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Water-use Practices in an Arid Mediterranean Habitat – Islands of Hvar and Sv. Klement, Croatia

First, I am interested in investigating whether fluctuations in water availability and security (e.g., war-driven freshwater supply interruptions) impact: a) **Water-use practices** and water saving behaviors and b) **Water harvesting practices** – use of rainwater harvesting systems (cisterns) in particular. Second, I am interested in investigating whether reliance on centralized vs. local water supply impacts **community's resilience to water scarcity**. Third, I will conduct analyses of water samples collected from water cisterns to determine whether promoting sustainability via cistern use may be in conflict with public health interests.

My research focuses on inhabitants of two Croatian islands located in an arid Mediterranean environment. These are excellent model systems as they cycled between extreme water scarcity and plentiful water supply over the last 25 years. Climate-driven water security issues were exacerbated in the mid-1990's by the war-driven interruption of the freshwater supply.

I address above questions by conducting personal interviews of both permanent/seasonal residents of Hvar and St. Clement islands. These interviews focus on the personal water supply and usage habits. The interviews will be conducted with the aid of a Croatian translator and a pre-formulated questionnaire (following Gilg and Barr, 2006 model), which will help to ensure relevant qualitative/quantitative data.

I use an ecological anthropology framework with a historical perspective to approach this research. At its most basic level this research focuses on understanding the relationship human inhabitants of these Croatian islands have formed with a natural resource (i.e. fresh water), and how this relationship has developed since ancient times and continues to evolve even now. An ecological anthropological approach helps me to understand how the inhabitants of Hvar and St. Clement adapted to the limited availability of fresh water in the past and how new technology (i.e. the Brač pipeline), which has drastically increased fresh water access, has altered their historical water usage habits. This approach also allows me to determine whether there are any negative consequences to these changes in behavior. A historical perspective is necessary for this research because it allows me to better understand how and why the cistern system of freshwater collection and storage was developed in ancient times, and why it has been utilized up through modern times. This historical perspective also helps me determine how much water-use practices have actually changed on Hvar and St. Clement with the advent of the Brač pipeline.

Water scarcity and water supply security are some of the most pressing global health issues. The World Bank reports that 1.6 billion people live in areas with absolute water scarcity; this number is expected to rise to 2.8 billion by 2025 (Alavian, 2009). Croatia is one of the countries specifically identified as area of concern. My project would contribute to better understanding of domestic water-use practices, and their resilience to disruption due to the climatic and social unrest. Researchers (e.g., Princen, 1999; Gilg and Barr, 2006) as well as variety of organizations involved in water policy and management (UN, WHO, World Bank), have issued a call for research of water-use practices.

Unsustainable water-use practices can develop in two ways: through changes in availability and by changes in demand for the benefits provided by it, both of which are occurring on the islands of Hvar and St. Clement with the construction of the Brač pipeline, expansion of the tourism industry, and climate-induced freshwater scarcity (Gleick,1998). The Croatian islands of Hvar and St. Clement maintain an arid climate. These areas receive an average annual rainfall of 816 mm and a summer temperature ranging between 25°C and 35°C. They possess few freshwater sources. The island of Hvar is one of the most arid and inhabited islands in Dalmatia. It is quite small at 114 square miles and has a relatively low number of permanent residents (~11,500 residents). St. Clement (Sv. Klement) Island is even smaller at only 2.0 square miles and far less populated, with only one person living there throughout the year in the village of Vlaka and varying amounts of seasonal workers and visitors in the warmer months. In the past people living on both Hvar Island and St. Clement collected

rainwater via cisterns usually located outside of their own homes or natural springs that may have been near, a practice continued from ancient times. The Brač pipeline was constructed in 1986 and renovated in 2013, doubling its flow capacity. It transports freshwater from the mainland river Cetina to the southern regions of Croatia and the islands of Brač, Šolta, and Hvar. Water practices have changed considerably, with the biggest change being that water is not treated as a limited resource. This new attitude, combined with increased tourism (~170,000 tourists visit Hvar island during summer months; the average stay is 5 days per individual) may have resulted in unsustainable water usage.

Targeting domestic water use is a direct way to increase the sustainability of an area's water use practices. Forming an initiative to use roof water harvesting systems (i.e. cisterns) as an alternative water source may be a feasible sustainable change for the islands of Hvar and St. Clement, as many residences have cisterns already and others could be easily retrofitted with them. It is also worth noting that roof harvested rainwater is considered one of the most cost effective alternative water sources (Ahmed et al., 2008). It is possible that increased availability due to the Brač pipeline may have reduced these islands' resilience to water scarcity. Promoting the use of cisterns as a primary water source may lead to increased resilience to climate-change driven water scarcity and more sustainable water-use practices. However, there are some public health concerns to consider with increasing cistern utilization, as roof harvested water can serve as sources of bacteria and other infectious agents (Ahmed et al., 2008).

Proposed methods: Demographic and attitudinal survey will be distributed via mail to 100 households. In addition to this, brief 10 minute in person, oral interviews (following below questionnaire and taking notes regarding additional info provided by interviewees) will be conducted with 20 individuals. These individuals will be identified with assistance of Drs. Schrunk and Martinovic who have familial/personal and/or professional connections with inhabitants. The main purpose of the survey is to solicit respondent ratings for the water conservation awareness and practice. A five-point Likert-type measurement scale will be used for the respondents' rating of attitudinal items, with 1 representing strongly disagree and 5 representing strongly agree. Postal mail will be the method for questionnaire distribution. Only one questionnaire survey per household will be solicited. The differences in behaviors during different periods will be evaluated using Kruskal-Wallis ANOVA ($p<0.05$).

Please answer all questions using numbers 1-5; 1 = strongly disagree, 5 = strongly agree				
	2013-2014	2013-2014	Before 1984	1991-1995
	Tourist Season	Off season	Before Brac pipeline	During the War
I am aware of opportunities to save water in household				
I am aware of the water saving benefits of retrofitting to water efficient fixtures and appliances				
I am competent when it comes to reading water meter				
I monitor water use regularly by either looking at the cistern levels, water meter or by looking at my bill carefully				
I am aware that my behaviors impact water consumption and availability				
I have a water saving knowhow				
My household is efficient when it comes to our water use practices				
I seek savings in water consumption over longer term				
I use water cistern as a potable water supply				
I use water cistern for non-potable uses				
I use seawater to prepare food				
I use seawater to bathe				
I turn off tap when washing dishes				
I turn off tap when soaping up				
I shower every day				
I flush toilet every time I use it				
I use shower rather than bath				
I water fruits and vegetables weekly				
I water flowers weekly				

Table 1. Water conservation awareness and practice questionnaire (modified from Gilg and Barr, 2006 and Willis et al., 2011)

A small, pilot study will also be conducted to investigate occurrence of coliforms (bacteria whose presence is used to indicate that other pathogenic organisms of fecal origin may be present) and legionella (pathogenic group of bacteria, that includes the species L. pneumophila, causing a pneumonia type illness called Legionnaires Disease) in roof harvested rainwater systems. These bacteria were selected because they have been identified as bacteria of concern in rainwater collection systems (Gardner and Toze, 2011). Twenty cisterns will be tested for occurrence and the state of use/maintenance will be recorded for these systems. The standardized kits will be utilized to test for the bacteria.

I believe my research will bring attention to the worldwide problem of water security and how sustainable changes in water-use practices are absolutely necessary to ensure a viable and prosperous future. This project will be my first chance to develop, troubleshoot, execute, and present my own research on issues that I am passionate about. This experience will be invaluable for me, as I am planning on applying for biology/anthropology graduate programs next year. This research will also give me the opportunity to experience a new country and culture, which will provide me with lifelong memories and aid me in developing an informed, global mindset.

References

Willis, Rachelle M., Rodney A. Stewart, Kriengsak Panuwatwanich, Philip R. Williams, and Anna L. Hollingsworth. "Quantifying the influence of environmental and water conservation attitudes on household end use water consumption." *Journal of environmental management* 92, no. 8 (2011): 1996-2009.

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