A Qualitative Assessment of Contemporary Glacier Loss in the Cordillera Blanca, Peru, Using Repeat Photography

Una Evaluación Cualitativa de la Pérdida Actual de Glaciares en la Cordillera Blanca, Perú, Usando la Fotografía Repetitiva

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Abstract

Repeat photographs of Cordillera Blanca glaciers, taken by the 1932, 1936, and 1939 climbing and cartographic expeditions of the Deutscher und Österreichischer Alpenverein (DuÖAV or German and Austrian Alpine Association), illustrate the significant retreat of glacial ice and the growth of new glacial lakes that have occurred during the past 80 years. As predictive modeling and remote sensing technologies become more sophisticated with each passing year, it is suggested that repeat photography can nevertheless complement these methods by providing a range of field-based historic, educational, and community involvement tools. It is also suggested that repeating photography will most likely remain a valuable research method in the decades to come as the oblique photographic database increases, and as new generations of physical and social scientists take to the field in pursuit of enhanced understandings of the high mountain world.

Keywords: Repeat photography, glacial retreat, glacial lake formation

Introduction

Repeat photography involves the replication of an older photograph, ideally from the exact location and same circumstances as the original, to gain a deeper understanding of changes in the physical and cultural landscape that have occurred in the interim (Byers, 1999, 2000; Klett, 2011). Most commonly used for landscape change assessments (e.g., Webb, 1996; Bahre, 1991; Grafe and Horsted, 2002; Gurung, 2004; Kull, 2005), repeat photography has been increasingly used to illustrate a number of the more dramatic impacts of contemporary climate change in high mountain environments, e.g., glacial recession and ablation, the formation of new glacial lakes and meltwater ponds, and upward retreat of hanging glacial ice (e.g., Byers, 2008, 2010a, 2010b; Hastenrath, 2008; Jiduc, 2016). The following essay provides nine unique historic and repeat photo pairs of glaciers in the Cordillera Blanca that offer an oblique perspective of glacier change since the early 1930s, and argues that repeat photography can continue to complement the power of more recent technologies, such as remote sensing analyses of change, by providing a range of complementary educational, community consultation, and interpretive tools.

Background

In 1997 and 1998, I completed a series of investigations focused on contemporary landscape change in the Cordillera Blanca of Peru using repeat photography and ground truth sampling. I used the photogrammetric images of Austrian climber/cartographer Erwin Schneider, and hand-held Leica images of Hans Kinzl, taken during the 1932, 1936, and 1939 climbing/cartographic expeditions of the Deutscher und Österreichischer Alpenverein (DuÖAV, or German and Austrian Alpine Associations) to the Cordilleras Blanca and Huayhuash (Figure 1) (Kinzl and Schneider, 1950; Byers, 1999; Hoerlin, 2011; Carey et al., 2016). As climate change had yet to enter the popular vernacular and development agenda, and as a continuation of my landscape change work in the Mt. Everest region of Nepal (Byers, 1987, 2005), these studies had as their focus the documentation of change in the physical and cultural landscape of the Cordillera Blanca, i.e., changes in forest cover, pastures, villages, and urban areas. Yet, a recent re-examination of many of these same photographs, plus the discovery of new DuÖAV photographs of the Cordillera...
Blanca and its glaciers since my work in the 1990s, now allows for a more focused, qualitative examination of changes in glacier cover since the 1930s. These are presented in the following photo essay as an addendum to my previous work, in the interests of making available these older photographs and their more recent replications to future generations of high mountain social and physical scientists.

Reproducing a photograph during the same season, time of day, and weather conditions can also enhance the resultant photo comparisons. Finding the exact location of a photopoint, however, is sometimes not possible in the high mountain environment because of a range of contemporary impacts of climate change, such as the formation of lakes that did not exist 60 years ago (e.g., see Figures 6 and 7), and/or natural hazards such as avalanches and landslides that have occurred in the interim, obscuring or destroying the original photopoint (Byers, forthcoming).

Methods

In 1997, I traveled to the Österreichischer Alpenverein in Innsbruck, Austria, which is one of several archives in Europe containing the glass plate negatives of the Himalayas, Andes, and/or other mountain ranges taken by the Austrian alpinist and cartographer Erwin Schneider (1906-1987) (M. Achrainer, pers. comm. 2016; H. Schneider, pers. comm. 2016). In 1998, I sent the late alpinist and geographer Adam Kolff, an American volunteer with the Instituto de Montaña in Huaraz, Peru, back to Innsbruck to continue the search. Together we collected dozens of Schneider’s 1932, 1936, and 1939 photogrammetric photographs of the Cordillera Blanca used to produce the beautiful Cordillera Blanca Alpenvereinskarte maps (Kostka, 1993), and hand-held Leica photographs of expedition leader and geographer Hans Kinzl. Thus began the task of relocating the mountains, glaciers, villages, fields, and forests shown in the older photographs, producing the replicates, and interpreting and documenting the changes observed (Byers, 1999, 2000).

Ideally, photo replicates are taken from the original photopoint, which can often be located through the creative use of expedition journals, old maps, interviews with local people, one’s own familiarity with the landscape, and the guidance of national experts (Byers, 1987, 1999, 2008). The late Alcides Ames, for example, could look at any of the Schneider or Kinzl photographs that Adam and I showed him and identify their precise location within seconds. Replicating a photograph during the same season, time of day, and weather conditions can also enhance the resultant photo comparisons. Finding the exact location of a photopoint, however, is sometimes not possible in the high mountain environment because of a range of contemporary impacts of climate change, such as the formation of lakes that did not exist 60 years ago (e.g., see Figures 6 and 7), and/or natural hazards such as avalanches and landslides that have occurred in the interim, obscuring or destroying the original photopoint (Byers, forthcoming).

The Photographs

For the present paper, I used the 1932-1939 Schneider and Kinzl photographs and replicates that I made in 1997, 1998, and 2009 to develop an expanded repeat photography essay with a specific focus on the receding glaciers of the Cordillera Blanca. Brief descriptions of the old and newer photographs, and the changes that they illustrate, are contained in the captions of each photo pair below.

Yanapacha (Figuras 2-5)

Figure 1. The 1932 German-Austrian Mountaineering and Cartographic Expedition to the Cordillera Blanca. Standing (left to right): Erwin Hein, Wilhelm Bernard, Bernard Lukas, Hermann Hoerlin and Erwin Schneider; seated (left to right): Philipp Borchers and Hans Kinzl. Photo: Historisches Archiv, Innsbruck.

Figure 2. Yanapacha (5469 m) ice cover in 1939. The photopoint is located just off the trail to the Pisco refugio and basecamp. Photo: E. Schneider.

Figure 3. Yanapacha ice cover in 1998. At the time, I was more interested in landscape change than in glaciers, particularly in the Polylepis forest in the lower left of the photograph. I concluded that the forest had survived through the years only because it was located on top of a huge, ancient rock avalanche that was inaccessible to cattle, which otherwise would have consumed all of the seedlings. Photo: A. Byers.
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Figure 4. Yanapacha in 1998. The red line traces the 1939 ice cover when photographed by Schneider. The blue line shows the extent of its recession in the 59-year interim period. Such perspectives can add decades to the insights derived from satellite-based remote sensing, which only became available in the early 1970s. Photo: A. Byers.

Figure 5. Yanapacha panorama in 2009. Although snow had accumulated at the ice line due to a recent storm, recession and thinning of the glacier has clearly continued in the 11-year interval. Photo: A. Byers.

Figure 6. Pucaranracocha glacier, Quebrada Honda, in 1932. Note that a small glacial lake had already begun to form at the time. The recession of Peruvian glaciers some 80-100 years before glaciers elsewhere in the world can be linked to their exposed (non-debris covered) surfaces, low gradients that encourage the formation of lakes, lower altitudes, and lower latitudes. Photo: H. Kinzl.

Figure 7. Pucaranracocha glacier in 2009. The red line shows the extent of the 1932 glacier; the blue line, the extent of the 2009 ice. The exact same photopoint was not possible to locate because of the growth of the lake in the interim period. Photo: A. Byers.

Pucaranracocha (Figuras 6-7)
Laguna Shallap (Figuras 8-9)

Figure 8. Laguna Shallap in 1936. The Tumarinaraju (5668 m) glacier extended all the way down to the glacial lake that started forming some years earlier. Note again that a small glacial lake had already begun to form at the base of the remaining glacier by the 1930s. Photo: H. Kinzl.

Cashan (Figuras 10-12)

Figure 10. Cashan (5701 m) in 1936. Note again that a sizeable glacial lake had already formed at the base of the glacier by the 1930s. Photo: H. Kinzl.

Figure 9. Laguna Shallap in 1998. Extensive recession of the Tumarinaraju glacier had occurred between 1936 and 1998. The structures in the foreground are left over housing for staff of the Glaciological Unit which began to lower and control potentially dangerous glacial lakes in the Cordillera Blanca in the 1950s, following three disastrous glacial lake outburst floods in the 1940s. Photo: A. Byers.

Figure 11. Cashan in 2009. The red line approximates the extent of the 1936 ice; the blue line, the extent of the ice in 2009. Photo: A. Byers.
Figure 12. Cashan panorama in 2009. Because of growing water scarcity, the lake provides water to downstream communities through a system of recently built irrigation canals. Photo: A. Byers.

Huantsán (Figuras 13-14)

Figure 13. Huantsán (6050 m) from the Cordillera Negra in 1932. Photo: E. Schneider.

Figure 14. Huantsán from the Cordillera Negra in 1998. The 1932 ice line is shown in red, illustrating that some recession and thinning of the ice has occurred in the interim. Photo: A. Byers.

Ticapampa (Figuras 15-16)

Figure 15. The village of Ticapampa from the Cordillera Negra in 1932. Photo: H. Kinzl.

Figure 16. The town of Ticapampa from the Cordillera Negra in 1998. Note the loss of ice on the mountains in the background, the increase in eucalyptus tree cover, the growth of the town, and the mining tailings in the left foreground. Photo: A. Byers.
**Ranrapalca (Figuras 17-19)**

Figure 17. Ranrapalca (6162 m) on the left and Ishinca (5530 m) on the right, taken from Huapi Pass in 1939. Photo: E. Schneider.

Figure 18. Ranrapalca and Ishinca from Huapi pass in 2009. The red line traces the extent of the 1940s ice cover and illustrates that considerable recession and thinning have occurred in the interim. Photo: A. Byers.

Figure 19. Panorama of Ranrapalca and Ishinca from Huapi pass in 2009. Photo: A. Byers.

**Llanganuco (Figuras 20-21)**

Figure 20. Huandoy South (6160 m) from above Lake Llanganuco in 1932. Photo: H. Kinzl.

Figure 21. Huandoy South from above Lake Llanganuco in 2009. Although the ice on the upper reaches of Huandoy appears to have changed little, the lower reaches are obscured by the mountains in the foreground so that no changes in ice cover can be seen. Photo: A. Byers.
**Yanamarey (Figuras 22-24)**

![Figure 22. Yanamarey (5237 m) from Laguna Querococha in 1936. Photo: H. Kinzl.](image)

**Figure 22. Yanamarey (5237 m) from Laguna Querococha in 1936. Photo: H. Kinzl.**

![Figure 23. Yanamarey from Laguna Querococha in 1998. The red lines show the extent of the ice in 1936, now largely gone. Photo: A. Byers.](image)

**Figure 23. Yanamarey from Laguna Querococha in 1998. The red lines show the extent of the ice in 1936, now largely gone. Photo: A. Byers.**

![Figure 24. Panorama of Yanamarey and Laguna Querococha in 2009. Photo: A. Byers.](image)

**Figure 24. Panorama of Yanamarey and Laguna Querococha in 2009. Photo: A. Byers.**

**Discussion: Contemporary Glacier Loss and Role of Repeat Photography**

As demonstrated by the preceding photo essay, glaciers in the Cordillera Blanca have changed dramatically during the past 100+ years. In fact, they began receding and forming glacial lakes in the late 19th and early 20th centuries (Carey, 2010), some 80-100 years before similar processes began occurring in the Himalayas and elsewhere (Bolch, Pieczonka and Benn, 2011; ICIMOD, 2008). Several contributing factors to the Blanca’s earlier response to warming trends includes its glaciers’ lack of a buffering debris-cover (Benn and Evans, 2010), lower altitudes compared with other high mountain glaciers, low surface gradients that can encourage the formation of glacial lakes (Quincey et al., 2007; C. Portocarrero, pers. comm. 2011), and generally lower latitudes than their Himalayan and other high mountain counterparts. Associated hazards and problems have included a series of catastrophic glacial lake outburst floods (GLOF) since the early 1940s that have killed thousands of people (Carey, 2010), other glacier-related hazards such as the destruction of Yungay in 1970 by an earthquake-triggered glacial ice avalanche and debris flow (Carey, 2008; Evans et al., 2009), uncertainties related to future water supplies for both rural and urban dwellers alike (Instituto de Montaña, 2013), and negative impacts on some forms of adventure tourism (e.g., mountaineering). As noted by Carey (2010), more than 25,000 people were killed in the Cordillera Blanca in glacier-related disasters during the 20th century, the highest of any region in the high mountain world (see also: Evans et al., 2009; Wegner, 2014). The Peruvian Government’s establishment of a Glaciological Unit in the 1950s led to the lowering and/or control of 35 dangerous glacial lakes (Portocarrero, 2013), using techniques developed by its own engineers. Today, however, continued warming trends, the melting of permafrost, accelerated growth of glacial lakes, and destabilization of overhanging ice are signaling a new era of possibly accelerated glacier, glacial lake, and high mountain risks and hazards (W. Haeberli, pers. comm. 2013). The city of Huaraz, for example, which experienced a GLOF from Laguna Palcacocha on 13 December, 1941 that killed an estimated 1,800 people (Wegner, 2014: 41), is once again highly vulnerable to a Palcacocha flood because of the lake’s accelerated re-growth since the 1970s, de-stabilization of overhanging ice, and current lack of an early warning system (Rivas et al., 2015; Somos et al., 2016).

In order to confront the growing number of climate change-related challenges to life and property within the Cordillera Blanca and other high mountain regions of the world, the continued development and refinement of a range of descriptive and predictive tools will be necessary. Remote sensing, for example, has proven to be particularly effective in the quantification and predictive modeling of climate change phenomena upon high mountain environments (e.g., glacial lake attributes, risk of flooding:
see Rounce et al., 2016), and its power and accuracy improve with each passing year. Repeat photography can nevertheless enhance the utility of remote sensing by providing a number of complementary, qualitative, and in some cases unique, attributes.

For example, oblique photography predates remote sensing by at least 90 years, thus offering a more extended window into the past, as well as providing useful high resolution and oblique data and detail (Kull, 2005). Photographs of glaciers throughout the world have been taken since at least the late 1800s, e.g., the photographs by the Italian photographer Victorio Sella of North American, Ugandan, Karakorum, and Himalayan glaciers during the climbing expeditions of the Duke of the Abruzzi in the early 1900s (Aperture Foundation, 2000; Tenderini and Shandrick, 1997).

Repeat and time lapse photography can also be used as effective educational tools as well illustrating, even to the untrained eye, if properly presented, the changes in landscapes (cultural and physical), vegetation, glaciers, glacial lakes, and polar ice that have taken place over the past 100 years or more. Examples include the educational videos and traveling displays of Glacier National Park by the USGS (2017), the Himalayan-Hindu Kush exhibits of GlacierWorks (2017), recent repeat photography exhibits of the Mt. Everest region by the International Centre for Integrated Mountain Development (Byers, 2007; ICIMOD, 2008; Figure 25), videos and exhibits of the Extreme Ice Survey (Balog, 2014), and in films such as the UNDP’s “Revealed: Himalayan Meltdown” (UNDP, 2010).

Repeat photography also encourages a spirit of exploration and discovery, as well as a merging of art, photography and science. Retracing the footsteps of the early climber-scientists who took the older photographs, such as Erwin Schneider and Hans Kinzl in the Cordillera Blanca, or Victoria Sella, Charles Houston, Charles Evans, and Fritz Müller in the Hindu Kush-Himalaya, can range from a pleasant hike through the high mountain landscape, to an interesting rock scramble, to a semi-technical rock or glacier climb that should only be attempted by the experienced mountaineer. Reading changes in the landscape and interpreting the changes that appear to have occurred based upon oral testimony, ground truth sampling, literature reviews and other methods, demand the use of a range of skills from the physical, social and photographic sciences. In an age where “citizen science” is becoming more and more popular (Carey et al., 2016), repeat photography can play important roles in our understanding of change while encouraging the development of field-based, interdisciplinary research approaches within the next generation of high mountain scholars and field practitioners.

Finally, repeat photography encourages a level of communication with local people rarely found in technical field studies, since simply finding photopoints is almost always facilitated by individual or group interviews, the sharing of older photographs, and discussions regarding perceived change. Regular discussions with arrieros (mule drivers), farmers, and trekking/climbing guides were of immense help in locating the photopoints, and in interpreting the changes in the historic photographs used in this essay (Figure 26). On a more rigorous level, Garrard et al. (2012) used repeat photography and participatory research as tools for assessing changes in environmental services in Sagarmatha (Mt. Everest) National Park, Nepal. They argue that the method can complement existing biophysical ecosystem assessments in mountain protected areas because of its ability to integrate “…diverse stakeholder’s knowledge, [recognize] power imbalances, and [grapple] with complex social-ecological systems.”

Figure 25. Display of the author’s Himalayan repeat photography work at the 2008 IUCN Annual Meetings, Barcelona, Spain, which toured an additional five European cities. Smaller exhibits were displayed in the Everest basecamp during the spring of 2008. Both were funded and hosted by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. Photo: A. Byers.

Figure 26. Finding photopoint locations, and interpreting the changes, was enhanced by sharing the historic photographs with arrieros, local farmers, and trekking/climbing guides. Photo: A. Byers.

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Conclusion

Nine sets of photo comparisons of glaciers from the 1930s to 2009 illustrate the profound changes in ice cover and glacial lake formation that have occurred in the Cordillera Blanca during the past 80 years. Because of the continuation of warming trends, continued and perhaps accelerated glacial recession can be expected to occur, accompanied by an increased risk in associated glacier-related hazards. As the accuracy and utility of remote sensing and other laboratory-based technologies continue to grow, repeat oblique photographs can still provide complementary tools because of their ability to extend the historic record further back into the past, proven use as educational tools, encouragement of interaction with local communities, and promotion of a spirit of exploration, discovery, and development of interdisciplinary field skills. Repeat photography will most likely remain a valuable qualitative tool and complement to remote sensing and other forms of laboratory- and field-based research in the decades to come, as the oblique photographic database increases and new generations of physical and social scientists take to the field in pursuit of answers and enhanced understandings of the high mountain world.

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[Note: A more detailed repeat photography bibliography related to the Cordillera Blanca can be found in Byers (1999, 2000).]

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