affect herders' livelihoods (Fassnacht *et al.*, 2011, Marin, 2010, Speranza *et al.*, 2010, Pierce, 2011). In most of these studies, participants reported significant changes in weather and climate. However, local herders' observations do not always correspond with analysis of meteorological records (Fassnacht *et al.*, 2011, Marín, 2010,Pierce, 2011). Perhaps more troubling is that several studies show that even when herders detect changes, they may take little action to adapt to these changes (Speranza *et al.*, 2010). In other cases, resource users are accustomed to making incremental or minor adjustments in management to adapt to inter-annual variation in conditions, but lack the capacity or, in some cases, foresight, to adapt to changes of greater magnitude in terms of their spatial or temporal extent or irreversibility (Robinson and Berkes, 2011).

Given changes in the social, demographic and economic aspects of Pyrenean pastoral systems (García Ruiz and Lasanta-Martínez, 1990 and 1993, García-Martínez *et al.*, 2009, Lasanta-Martínez *et al.*, 2005), and recent trends in climate change, we sought to document Pyrenean pastoralists' observations of environmental changes, compare these observations to what is known about changing conditions from the corresponding scientific records (from published sources), and explore how TEK about environmental change might contribute to sustainable management and adaptation to future change. Our objective were to document 1) the types of environmental changes observed and consensus about the changes, 2) pastoralists' explanations for the observed changes, and 3) how are management and livelihoods have been affected by the changes. As an exploratory study and the first to document Pyrenean pastoralists' ecological knowledge, we did not set out to test pre-defined hypotheses, but rather to examine the nature of herders' knowledge and their observations of change. A companion paper (Fernandez-Giménez and Fillat, 2012) reports in greater detail on the nature of pastoralists' knowledge and its application to management and adaptation. This study focuses exclusively on herders' observations of environmental change.

2. Study Sites and Methods

This research was carried out in the two westernmost Pyrenean valleys in the Spanish autonomous region of Aragón, in the province of Huesca. These valleys, Ansó and Hecho, were long famed for their livestock industry and

 (Pirineos, 2012, Vol. 167, 143-163, ISSN 0373-2568, eISSN: 1988-4281, doi: 10.3989/Pirineos.2012.167007)

powerful stock-owning families. In both communities the population has declined in recent decades, along with the relative importance of the livestock sector in the local economy (Díaz Martí, 2000). For example, the number of officially registered livestock operations in Hecho fell from 93 to 45 between 1999 and 2009 and in Ansó declined from 29 to 21 over the same time period.The number of livestock grazed on Ansó's pastures has declined, but not so in Hecho, where the livestock count has remained relatively stable in recent years, but the species composition has shifted towards cattle. Both villages also supported a small but important timber industry until the early 1990s when the combination of growing environmental concern about abusive logging methods and competition with foreign wood suppliers, forced the mills in both communities to shut down. The mill in Hecho has since reopened as a private concern but processes wood from elsewhere, and the village of Ansó recently opened a biomass plant that it is hoped will revitalize the local forest products industry (Zamborain, 2011).

Data collection involved three main methods: 1) in-depth semi-structured interviews with active and retired livestock producers (27), 2) community feedback meetings, and 3) informal field interviews and participant observation. We conducted in-depth semi-structured interviews with 27 livestock producers representing 26 different livestock operations in the two study valleys, 14 in Ansó and 13 in the Valley of Hecho in October through December 2010, to document their ecological knowledge and observations of environmental changes.In each valley the local municipal administration provided a list of all livestock producers registered in the community. This list of active producers was supplemented by seeking referrals of retired herders who were regarded as knowledgeable by other community members. We contacted all people on our list for whom we were able to obtain both a mailing address and a telephone number by writing them a letter inviting their participation and following up with a telephone call.In Ansó, we interviewed all of those contacted who agreed to participate in the study.In Hecho, we interviewed a similar number of participants, making sure to interview a sample representative of the range of age, experience and livestock species in the community, and to include key individuals identified through community referrals as the most knowledgeable. We stopped interviewing in Hecho when additional interviews offered little new information. Interviews lasted 1-2 hours and took place at the respondent's home, barn or field, or in a quiet and undisturbed public location. All interviews were audiorecorded and transcribed for analysis.

In the interviews, we asked herders about the environmental changes they had observed, the causes and reversibility of these changes, and information about the respondent's personal background and livestock operation.We also

collected information about production cycle and typical management practices used by each informant.

Transcribed interviews were imported into NVivo(QSR, 1999-2010) for coding. Initial coding relied on a pre-determined list of codes based on the interview questions. Emergent themes were incorporated in a second round of coding. Coded passages were organized into tables to facilitate comparison within and across study sites. In synthesizing the results we aimed to characterize dominant viewpoints and widely shared knowledge, as well as variation in knowledge and perceptions within and between our study sites.

Following preliminary data analysis, we organized community feedback meetings in each of the study valleys.Each meeting consisted of a formal presentation of the results with questions and discussion in the large group, followed by an informal gathering with refreshments where participants provided additional feedback individually or in small groups. This process enabled us to ask research participants whether our interpretations accurately reflected their knowledge and request further information on specific points. The community meetings also helped us to determine whether the sampled group's views were representative of the broader population of herders in each valley. In Ansó 8 of the interviewed pastoralists attended the meeting, as well as 3 herders who were not interviewed, and 21 other community members. In Hecho 5 of the herder participants attended as well as 5 non-participant herders and 8 other community members. Non-herder community members at each meeting included local forest guards, government officials, school teachers, a local priest, and an inn-keeper, among others.

Twenty-six of the 27 participants were men, reflecting the continued dominance of men in the herding occupation.Respondents ranged in age from 32 to 75 with an average age of 52. The mean number of years of herding experience was 34 (range: 10-65). Five of the 27 participants were officially retired (although often they continued to assist with a family livestock business) and the rest were active herders. Eighty-five percent of the respondents came from families that had raised livestock for 3 or more generations.Seventy-seven percent of the participants were native to the study valleys and another 15% were born in another part of the Pyrenees or rural Aragon. One participant was from a Spanish city and one producer had emigrated from another country. Fourteen of the interviewees raised sheep predominantly, 11 were cattle producers, 1 raised goats and 1 raised horses. Fifty-four percent of respondents relied on livestock production as their sole source of household income, and another 23% reported that livestock accounted for 75% or more of household income.For 11.5% of respondents, livestock accounted for less than 25% of their household income.Among producers who raise sheep primarily, herd sizes ranged from 300 to 2300 head.Among cattle producers,

herd sizes varied from 35 to140 animals.Thirty percent of the respondents (8 of 27) currently practiced transhumance or were transhumant until their recent retirement.

3. Results

3.1. Changes in Climate and Stream Flow

Three quarters of the interviewees in Ansó and 81% of those in Hecho observed changes in the climate and many also observed related changes in stream flow or springs. The most frequent observation was a change in winter temperatures and snowfall (Table 1). Many herders observed that in the past the snow fell earlier and deeper than in the present and that winter temperatures were colder (Table 2). Older transhumant herders in particular compared the dates when they would come down from the mountains in the past with the length of the mountain grazing season today. In the present, winters are observed to be warmer and drier. One stockman noted that in the past there were permanent snowfields in the high mountain passes, where snow could be found year-round, but that these have disappeared.

Several herders also observed less rainfall in the present than in the past. One observed that in the past, it was typical to have rain for 7-8 days in a row, whereas now it only rains for one or two days. These herders also observed that rains begin later in the fall than they used to. One stockman thought that weather patterns generally were more unpredictable now than in the past, referring to them as "crazy," with snows arriving later than usual in the autumn, but also unexpected late spring snows which froze the buds on the beech trees resulting in a loss of the year's beechnut crop.

The declines in snow depth and rainfall were reflected in herders' observations of changes in stream flow and especially the flow of mountain springs they depend on to water their livestock in summer pastures. Half of those who mentioned spring or stream flow said that it had declined, while half observed no change (Table 1). All who mentioned stream or spring flow explained that the flow of the waters is dependent on snowfall and summer rains. When the snow cover is light or there is little rain, the spring dry up. Several interviewees also mentioned changes in management of the springs. In the past herders worked to keep the springs cleared of debris and flowing, but now they are neglected and no one cleans them. This, too, was thought to contribute to the decline in flow.

Table 1. Perceptions of environmental changes among Pyrenean pastoralists.Data are the percentage (number) of respondents that mentioned each type of change in response to open ended questions about observed environmental changes.For changes where some respondents stated that they did not think a change had occurred or disagreed with the explanation, data are the percentage (number) who agreed, disagreed or were uncertain out of all respondents who mentioned that type of change.

Tabla 1. Percepciones de los cambios medioambientales entre los ganaderos del Pirineo. Los datos están en porcentaje (número) de los entrevistados que mencionaron cada tipo de cambio en respuestas a preguntas abiertas sobre los cambios medioambientales observados. Para cambios en los que los entrevistados decían desconocer el cambio que había ocurrido o no estaban de acuerdo con la explicación, los datos son el porcentaje (número) de quienes estaban de acuerdo, en desacuerdo o no sabían con seguridad las respuestas de quienes mencionaban ese tipo de cambio.

	Ansó (N=14)	*Hecho (N=12)*	X^2	*P-value*
Climate change	75 (6) yes 12.5 (1) uncertain	81.8 (10) yes 18.1 (2) no	1.497	0.473
Change in water abundance	80 (4) yes 20 (1) no	0 (0) yes 100 (3) no	4.800	0.028
Change in shrub and tree cover	100 (14) yes 0 (0) no	100 (12) yes 0 (0) no	n/a	n/a
Explanation-lack of livestock	92.3 (12) yes 7.7 (1) uncertain	12.5 (1) yes 25 (2) uncertain 62.5 (5) no	14.295	0.001
Explanation-change in livestock species	66.7 (4) yes 33.3 (2) no	66.7 (2) yes 33.3 (1) no	1.0	1.0
Explanation-climate change	50 (2) yes 50 (2) no	71.4 (5) yes 28.6 (2) no	0.477	0.576
Explanation-lack of fire	87.5 (7) yes 12.5 (2) no	42.9 (3) yes 28.6 (2) uncertain 28.6 (2) no	3.884	0.143
Explanation-lack of people in the mountains	88.9 (8) yes 11.1 (1) no	80 (8) yes 20 (2) no	.596	1.0

Although most interviewees who mentioned changes in climate were confident that these were important and noticeable changes, a few herders were uncertain as to whether these changes represented significant trends or simply cycles. One of the older stockmen thought that the perceptions of change could be the result of herders today spending less time in the mountains than they did in the past. Another felt that river flows varied each year depending on the snow and rainfall, but that there was no long-term difference in river flows.

3.2. Climate Change Effects on Management and Livelihoods

Changes in climate or weather patterns appear to be having some influence on herders' management patterns. For example, because herders have low-cost access to forage in high-mountain pastures of the Pyrenees, it is to a producer's financial advantage to leave his stock in the mountains as late as possible in the fall before bringing them down to the village, where they must be confined to a barn and stall-fed with purchased grain and hay for most of the winter. Thus, a number of herders were increasingly gambling with the winter, by leaving stock in the summer or fall pastures until as late as December, running the risk of losing animals if a deep snow or freeze were to occur before they were brought down. Some herders also mentioned that certain summer pastures were falling out of use due to lack of fresh water as springs dry up. If the green-up season is consistently delayed in the spring or summer, as some herders observed, this may shorten the growing season and the quantity of forage produced, which could influence animal weight gain and profitability.

3.3. Perceptions of Ecological Changes and Drivers

The major ecological change noted by all the interviewed herders is the increase in shrub and tree cover in both the *puertos* (high mountain summer pastures) and the *montes bajos*(low mountain fall and spring pastures), but especially the *montes bajos* (100 %).Herders spoke about this change as the "mountains becoming dressed", the "shrubs eating the mountains", or the "shrubs winning over the mountains". Herders universally saw this as a negative change in the landscape that leads to less and less usable pasture. Several also commented on the increased risk of catastrophic wildfire resulting from denser shrub and, especially, forest cover. Although the expansion of shrubs was by far the most frequently mentioned change and the one that concerned herders the most, other environmental changes were observed.

Because shrub expansion was perceived as a major change and an undesirable one by virtually all of the respondents, our interviews focused largely on the perceived causes of this change, its reversibility, and measures that could be taken to counteract shrub expansion. The explanations for shrub expansion differed between the two valleys studied (Table 1).In Ansó, almost all herders believed the change in the number of livestock as the primary cause of these changes, whereas in Hecho, only one individual thought that changes in the number of livestock and grazing pressure was the primary explanation, although some considered it a contributing factor (Table 3). Five

Table 2. Pyrenean pastoralists' perceptions of changes in climate and water flow.
Tabla 2. Percepción de los cambios en el clima y caudal de agua por parte de los ganaderos.

Theme	*Illustrative Quotations*
Increased Temperature	"Maybe it is warmer than before, …, for years we had 15-20 days of snow and cold, and later comes the heat, a heat like we have never seen.Anyway, there are very major changes". "Before it snowed more and it froze.You could cross the river on ice, but now you can never cross it".
Changes in Rainfall	"For example, before during the rainy season it would rain 7-8 days, rain, rain, rain, now one day, two days, and it passes". "Oh! Well climate change, well it rains little.Because before, it rained a lot".
Decreased Snow	"And now it snows, but I remember for example seeing snowfalls in Ansó of more than 1 meter of snow and up high there was a meter and I don't know how much, and I think if it hits the cows up there we'll never get them out and nevertheless, we have them there now.In other words, I don't say is doesn't snow, and maybe occasionally a deep snow, but I remember snows in January where the snow was on the ground for a month and now that doesn't happen much, the snow doesn't last long… there have even been years when it hardly snowed at all". "Snowfalls of a meter when I was small, I remember one.My grandparents, I remember them going to the cemetery.When they had had to take the dead to the cemetery, they had to go with a team of horses to make a path or they couldn't get there.And my father in law from Ansó had to keep a dead body in his house for four days because they couldn't get through (the snow).And now, apart from the fact that there are means to clean the snow, the snow doesn't fall.It doesn't fall like it used to fall. It has changed.We are in agreementthatclimatechangeexists".
Loss of Permanent Snowfields	"There have been snowfields that last a long time but in the past there were permanent snowfields where there was snow year around, but now you see those less and less".

Theme	*Illustrative Quotations*
Change in Seasonality; Crazy Weather	"In the month of June, on the day they went up to [place name], there were years where it rained a lot, real downpours, but the temperature was mild, and now it is sometimes very cold and even snows.A bit, not a lot, but it even snows in the month of June". "And before, for example, September arrived and it started to snow, but now it doesn't.Every year it is later. The weather is changing.Of course it's changing.In these dates (late October) here (in the summer pastures) no one was left, they were all in the low mountains.Of course.Now, because the weather is better people stay later". "For example also, the time when spring comes.Now it could snow in May.The weather is really crazy.Last winter for example on the 10th of October there was a big snowfall here.It doesn't respect the cycles.It might not snow until December and then boom, in two days a big snowfall.Of course you notice it".
Changes in Springs and Stream flow	"And there were springs, everywhere, there were springs.And now they are all dry, they have all dried up". "Every year we lose a few (springs).The climate is to blame, not the livestock". "Before the spring came with more storms, now it is more dry, windy, but more dry, infinitely more dry.I remember one year recording a year of 1,600 liters and in three or four years it was 600 and a bit". "One thing is for certain and that is the springs, because the springs are drying.There are many springs that have dried and there is less water.For example there are springs that have run out that have never run out before, whether due to the weather, or because they have been neglected, that is noticeable, too.Because before the people took care of them, they went to the small springs and fixed them and cleaned them and took care of them well".

(Pirineos, 2012, Vol. 167, 143-163, ISSN 0373-2568, eISSN: 1988-4281, doi: 10.3989/Pirineos.2012.167007)

Table 3. Perceptions of shrub expansion, its consequences and causes among Pyrenean pastoralists.
Tabla 3. Percepción de la expansión del matorral, sus consecuencias y causas entre los ganaderos del Pirineo.

Theme	*Illustrative Quotations*
Shrub Encroachment	"The main change is the shrubs.That is the main change.And they are climbing and taking over.The shrubs are consuming the intermediate mountain pastures.The shrubs. Juniper, *aliaga*, and pines, all increasing, more and more".
Negative View of Shrub Expansion	"The landscape now is not as open as before.Before, the landscape was very pretty…there were fewer shrubs on the mountains, there was more pasture.Now nature is becoming very aggressive and there aren't the open spaces that existed before.Now everything is much more closed.But this is because there are fewer animals grazing in the mountains and with fewer animals the mountains are becoming worse.Before there was much more feed [for livestock] than there is now".
Impact on Livestock Management	"In the lower mountains the shrubs have increased a lot and as a result now there is nowhere to graze our sheep, because everything is very closed, they can't cross it.This is the lower mountains, which are worthless now".
Impact on Fire Risk	"Well here we have the problem that the pastures are getting worse and the problem that we are all afraid of is that any day there could be a fire, intentional or unintentional, or a lightning strike.The problem is very serious".
Explanation-LivestockNumber	"What is happening now in the lower mountains, is so much of the livestock have disappeared-because before there was a lot of livestock here, and now there are few.In the past the lower mountains were grazed a lot and there were fewer shrubs because the livestock ate them.Now [the shrubs] have grown so much that [the animals] can't enter.The lower mountains are lost".
Explanation-: NOT Livestock	"Now in the lower mountains, the cattle, especially, are pounding them.The cows are there a long time and nevertheless, the shrubs grow just the same.The livestock numbers have nothing to do with why the shrubs are growing.It grows just the same… And in the high mountains it's the same.They are grazed the same as before, with more cows because there are more cows than before, and still the pines and junipers are increasing… it is incredible".

Theme	*Illustrative Quotations*
Explanation-Type of Livestock	"In the pastures where there are only cattle and mares and the sheep and goats don't graze, yes, there is a greater proliferation of pines and junipers above all".
Explanation-Climate Change	"I think this is part of the change in climate, it's my perception.To me, just as the desert comes walking from the south, the forests are gaining altitude, to escape.This is my perception. …To me the climate has always been the brake at the higher altitudes, with their freezes, bad weather, they said-'up here you can't live because of the altitude, the cold, the wind.'Now the temperatures are changing and this change brings with it…"
Explanation-NOT Climate Change	"Climate change? I don't think so.We are talking about a very short period of time.So, I think climate change cannot have had an effect".
Explanation-Lack of Fire	"Every afternoon in this season, in the month of October when we came down from the high mountains to the lower mountain pastures, every afternoon we would burn a juniper bush or two or twenty, and it was noticeable, because now that 20 years have passed that they have forbidden us from burning, well [the shrubs] have grown and invaded and now it is closed with junipers".
Explanation-Lack of People in the Mountains	"There were as many people in the barns as there were in the village. On every rise there was a barn, and there were many people on the roads, they made firewood or did other things in the mountain. Now no one goes, except a few walkers. Now there are places where you can't go for anything [due to the thick growth]".
Explanation-Wild Boar	"I don't know. There is a problem with the wild boars, that dig up the ground, and so [the shrubs] grow more easily.They bury the seeds and the shrubs grow more".
Explanation-Policies Promoting Hunting	"What is happening? We have created the problem by not having livestock, agreed. But also the local governments have created it, too, by promoting hunting with economic offers.They have allowed livestock to be excluded from the mountains, because it was a hunting reserve for wild boar. And I don't think this is right.There have always been dates that livestock were allowed to graze and it is a benefit for everything because there is no better firefighter than the sheep, the goats, the mares, the cattle".
Explanation-Pine Plantations	"Here below there is a big issue, there were reforested zones and years that these mountains were fenced [and livestock excluded], and of course, these pines have grown and in their shade the shrubs have come up and today there are many places that have become impassable. …. And every year there is more boxwood and less pasture".

Hecho respondents explained clearly why livestock could not be responsible for the observed changes. These explanations centered on the fact that significant shrub encroachment has occurred even in areas where grazing pressure has remained high in recent years. 60% of herders in both valleys felt the lack of people in the mountains was a major cause, and 37% mentioned the lack of burning.

Some herders (7, 26%), primarily from Hecho, felt that climate change or climate cycles were a causal factor, although several (4, 15%) did not think climate could be responsible.Two stockmen from Hecho, mentioned government-supported pine plantations as a cause of increased forest cover.A single respondent in each valley provided a wildlife-related explanation.In Ansó one informant blamed local government policies favoring hunting (for which an increase in shrub and forest habitat would potentially be beneficial), and one Hecho interviewee hypothesized that the increase in wild boar populations might have contributed to distributing shrub seeds or creating, through their rooting activities, favorable conditions for shrub germination.

3.4. Implications of Ecological Changes for Management and Livelihoods

Many stockmen expressed concern about shrub and forest expansion because of its implications for livestock management (Table 3). The primary impacts on livestock management are the reduction in forage quantity and a shift in forage quality towards lower quality plants with high levels of secondary compounds and woody fiber. A second impact is the difficulty that dense shrubs create in moving livestock through the landscape. Dense thickets of spiny shrubs create a physical barrier that limits animals' access to other productive pastures. Some of the remaining transhumant herders in the area complained about how shrubs had overgrown some of the traditional stock driveways along their transhumance route, making the long and difficult trek even more challenging. In addition to declining forage production and impeded access to pastures, stockmen also worried about increased fire danger due to encroaching shrublands and forests (Table 3). Finally, many interviewees expressed aesthetic or cultural preference for a more open and inhabited rural landscape in contrast to the "closed" and hostile forest (Table 3).

3.5. Reversibility and Options for Management

As the interviews revealed the widespread perception of and concern over shrub expansion, we asked subsequent participants whether they perceived

 (Pirineos, 2012, Vol. 167, 143-163, ISSN 0373-2568, eISSN: 1988-4281, doi: 10.3989/Pirineos.2012.167007)

these changes in vegetation cover to be reversible or not, and what measures, if any, could be taken to reverse the changes. Of the fourteen participants who discussed the reversibility of changes in the interviews, 8 responded that they were practically irreversible, 4 felt that they could be reversed and two were uncertain.Most agreed that efforts to halt future expansion or remove shrubs or forest would take extensive financial and labor resources and could not be achieved with passive restoration methods such as increasing livestock numbers or changing herd composition.

Participants proposed a variety of different measures to reduce shrub cover and restore a more open, herbaceous aspect to the mountain landscape. Most respondents believed that restoration would require active management by mechanically removing shrubs and trees, or using mechanical methods in combination with prescribed fire and/or grazing.Few felt that a reversal could be accomplished with grazing alone, although several thought that this was possible, if animals were confined with portable fences and forced to consume the vegetation within.However, most herders were not eager to carry out this type of management with their own animals, as it would compromise their productivity and well-being.

4. Discussion

Herders' observations about declining snowpack and corresponding declines in streamflow are supported by recent research in the area (López-Moreno and García-Ruiz, 2004). López-Moreno *et al.* (2004) documented significant declines in spring streamflow in the River Veral, which flows through the Valley of Ansó. Similarly, observations of warming temperatures and declining rainfall frequency also correspond to recent analyses of long-term (1956-2006) precipitation (López-Moreno et al., 2010) and temperature (El Kenawy *et al.*, 2011) records for the region. Based on their analysis of daily precipitation data from 217 observation sites in northeast Spain, López-Moreno *et al*. (2010) concluded that precipitation trends varied greatly in both direction and magnitude over short distances, citing the need for a dense network of observation stations. Although a dense network would be highly desirable, this study suggests that local knowledge might contribute to "filling in" these spatial gaps, or at least helping to identify candidate monitoring sites that may not conform with regional-scale trends. El Kenawy *et al.* (2011) found more significant trends in hot temperature extremes than cold temperature extremes, and few significant trends in growing season length. We were unable to locate records related to the timing and intensity of snowfalls to determine whether there was support for some herders' observations about

late spring deep snowfalls or freezes, which might shorten the summer growing season. In sum, many of herders' observations about changes in climate and hydrology were supported by the scientific record. For some of their observations (or our inferences based on herder observations), notably those related to intensity and timing of deep snowfalls, timing of green-up and growing season length, we found no evidence to support or contradict herders' observations. Thus there may be climate trends that affect livestock husbandry that have not yet been studied by scientists in this region, demonstrating that local knowledge may complement science and suggest management-relevant avenues for further research.

All the participants in this study reported an increase in the cover of shrub and forest vegetation types and a decrease in the cover of herbaceous vegetation.These observations are supported by research carried out in neighboring valleys (Lasanta-Martínez *et al.*, 2005) and correspond with the broader trend in land cover change in abandoned farmlands across Europe (García-Ruiz and Lana-Renault, 2011, Keenleyside and Tucker, 2010). Our most striking finding was the distinctly different explanations for these changes provided by herders from the two adjacent valleys. Herders in Ansó, where livestock populations have declined, assumed that the changes were due to insufficient grazing pressure, coupled with a general lack of human activity in the mountains.In contrast, about half of the pastoralists in Hecho, where livestock populations have remained constant, argued that diminished grazing pressure could not explain the changes, and attributed them to climate change as well as the decline in active management and use of shrubs and forests. This difference in perceptions of the causes of environmental change was unexpected, as the dominant ecological narrative in the region is that declining livestock grazing is the major causal agent (Lasanta-Martínez *et al.*, 2005). However, other studies of treeline variation in alpine zones of the Pyrenees, suggest a possible interaction between declining grazing pressure and a changing climate may better explain recruitment of the alpine species *Pinus uncinata* (Camarero and Gutierrez, 2007).

The implications of these distinct narratives of ecological change in two immediately adjacent valleys are several.First, the different explanations highlight the place-specific and context-embedded nature of local knowledge, and caution us against over-generalizing from one locality to another, even when the sites appear very similar.They also suggest relatively isolated social networks in each community, which lead to the perpetuation of particular narratives within each network. Second, the contrasting explanation of Hecho herders demonstrates their capacity to apply ecological reasoning to understand change, and to search for alternative explanations when confronted by evidence that contradicts the dominant narrative.Third, the multi-

ple potential explanations for shrub expansion that emerged from this study suggest the need for more nuanced scientific studies that disaggregate the effects of grazing from those of other human activities in the mountains, and assess grazing impacts and vegetation change at a finer spatial resolution. This study illustrates how traditional knowledge can inform broader scientific understanding of ecological dynamics by providing alternative testable hypotheses. In the next phase of research inspired by this documentation study, we plan to collaborate with local herders to empirically test these multiple hypotheses.

Although herders in Ansó and Hecho differed in their views about livestock as a causal factor, they agreed that the "lack of people in the mountains" and their active management of shrubs through wood-cutting, artisanal burning, and cultivation of the land, was a major driver of this change. We have argued elsewhere (Fernández-Giménez and Fillat, 2012) for the continued relevance of herders' knowledge to managing vegetation in the Valles Occidentales, and the need for greater involvement of local resource users in decision-making within the Parque Natural de los Valles Occidentales. Herders' detailed knowledge of the spatial and temporal patterns of shrub encroachment within their local grazing territory coupled with the implications of these changes for their management, livelihoods and well-being, suggest that stockmen can contribute meaningfully to 1) the design of research and monitoring studies to further elucidate the pattern and causal mechanisms of shrub and forest enchroachment, and 2) the design and implementation of management treatments to limit further shrub expansion assuming this is the socially and environmentally desirable management goal. However, interactions with stockmen at our community meetings suggest that livestock producers have not yet envisioned an alternative future that could increase their presence in and active management of the mountains and that does not require a return to the challenging living and working conditions of the past.

5. Conclusions and Implications

This exploratory qualitative study revealed that Pyrenean pastoralists observe a number of important changes in their environment including climate changes, resulting alterations in stream and springflow, and changes in vegetation cover. Many of these observations correspond with measured trends in meteorological records and studies of changing land cover in the region, but herders' observations provide insights at a finer spatial resolution that complements the scientific record and suggest additional research needs

regarding both climate change (trends in timing and intensity of snowfall and timing of green-up) and the causal factors influencing shrub expansion. We encourage both scientists and managers to collaborate more closely with pastoralists in the region, so that herders' observations can be incorporated more directly into the design of both research and natural resource management planning. Likewise, we suggest that pastoralists engage proactively with researchers and decision-makers to envision their future roles in maintaining the mountains and adapting to change. Existing studies suggest that involving local resource users directly in monitoring and management decisions is one way to ensure that monitoring data are used promptly to make decisions (Danielsen *et al.*, 2010). In an era of dynamic and changing climatic and socioeconomic conditions, this ability to detect and respond to change will likely determine which systems retain their resilience and which cross undesired thresholds into an alternate stable state.

Acknowledgements

We thank the stockmen and residents of the Valleys of Ansó and Hecho for their time and participation; the administrations of the municipalities of Ansó and Hecho, and the Office of Economic Development of the Comarca of Jaca, for their assistance and cooperation; Javier Agguirre for helpful suggestions on our interview protocol, and Isabel Catalán Barrio and Guillermo Bueno for their reviews of an earlier version of this manuscript. This research was supported in part by Fellowships from the Spanish Fulbright Commission and the Center for Collaborative Conservation at Colorado State University.

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