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RESEARCH ARTICLE

Water insecurity, water borrowing and psychosocial stress among Daasanach pastoralists in northern Kenya

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ABSTRACT

This article quantifies Daasanach water insecurity experiences in northern Kenya, examines how water insecurity is associated with water borrowing and psychosocial stress, and evaluates if water borrowing mitigates the stress from water insecurity. Of 133 households interviewed in seven communities, 94.0% were water insecure and 74.4% borrowed water three or more times in the prior month. Regression analyses demonstrate water-borrowing frequency moderates the relationship between water insecurity and psychosocial stress. Only those who rarely or never borrowed water reported greater stress with higher water insecurity. The coping mechanism of water borrowing may help blunt water insecurity-related stress.

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Introduction

Between 1990 and 2015, the United Nations estimates that 2.6 billion people gained access to improved drinking water sources globally (United Nations Water, n.d.). Despite this, 4 billion people still lack sufficient safe water for at least one month per year (Mekonnen & Hoekstra, 2016), and 2.2 billion people obtain their water from an unsafe source (United Nations Children's Fund (UNICEF) & World Health Organization (WHO), 2019). With global water need expected to increase at a rate of approximately

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1% annually over the next 30 years (United Nations Water, 2019), a growing number of people may have to rely on non-institutional or informal systems to meet their water needs (Rosinger et al., 2020).

Shortages of clean safe water are the result of both natural water distributions, such as climate shifts and geography, and social influences, including political structures, cultural norms and technical interventions (Zwarteveen et al., 2017). Climate shifts and extreme weather events have led to some areas becoming hotter and drier, while others are experiencing catastrophic flooding (Konapala et al., 2020; United Nations Water, n.d.). This is compounded by changing political structures, which influence the ways in which water is distributed, favouring some and further marginalizing others, particularly in rural regions (Wutich et al., 2017). Cultural norms around gender and water governance (Brewis et al., 2019a), as well as implementation of exploitive technologies such as deep wells or dams, have also shaped water distributions and availability.

Insufficient access to clean water negatively affects health and human biology (Rosinger & Young, 2020), from proximate acute health conditions, such as dehydration and diarrhoea (Rosinger, 2018), to chronic conditions, including hypertension (Brewis et al., 2019a; Rosinger et al., 2021), and psychosocial and emotional distress (Boateng et al., 2020; Collins et al., 2019; Stevenson et al., 2012; Wutich, 2009). Both acute and chronic health outcomes linked with water insecurity have historically affected those in the global south disproportionately (Wutich et al., 2017). Thus, understanding how populations cope with water insecurity is critical for untangling the relationship between water insecurity and psychosocial stress.

Water insecurity and coping strategies

Water insecurity, or the inability to access or gain adequate, reliable, and safe water for wellbeing and a healthy life (Jepson et al., 2017), varies by context. Operationalizing this concept relies on the societal discourse and cultural norms surrounding water and water procuring practices in each context (Pahl-Wostl et al., 2016). In many areas, water insecurity experiences are poorly documented or understood (Wutich et al., 2017). These experiences may relate to individual and collective decisions about the acquisition, distribution and prioritization of water for different water needs and users (Collins et al., 2019).

Water insecurity coping strategies, or actions taken by a household in response to unreliable water supplies (Majuru et al., 2016), are strategies used to reduce water problems and improve access (Venkataramanan et al., 2020). In a recent meta-ethnographic synthesis of the relevant qualitative literature, Achore et al. (2020) identified nine common coping strategies for water insecurity. The type of coping strategies employed varied by income.

Wealthier households often choose 'hard' coping strategies, which are more costly or technical solutions, such as water storage, construction of alternative water sources, buying water from private vendors, illegal connections to public water networks, rainwater harvesting and water treatment to improve the quality. Poorer households often choose 'soft' or behavioural interventions, which are less expensive but more time-consuming. These coping strategies include water borrowing from social networks,

water management and reuse, and fetching water from distant sources (Achore et al., 2020).

While necessary for meeting their immediate water needs, many of these coping strategies have trade-offs that affect income-generating or leisure potential as well as having implications for water-insecurity-related stress. The cumulative experience of water insecurity has been linked to emotional distress and poor mental health outcomes (Wutich et al., 2020; Wutich & Ragsdale, 2008). Due to their potential psychosocial toll, many water-coping strategies are not sustainable as permanent solutions for water insecurity (Achore et al., 2020; Venkataramanan et al., 2020). For example, many household-level water managers experience psychosocial stress as a by-product of the negotiations in which they must engage to ensure sufficient water supplies in the household (Wutich & Ragsdale, 2008). This link between psychological distress and water insecurity has been documented around the world, including in Cochabamba, Bolivia (Wutich & Ragsdale, 2008), Lake Urmia, Iran (Zenko & Menga, 2019), Nepal (Brewis et al., 2019a), and Nyanza, Kenya (Collins et al., 2019). Thus, the coping strategies used, such as water borrowing, may contribute to how individuals experience water insecurity, including the level of psychological burden (Brewis et al., 2019a; Stevenson et al., 2016; Stoler et al., 2019).

Water sharing and water-related stress

Water sharing is an often 'invisible' coping strategy used to meet water needs (Rosinger et al., 2020; Wutich et al., 2018). Water-borrowing networks emerged from the traditional adaptation of pooling resources among vulnerable, often marginalized communities to meet collective water needs (Wutich et al., 2018). As a result, these communities often self-organize their water governance systems, which ensure a more equitable distribution of their limited water resources (Brewis et al., 2019b).

Even the small amounts of water that are transferred through household-to-household water sharing can have health implications. Sharing water between households has been linked to decreased dependence on inadequate water quality and reduced psychosocial stress (Wutich et al., 2018). It has also been linked with increased burden and distress during times of need through the creation of differentiated networks that include some and exclude others (Brewis et al., 2021; Stoler et al., 2019; Wutich et al., 2018). It is often through these networks that social groups use natural resources, such as water, to reinforce political, economic and social barriers between those with authority and those without (Rademacher, 2015). Historical systems, cultural norms, ethnicity and socio-economic status are just a few of the factors that (re)produce and reinforce power relations and subsequently determine who has and who does not have access to water (Cole, 2017).

Previous research has demonstrated that water borrowing acts as a ubiquitous coping strategy for water insecurity in communities with water problems globally (Rosinger et al., 2020). Pearson et al. (2015) found that among pastoralists in southern Uganda water sharing and reciprocity were crucial for meeting water needs. However, it remains unclear if engaging in water borrowing helps alleviate psychosocial stress from water insecurity. Few studies have examined this problem in pastoralist communities that often

have conflicts with neighbouring groups over water resources (Balfour et al., 2020; Pearson et al., 2015; Straight et al., 2016).

Pastoralists and water insecurity

Eastern African pastoralists have lived in semi-arid environments for millennia (Hildebrand et al., 2018). Among pastoralist communities, climate resilience has historically been linked to their mobility and broad social networks (Pearson et al., 2015; Robinson & Berkes, 2010). These adaptations allowed them to mitigate the impact of water scarcity by moving herds, limiting herd size or selling livestock for goods needed to survive during periods of limited water availability (Wright, 2019). Yet, with changing environmental and social conditions, many pastoralists may no longer be able to rely on previous strategies, such as moving their homes and livestock, to cope with water shortages (Wright, 2019). Instead, some pastoralist groups have had to resort to alternative solutions, such as buying, sharing or changing to distant but more reliable water sources in order to cope with water shortages (Pearson et al., 2015; Wutich et al., 2018). However, we do not know how these strategies may increase or reduce their psychosocial stress associated with water insecurity.

Therefore, this paper aims to fill these gaps by examining the water insecurity experiences, water-sharing practices and psychosocial stress of Daasanach pastoralists in northern Kenya. We focus on Daasanach communities because they are an underserved population that has a long history of living in a water-scarce environment with limited resources (Kiura, 2008). We examine a critical 'soft' coping strategy, water borrowing, to see if and how it is used to mitigate water insecurity-related stress.

We first describe the water insecurity experiences of Daasanach and how environmental and household characteristics are associated with their water insecurity scores. Second, we examine how water insecurity is associated with frequency of water borrowing. Finally, we examine perceived stress and explore if water borrowing is an effective coping mechanism to decrease water insecurity. We test whether frequency of water borrowing moderates the relationship between water insecurity on psychosocial stress. We hypothesized that greater degrees of household water insecurity will be associated with higher psychosocial stress (Boateng et al., 2020; Brewis et al., 2019a; Wutich & Ragsdale, 2008; Zenko & Menga, 2019), but that higher frequency of water borrowing levels will buffer this relationship (Stoler et al., 2019).

Materials and methods

Study population

Daasanach are semi-nomadic pastoralists who have begun to adapt a semi-sedentary lifestyle. Their primary livelihood is herding livestock including goats, cattle and camels (Sagawa, 2010). Daasanach communities inhabit the north-eastern shores of Lake Turkana in present-day northern Kenya and southern Ethiopia. The Lake Turkana basin is home to several distinct pastoralist groups that share common grazing territories and water sources for livestock. These pastoralist groups have a long history of mitigating

climate changes and water shortages through migrating with livestock to find alternative water sources and pasture as needed (Hildebrand et al., 2018; Kefale & Gebresenbet, 2012). Based on archaeological records, pastoralists in the Turkana basin have been highly resilient to changing environmental conditions; however, that resilience has been undermined in the last century by changing social and climatic conditions (Wright, 2019).

Further, migration has become increasingly difficult due to external political, social, economic and environmental influences (Sagawa, 2010). For example, the construction of the Gibe III hydropower dam in Ethiopia and the demarcation of the Sibiloi National Park in Kenya have created challenges for Daasanach. The Gibe III dam was constructed on the Omo River, which is the primary water source for Lake Turkana. This construction initially lowered the water table, contributing to reduced vegetation for livestock in the Lower Omo Valley (Mwamidi et al., 2018) and increased the salinity of Lake Turkana. Non-governmental organizations have been attempting to increase water access for Daasanach with construction of boreholes and wells in and around their main settlement as well as in the fora (Rosinger et al., 2021). The demarcation of their land for conservation has also curtailed mobility patterns, hence limiting access to water resources (Greiner, 2012). As a result, Daasanach and other tribes have been experiencing water shortages and increased conflict over limited resources (Hodbod et al., 2019). Recent work has demonstrated that Daasanach experience high levels of food and water insecurity (Bethancourt et al., 2021, 2022), which indicates that they may be experiencing high levels of perceived stress as well.

Design and sample

Interview and survey data were collected in June–July 2019 with follow-up community discussions and observations in October 2020 and May 2021. The months June–August are after the long rainy season, making it an ideal time to observe and collect data on water insecurity. The weather during the follow-up observations in October 2020 were drier than the June–July 2019 period as the short rains had not yet occurred, while the May 2021 follow-up period was wetter than the initial data collection period as it was during the long rainy period, though it was not as rainy as a normal rainy season. Thus, the follow-up discussions and observations likely did not differ substantially from the initial data collection period. For this study, six permanent Daasanach communities and one temporary camp were selected as sites out of roughly 26 communities from which to recruit participants. These seven communities are located at varying distances from the town of Illeret, located on the shore of Lake Turkana and is the largest settlement in the area.

With the assistance of community partners, including local elders and community health volunteers, we randomly selected every third household in each community, and extended an invitation to participate in this study. If the first household sampled was not home or declined to participate, the next household was invited. Between 12 and 28 households were sampled in each community, depending on community size and amount of time spent in each location. Once households agreed to participate, they came to a central location in each community where the study team was conducting the study and enrolled them. After households provided consent, both household

heads and up to two children if present participated in a 40-min survey and interview related to water insecurity, demographics and other stressors in their environment. Directly following the survey, they had their heights and weights measured. Using the information from the surveys related to the water sources used within each community, the study team then visited the water sources to collect Global Positioning System (GPS) points to estimate time and distance as well as take water samples for water quality analysis. Full study design details are described elsewhere (Bethancourt et al., 2021).

The research was approved by the Institutional Review Board of Pennsylvania State University (STUDY00009589) and the Kenya Medical Research Institute (KEMRI/RES/7/3/1). Permission was also obtained from the Director of Health in the county government of Marsabit, Kenya, and from community leaders. All participants provided written and verbal informed consent.

Household water insecurity

Household water insecurity was measured using the 12-question Household Water Insecurity Experiences (HWISE) scale, which has been cross-culturally validated in low- and middle-income countries, including Kenya (Young et al., 2019). We worked with Daasanach research assistants to translate the survey into Daasanach. The HWISE items describe the frequency of different water-related experiences (e.g., inability to bathe, going to bed thirsty) that occurred over the past four weeks. Each item was scored from 0 to 3 for responses of never (0 times), rarely (1–2 times), sometimes (3–10 times) and often/always (11+ times), respectively, with the score range between 0 and 36. We categorized scores of 0–11 as water secure, 12–23 as moderately water insecure and 24–36 as severely water insecure. The HWISE scale was reliable in this context (Cronbach's alpha = 0.88).

Psychosocial stress

Psychosocial stress in the prior four weeks was estimated among all household heads using the four-item version of the validated Cohen Perceived Stress Scale (PSS-4). The PSS-4 has been used in multiple settings in conjunction with the HWISE scale, including Kenya (Young et al., 2019) and other water-insecurity studies (Tallman, 2019). The PSS-4 asks individuals to recall the frequency in which they found their life over the past four weeks to be unpredictable, unmanageable, uncontrollable, uncertain and/or overloaded (Cohen et al., 1983). Scores for each item ranged from 0 to 4 for responses of never, almost never (1–2 times), sometimes (3–10 times), fairly often (11–20 times) and very often (> 20 times), respectively. Two positively phrased questions were reverse-coded, and scores for the items were summed for a total PSS-4 score range of 0–16 (Cohen et al., 1983).

We also estimated stress for the prior 24 h using the validated Daily Inventory of Stressful Events following Almeida et al. (2002). The items asked about seven different stressful events (e.g., having an argument with anyone) since 'this time yesterday'. Scores for each question were affirmations (0 or 1); summed Daily Inventory of Stressful Events scores ranged from 0 to 7. Both stress scales PSS-4 and Daily Inventory of Stressful Events were asked at the individual level.

Water borrowing and water lending

Households were asked during surveys how frequently they borrowed water from people outside their household in the prior four weeks, following Rosinger et al. (2020). Water lending was assessed in the same manner. Responses for both questions were coded using the same options as the HWISE items, never (0 times), rarely (1–2 times), sometimes (3–10 times) and often/always (11+ times). For analytical purposes (i.e., cell sizes), we grouped the responses for never and rarely into one category.

When participants answered affirmatively to either borrowing or lending water, we further enquired whether the person to whom they lent water or from whom they borrowed water was family living nearby/neighbours, family not living nearby, neighbours (not family), friends (not neighbours) or another person.

Covariates

We adjusted for a number of covariates in our analyses due to their association with either water insecurity, water borrowing or perceived stress.

Gender was included because studies have shown that males and females have differing experiences with water insecurity (Brewis et al., 2019a; Wutich, 2009). Among Sub-Saharan African countries, adult women are the primary water collectors (Graham et al., 2016), as is the case among Daasanach. Hence, women may be more likely than men to experience stress resulting from water insecurity (Brewis et al., 2019a).

Studies also show that households experience and cope with water insecurity differently based on their wealth and socio-economic status (Achore et al., 2020; Venkataramanan et al., 2020). To account for these differences three measures of socio-economic status were used: livestock wealth, household income and perceived standing in the community. To serve as an indicator of household wealth, we asked households about the number of each type of animal they owned and multiplied that number by their approximate value and summed the total as outlined in Rosinger et al. (2021). We further asked about and summed all income earned from any household members from any sources in the prior month. Finally, perceived socio-economic status was measured using a MacArthur Scale of Subjective Social Status (Adler et al., 2008; Giatti et al., 2012). This pictorial tool allows an individual to select their status within the community as it related to wealth, education and social status using 10 ladder rungs as a ranking (1 being the best off and 10 being the worst off).

Body mass index, an indicator of nutritional status, was calculated using participant weight to the nearest 0.1 kg and height to the nearest 0.1 cm. Weight was measured using a bio-impedance scale (Tanita BF-680 W). Height was measured without shoes using a portable Seca standing stadiometer placed on a hard flat surface.

Age (years) was self-reported and confirmed with an ID card when present. Since many Daasanach do not have a recorded date of birth, age was estimated based on birth around a historical event if necessary. The age of the female household head was used as a control in analyses conducted at the household level since Daasanach women are responsible for water.

Poor water quality is associated with higher levels of water insecurity and subsequent negative health outcomes (Bennyworth et al., 2016; Rosinger, 2018). Water salinity, one measure of poor water quality and a key concern among Daasanach (Rosinger et al., 2021), was measured using an YSI ProDSS Multi-Parameter Water Quality Metre and accompanying sensors. This meter provides a measure of the total concentration of dissolved salts in water. The recommended taste threshold for sodium is 200 mg/L (WHO, 2017).

We also constructed a perceived water quality variable from two survey questions about the number of times in the last four weeks anyone in the household consumed water that looked, tasted or smelled bad, and the number of times they worried the drinking water would cause sickness. The summed perceived water quality scores were calculated in a similar manner as the HWISE scale and ranged from 0 to 6.

Respondents were asked to report the amount of time a usual round-trip to fetch water including queue time, which sometimes may include time spent digging or re-digging a well, took them. Further, they reported the total number of trips the household took to collect water in the previous week.

Household size and composition were determined by asking how many children aged seven years old and under, children aged 8–16 years and adults aged 17+ years lived in the household. Following a procedure similar to methods used for estimating adult male equivalents for comparing households overall caloric needs (Weisell & Dop, 2012), we used information on household members of each age group combined with European Food Safety Authority (EFSA) water recommendations (EFSA, 2010) to estimate average water needs. We used these values to create an adult-equivalent household size for which we multiplied the number of 8–16-year-old children by a corrective factor of 0.85 and the number of children aged < 8 years old by a factor of 0.58. We summed these numbers with the household members aged > 16 years old.

Finally, given traditional practices of migrating with livestock to meet water needs, respondents were asked the number of times they moved or travelled with their livestock over the past year. This number was used as an indicator of which households had higher mobility and practiced a nomadic lifestyle. Those with higher mobility are predicted to have lower water insecurity because of their ability to move to meet their water needs.

Statistical analysis

All analyses were performed using Stata V.15.1 (College Station, TX, USA). Our analytical sample included 133 households and 233 adults aged ≥ 18 years with complete data for our variables of interest. For regression analyses, we used robust standard errors clustered by community of residence or household for household- and individual-level models, respectively. For all models we adjusted for community fixed effects.

For our first aim, we examined how household and environmental characteristics were associated with the HWISE scale using a Tobit regression since the outcome is censored at 0 and 36. Our model included the covariates for drinking water salinity, perceived water quality score, time spent fetching water, number of water fetching trips, household monthly income, livestock wealth, perceived socio-economic status, household size

adjusted for water needs, number of times the household moved and the age of female household head. This analysis was conducted at the household level.

For our second aim, we dichotomized borrowing water and used logistic regression to estimate how HWISE score was associated with the odds of borrowing water never/rarely compared with those who do it more frequently (three of more times) at the household level. We controlled for the same covariates as in the prior model. We then used marginal standardization to estimate the predicted probability of borrowing water by HWISE score adjusting for the distribution of covariates (Muller & MacLehose, 2014).

For our third aim, we used Tobit regression analysis to determine if water borrowing moderates the relationship between household water insecurity and psychosocial stress (PSS-4) at the individual level. We tested an interaction term between continuous HWISE score and level of water borrowing. Covariates included in the analysis were gender, livestock wealth, perceived socio-economic status, body mass index (as an indicator of nutritional stress) and individual age (Achore et al., 2020; Graham et al., 2016). Using marginal standardization as described above, we visualized the interaction between water borrowing and HWISE score on predicted PSS-4 scores based on the results of the model. Finally, as a robustness analysis, we re-estimated this analysis with the Daily Inventory of Stressful Events score in place of the PSS-4 score.

Results

Table 1 summarizes survey and interview data for the demographics and covariates of the study households without missing data (n = 133). Approximately 4% were water secure (HWISE scores = 0–11), 60.1% were moderately water insecure (HWISE = 12–23) and

Table 1. Descriptive characteristics of Daasanach households and household heads.

	Households (n = 133)	
	Mean or %	SD
HWISE score[a] (range = 0–36)	20.2	6.9
Perceived water quality score[2] (range = 0–6)	2.3	1.6
Borrowed water (%): Never/rarely (0–2 times)	25.6%	
Sometimes (3–10 times)	45.9%	
Often/always (11+ times)	28.6%	
Lent water (%): Never/rarely (0–2 times)	14.3%	
Sometimes (3–10 times)	48.9%	
Often/always (11+ times)	36.8%	
Salinity (mg/L)	366	119
Time spent fetching water per trip (min)	121	44.6
Weekly water trips	15.5	6.9
Times moved in last year	4.2	6.2
Household size modified by water need	5.9	2.2
Livestock wealth (US$)	2002.5	5367
HH monthly income (Kenyan shillings)	3400	9798
Perceived socio-economic status ladder (1–10)	7.5	2.3
	Adults (n = 233)	
Age (years)	40.2	15.0
PSS-4 score (range = 0–16)	7.9	2.2
Daily inventory of stressful events score (range = 0–7)	0.92	1.1
Body mass index (kg/m^2)	18.3	3.1
Male (%)	45.9%	

Notes: [a]HWISE, Household Water Insecurity Experiences scale.
HH, household.

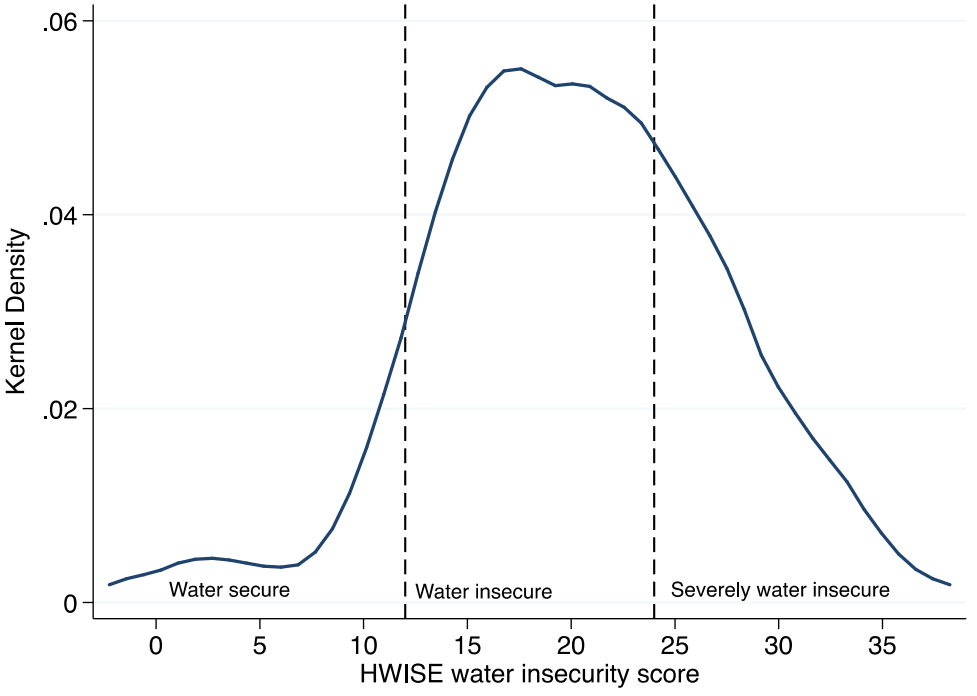

Figure 1. Kernel density of Household Water Insecurity Experiences (HWISE) score and categories of water insecurity among Daasanach households (n = 133).

33.8% were severely water insecure (HWISE ≥ 24) (Figure 1). The mean water insecurity score was 20.2 (±SD = 6.9). The average water salinity of water sources used by households for drinking was 366 mg/L (±119). Approximately 97% of adult respondents spent more than one hour for a single trip to fetch water (including waiting time), while 77% spent two or more hours, for a mean of 121 (±45) min per trip (Table 1).

It was common among respondents to borrow and lend water; 74.4% of respondents borrowed water three or more times in the previous four weeks, while 85.7% lent water three or more times (Figure 2a–b). Those who borrowed water were most likely to borrow from their neighbours (86%), while those who lent water were also likely to give water to their neighbours (75%) (Figure 2c–d). The majority of respondents both borrowed and lent water (63%).

Aim 1: Predictors of water insecurity

The results of the Tobit regression indicate that several environmental and household factors were associated with HWISE score (Table 2). Objective water quality as measured by water salinity was found to be significantly associated with water insecurity, each 100 mg/L increase in salinity was associated with 1.58 points (SE = 0.40, $p < 0.001$) greater HWISE score. Perceived water quality was also strongly associated with water insecurity; each point higher was associated with 2.03 points (SE = 0.55, $p < 0.001$) higher HWISE score. The accessibility of water was another significant predictor. Both time spent fetching water (β = 0.30 per

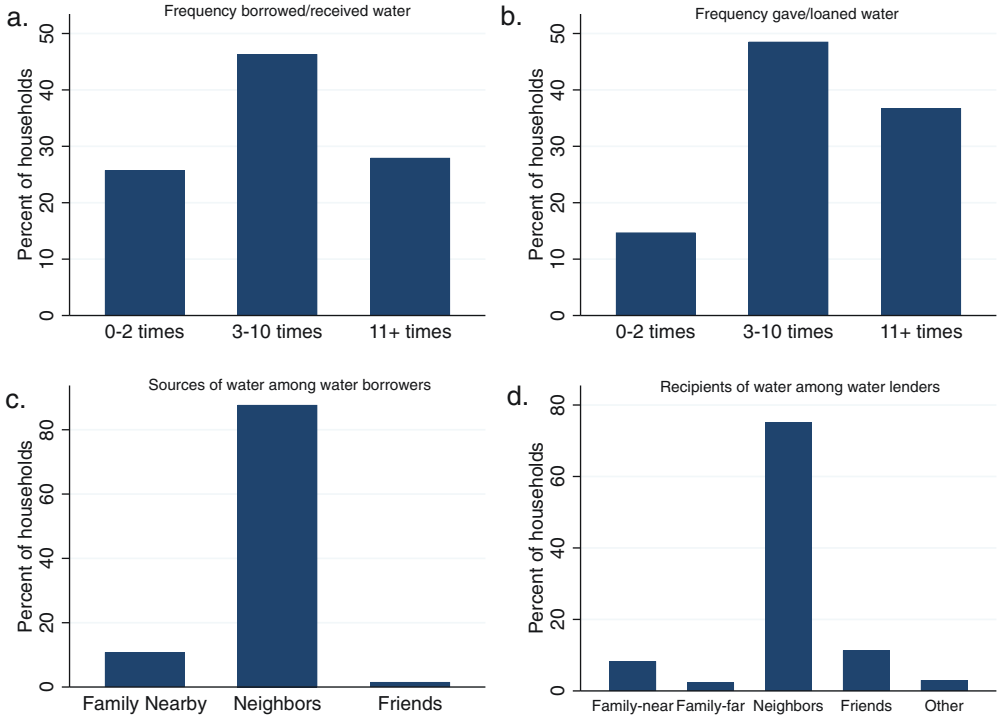

Figure 2. Water borrowing among Daasanach: (a) frequency of water borrowing; (b) frequency of water lending/giving; (c) reported givers/sources of water among those who borrowed water; and (d) reported recipients of water among water lenders.

Table 2. Tobit regression examining predictors of water insecurity among Daasanach households.

	HWISE score[a]		
Predictors	Beta	SE	p-value
Drinking water salinity (per 100 mg/L)	1.58	0.40	< 0.001
Perceived water quality^2 (per point)	2.03	0.55	< 0.001
Time to collect water (per 10 min)	0.30	0.11	0.007
Weekly trips to fetch water (per three trips)	0.56	0.27	0.04
Household monthly income (natural log-transformed)	−0.04	0.12	0.74
Livestock wealth (natural log-transformed)	0.002	0.29	0.99
Perceived socio-economic status ladder (each point worse)	0.22	0.32	0.50
HH size adjusted for water needs	0.64	0.21	0.003
Times moved in last year	0.23	0.13	0.071
Age of female HH head	0.02	0.03	0.63

Notes: All models adjust for community residence fixed effects. Robust standard errors are clustered by seven communities. $N = 133$ households. HH, household.
[a]Continuous Household Water Insecurity Experiences (HWISE) water insecurity score.

10 min, SE = 0.11, $p = 0.007$) and number of weekly trips ($\beta = 0.56$ per three trips, SE = 0.27, $p = 0.04$) were significantly associated with higher HWISE scores. The only other predictor significantly associated with water insecurity was household size adjusted for water needs as each additional adult equivalent was associated with 0.64 points (SE = 0.21, $p = 0.003$) higher

Table 3. Logistic regression examining predictors of water borrowing among Daasanach households.

	Borrowed water		
Variables	Odds ratio (OR)	95% CI	p-value
HWISE score (per point)	1.16	1.04–1.29	0.006
Drinking water salinity (per 100 mg/L)	0.99	0.09–11.2	0.99
Perceived water quality	1.47	0.79–2.71	0.22
Time to collect water (per 10 min)	1.08	0.95–1.24	0.25
Weekly trips to fetch water (per three trips)	1.02	0.93–1.11	0.72
HH monthly income (natural log-transformed)	0.91	0.77–1.06	0.23
Livestock wealth (natural log-transformed)	0.92	0.74–1.15	0.45
Perceived socio-economic status ladder (each point worse)	1.29	1.02–1.64	0.03
HH size adjusted for water needs of age groups	1.02	0.88–1.18	0.81
Age of female HH head	0.97	0.93–1.01	0.10
n = 133 households			

Note: The model is adjusted for community fixed effects. Standard errors are clustered on seven communities. Outcome borrowed water is dichotomized as three or more times compared with zero to two times. HH, household; HWISE, Household Water Insecurity Experiences scale.

HWISE score. Socio-economic status variables, monthly income, socio-economic status ladder and livestock wealth were not associated with water insecurity.

Aim 2: Water insecurity and water borrowing

Results of the logistic regression demonstrate that HWISE score was strongly associated with the odds of borrowing water three or more times in the prior four weeks. Each additional point on the HWISE scale was associated with 16% higher odds of water borrowing (odds ratio (OR) = 1.16; 95% confidence interval (CI) = 1.04–1.29; p = 0.006) adjusted for other household and environmental covariates (Table 3). Lower socio-economic status was associated with relying on borrowing water more frequently. Each point worse on the ladder was associated with 29% higher odds (OR = 1.29; 95% CI = 1.02–1.64; p = 0.03) of borrowing water more frequently.

Water borrowing was tightly connected to water insecurity score. The predicted probability of borrowing water increased from 38.7% at an HWISE score of 6, to 56.6% at 12, and to 84.4% at an HWISE score of 24 (Figure 3).

During follow-up discussions with communities about water borrowing, there was consensus that they often borrow water during the dry season because they can become tired of searching for water in the dry riverbeds. They are, however, expected to repay when they obtain their water. Yet, others indicated that they share water with neighbours during the wet season, when it is more plentiful with no expectation for payback, but not always during the dry season. Thus, water borrowing may relate to seasonality, water availability, along with the expectation of return.

Aim 3: Water borrowing, water insecurity and perceived stress

In bivariate analyses, HWISE score was significantly correlated with the four-item Perceived Stress Scale (PSS-4) (r = 0.18, p = 0.006) (Figure 4). In the multiple Tobit regression analysis, the main terms of HWISE score (β = 0.17, SE = 0.07, p = 0.02) and borrowing water often/always (β = 4.2, SE = 2.1, p = 0.044) were both associated with

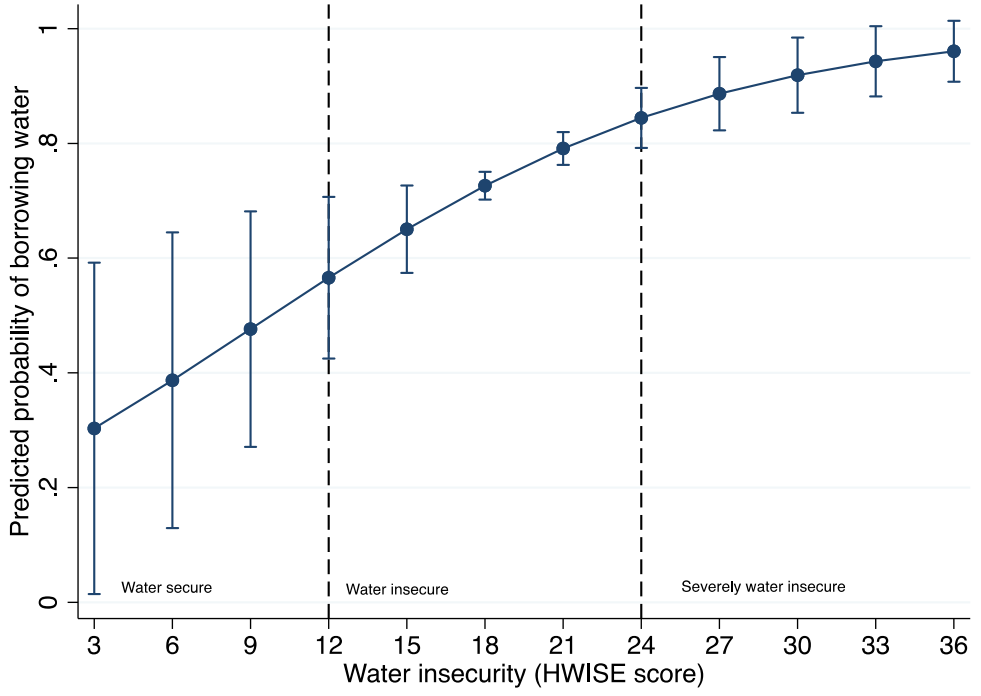

Figure 3. Predicted probabilities and 95% confidence intervals (CIs) of borrowing water three or more times in the prior four weeks by water insecurity score among Daasanach households (n = 133). Note: Adjusted for the range of covariates presented in the model presented in Table 3.

higher PSS-4 scores (Table 4). Further, there was a significant interaction between frequency of water borrowing and HWISE score. Compared with those who never or rarely borrowed water, those who borrowed water sometimes and often/always had 0.19 (SE = 0.09, p = 0.041) and 0.20 (SE = 0.09, p = 0.035) lower PSS-4 scores, for each 1 point higher on the HWISE scale.

This moderation effect demonstrates significantly different slopes between the levels or categories of water-borrowing frequency on PSS-4 as water insecurity increased (Figure 5). It indicates that those who borrowed water never or rarely saw a linear increase in PSS as HWISE score increased, whereas for those engaged in higher levels of water borrowing, the relationship was slightly negative.

Robustness analysis

Re-estimating the relationship between water insecurity, stress and water borrowing using the Daily Inventory of Stressful Events score in place of the PSS-4 score, we find consistent results despite the change in timescales from the previous month to the previous day (see Table S1 in the supplemental data online). Those who never or rarely borrowed water had a linear increase in daily stressors as HWISE score increased, whereas those who borrowed water sometimes and often/always had a negative association between HWISE score and Daily Inventory of Stressful Events score (see Figure S1 in the supplemental data online).

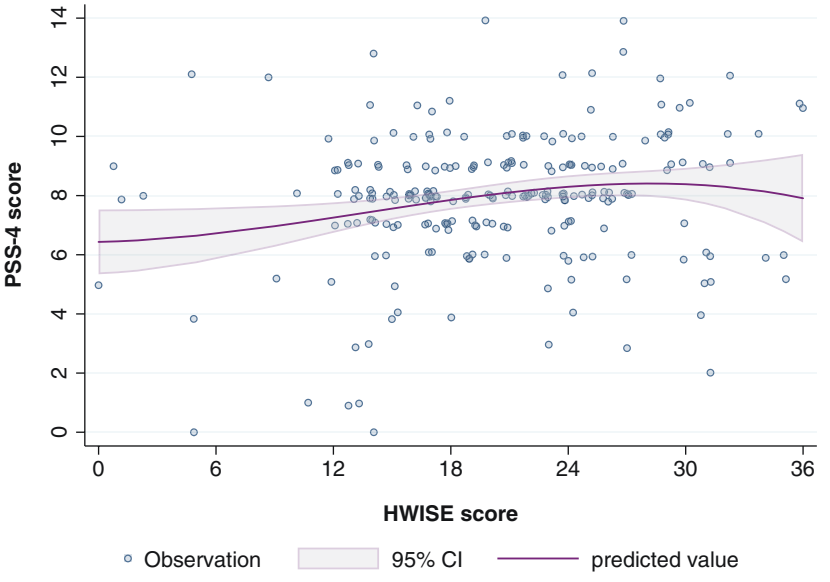

Figure 4. Scatterplot of Household Water Insecurity Experiences (HWISE) scores on perceived stress scores and 95% confidence interval (CI) among Daasanach adults (n = 233). Note: PSS-4, Cohen's four-Item Perceived Stress Scale (PSS).

Table 4. Tobit regression examining the association between water insecurity and psychosocial stress testing water borrowing as a possible moderator among Daasanach adults.

Variables	PSS-4[a]		
	Beta	SE	p-value
HWISE score (per point)	0.17	0.07	0.02
Frequency of water borrowing (WB)			
Never or rarely (0–2 times)	Reference	–	–
Sometimes (3–10 times)	3.0	1.79	0.097
Often or always (11+ times)	4.2	2.08	0.044
HWISE score by WB interaction			
Never or rarely	Reference		
Sometimes	−0.19	0.09	0.041
Always or often	−0.20	0.09	0.035
Male	0.05	0.23	0.82
Livestock wealth (natural log-transformed)	−0.07	0.11	0.53
Perceived socio-economic status ladder (each point worse)	0.17	0.098	0.088
Body mass index (kg/m^2)	−0.03	0.06	0.64
Individual's age	0.002	0.01	0.83
n = 233			

Notes: [a]Based on Cohen's four-Item Perceived Stress Scale (PSS).
The model is adjusted for community residence fixed effects.
Robust standard errors are clustered in 133 households.
HWISE, Household Water Insecurity Experiences scale.

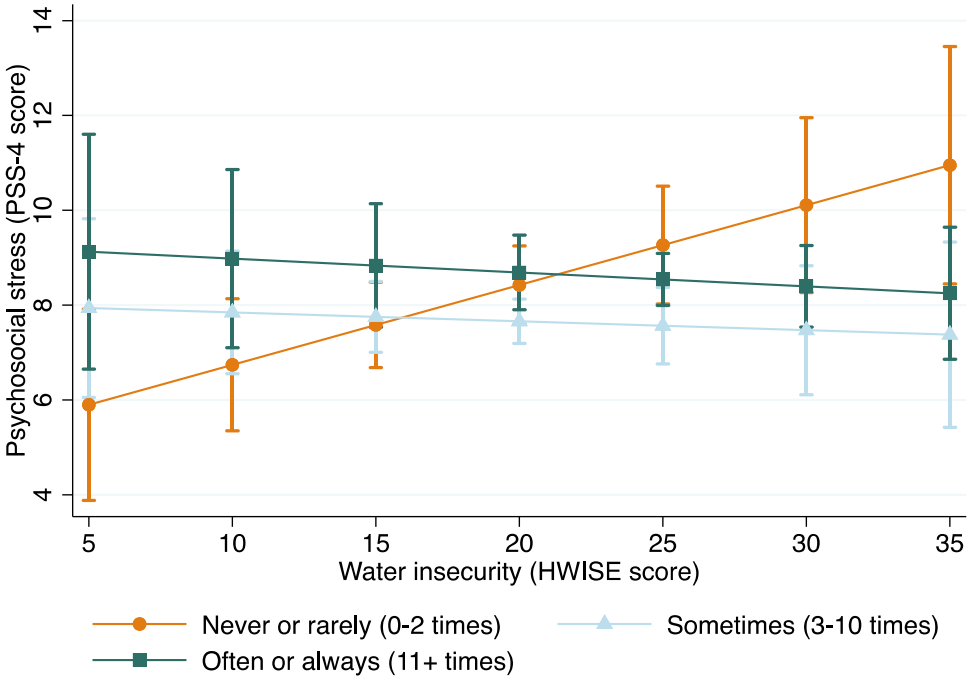

Figure 5. Predicted psychosocial stress by water borrowing in last four weeks and household water insecurity score among Daasanach adults (n = 233).

Discussion

This study aimed (1) to quantify water insecurity experiences among Daasanach pastoralists living in an extreme hot-arid environment and examine how environmental and household factors are associated with household water insecurity scores; (2) to examine how water insecurity is associated with water borrowing; and (3) to evaluate whether water borrowing acts as a coping mechanism to moderate the association between household water insecurity and individual psychosocial stress.

Water insecurity among Daasanach

Water insecurity was nearly ubiquitous among Daasanach households as results from the survey data suggest 94% of households were moderately or severely water insecure according to the HWISE scale. It is not clear how many other populations experience similarly high prevalence of water insecurity, though at least two other sites (Punjab in Pakistan and Cartagena in Colombia) reported mean HWISE scores on par with our sample (Stoler et al., 2021). Other studies among underserved pastoral populations in Sub-Saharan Africa, including Ethiopia (Stevenson et al., 2012), Uganda (Pearson et al., 2015) and northern Kenya (Balfour et al., 2020), have documented high levels of water scarcity and water insecurity.

Among Daasanach households, indicators of water quality, access and quantity were all significantly associated with experiences of water insecurity. Specifically, indicators of water salinity and perceived water quality were associated with higher HWISE scores. This finding is consistent with a study conducted in Bangladesh that found that slightly saline groundwater was a key water security concern of the respondents, though the relation was not quantified (Bennyworth et al., 2016). Among Daasanach, the average drinking water salinity level was 360 mg/L, which is above the recommended taste threshold for sodium of 200 mg/L. Further, our salinity findings map onto local concerns expressed during fieldwork about the salinity of the groundwater (Rosinger et al., 2021). While there are currently no health guideline values for sodium in drinking water (WHO, 2017), prolonged consumption of saline water has been linked with negative health outcomes such as elevated systolic and diastolic blood pressure, increased risk of hypertension, reproductive concerns for women, and altered cognitive performance (Rosinger et al., 2021).

Our measures of water accessibility, time spent fetching water and number of water-fetching trips per week were both significantly associated with water insecurity score. Other household factors, such as household size, were also associated with water insecurity as a marker of increasing water need. In contrast with our expectations, socio-economic status variables were not associated with HWISE score. Yet, prior work indicates that not only does the time required to fetch water directly contribute to water insecurity, but also it can indirectly contribute to it by reinforcing economic barriers that prevent household from sustainably addressing water insecurity concerns (Achore et al., 2020).

Water borrowing as a response to water insecurity

Our survey results suggest that about 75% of Daasanach households borrowed water at least three times in the prior month and that water insecurity was strongly associated with water-borrowing frequency. The fact that the majority of households that borrowed water also lent water, and that both of these occurred primarily among neighbours, indicates that reciprocity may be an important consideration in the water-borrowing network. This is consistent with Daasanach culture of borrowing and sharing goods and food to benefit the community at large (Wright, 2019).

Historical and ethnographic records from other populations, including pastoralist records also suggest that water sharing is a common strategy for meeting water needs in times of extreme water shortages (Wutich et al., 2018). In the largest study documenting this, water borrowing ranged from 11% to 85% across 21 sites in low- and middle-income countries with known water problems (Rosinger et al., 2020). The relatively high prevalence of water borrowing across diverse, water-stressed environments as a strategy to mitigate water insecurity and water system failures highlights the need to understand how these practices affect the social and cultural norms, which influence water acquisition, distribution and prioritization (Rosinger et al., 2020). Other studies indicate that reciprocity of water between wealthy and poor households is critical for maintaining social capital between these groups (Pearson et al., 2015).

Higher social capital has been associated with lower food and water insecurity resulting in health improvements (Goodman et al., 2022). An individual's level of social capital is often a by-product of their participation in their social networks. Trust between individuals within a network, the strength of their connections and the likelihood of reciprocity all influence the accrual of social capital. Social capital has a positive influence on trust, social cohesion and mutual support. This is why public health researchers have recently targeted social capital as a way of addressing food and water insecurity (Goodman et al., 2022). Imbalances in social capital, however, may also be a mechanism through which social power relations are maintained (Pearson et al., 2015; Wutich et al., 2018). Thus, it is important to understand underlying social relations when examining water-sharing practices.

Water borrowing as a moderator of stress

Water insecurity was significantly associated with psychosocial stress in our study, a finding consistent with our original hypothesis and similar to findings from other studies (Brewis et al., 2019a; Collins et al., 2019; Stevenson et al., 2012; Stoler et al., 2019; Wutich, 2009). In many contexts household water managers often experience psychosocial stress as a result of the negotiations, such as borrowing, purchasing or rationing water, in which they must engage to ensure sufficient water (Wutich & Ragsdale, 2008). Marginalized households with low socio-economic status often rely on less costly but more time-consuming coping mechanisms for water insecurity, which may contribute to even greater stress among those households (Achore et al., 2020; Venkataramanan et al., 2020). We found that lower perceived standing was associated with higher odds of borrowing water. Daasanach frequently noted during interviews that they would borrow water from neighbours when they did not have enough time to fetch their own. One woman told us that if she lacked water in the late afternoon, she would often ask a neighbour for water to cook dinner with and then repay that water in the future.

Among Daasanach, the frequency of water borrowing moderated the relationship between water insecurity and psychosocial stress. For households that never or rarely borrowed, higher water insecurity was associated with significantly higher perceived stress; while for those engaged in water borrowing more frequently, greater water insecurity was slightly negatively associated with perceived stress (Figure 5). While at low levels of water insecurity, those who never or rarely borrowed water had lower stress than individuals who relied on water borrowing, at higher levels of water insecurity they had higher stress than those who borrowed water. These findings are consistent with theory that suggests water sharing can lower psychosocial stress by providing safety nets for those households who experience water insecurity (Stoler et al., 2019; Wutich et al., 2018).

Our results further suggest that water borrowing is an effective coping mechanism for those who are included in the water-borrowing network because it is associated with lower psychosocial stress among those who participate regularly. However, those who do not borrow water, for whatever reason, may suffer more stress than those who borrow water at higher levels of water insecurity. This finding echoes the theoretical underpinnings of water borrowing outlined in Wutich et al. (2018) which suggests that while water sharing may reduce levels of psychosocial stress for those included in the network,

those who are excluded may experience increased stress. Our results are also consistent with recent research from Ethiopia, which finds that the level of participation in informal water-sharing networks is critical to understand in conjunction with unfairness for psychological distress (Brewis et al., 2021). As a result, water borrowing as a coping mechanism may be dependent on a household's relationship with neighbouring households and their inclusion in the network (Achore et al., 2020).

Despite our findings, there may be other unintended consequences of water borrowing which were not measured in this study that might affect its effectiveness as a strategy for meeting short- and long-term water needs. For example, potential indebtedness to lenders or lenders being deprived of water for their own personal and domestic uses because of an obligation to give (Wutich et al., 2018). Future work is needed to investigate all the consequences, both intended and unintended, that results from participation in water-borrowing networks. Future work should also untangle what determines networks and why certain households are or are not in-network and how distance to the main market town affect these relationships.

Limitations

Limitations include that the survey was cross-sectional, such that results should be viewed as associations and not causal, though results were substantiated with follow-up focus group discussions and observations with the communities. The observations and quantitative scores are the authors' interpretation of local views. Data for the survey were collected during the early dry season but before water insecurity is arguably at its worst (around September). The water insecurity experiences captured during June and July may not be representative of the entire year because they do not capture seasonal variations and migration with livestock. The follow-up discussions that occurred at different points in the year (October and May) yielded consistent sentiments regarding water borrowing.

Second, while our psychosocial stress (PSS-4) instrument has been validated in different populations and we consulted with local informants about the appropriate translation and interpretation of these questions, it is possible that some domains of psychosocial stress and mental health distress that members of the Daasanach community experience as a result of water insecurity were not captured. It is also possible that our analysis is subject to omitted variable bias where there is another unmeasured stressor in the environment, such as broader conflict or food insecurity (Sagawa, 2010), that may be associated with psychosocial stress and is unadjusted for in our analysis. However, our HWISE scale measures insufficient water for food, which is associated with food insecurity score (Bethancourt et al., 2022), and we adjust for major stressors in Daasanach life related to social standing, income and livestock wealth, as well as nutritional status and age. Further, our results were substantiated by the Daily Inventory of Stressful Events which is an instrument that assesses actual stressor events such as conflict, arguments, discrimination or other events rather than appraised subjective stress from the PSS-4.

Additionally, as is common among pastoralist groups, ownership of livestock may be systemically under-reported among Daasanach in this study, with true ownership of livestock being sometimes difficult to ascertain. To limit this potential bias, livestock numbers were obtained by local translators and other socio-economic measures were used to validate household wealth such as income and perceived social standing.

Finally, we do not know if people who did not borrow water chose not to do so or were excluded from doing so. This is important because the effect on stress could differ depending on whether they feel resentful about having to borrow water, or about being excluded from the borrowing network. Future work should examine reasons for borrowing, its relationships with water security and complement this work with qualitative data to ensure nuances are understood.

Conclusions

In conclusion, this cross-sectional, observational study of household surveys and interviews coupled with environmental data demonstrated that Daasanach pastoralists experience high levels of household water insecurity during the early dry season and that water insecurity predicts higher frequency of water borrowing. Further, water-borrowing frequency has important implications for Daasanach psychosocial stress experienced in association with water insecurity. We found that the positive relationship between water insecurity and psychosocial stress was not observed among those who borrowed water frequently, suggesting that borrowing water may blunt the psychosocial burden of water insecurity. These findings are valuable because they contribute to a small but growing body of literature that seeks to quantify household-level water insecurity experiences among pastoralist and semi-nomadic groups in the arid regions of Eastern Africa (Balfour et al., 2020; Pearson et al., 2015). These finding are also informative for agencies who seek to implement broad policies to address household-level water insecurity through water borrowing group initiatives. Additionally, these findings are among the first to explore the interaction between household-level water insecurity and water borrowing as a coping mechanism to mitigate psychosocial stress. Because water-borrowing networks exist globally (Rosinger et al., 2020), future studies investigating water insecurity and psychosocial stress should consider water borrowing as a possible moderator in other populations. Further, future work should examine how different coping strategies to water insecurity, such as water storage capacity, rainwater harvesting and utilization of multiple water sources, may mitigate psychosocial stress and physical health outcomes. Water borrowing may serve as a powerful informal system to blunt psychosocial stress from water insecurity for those included in water-borrowing networks, making it an important system to consider for meeting global water needs.

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Author contributions

AYR and LBF conceptualized the study. AYR, HP, RN, EKN, DRB, and MD obtained funding to collect the data. AYR, HJB, HP, ZSS, RN, and EKN collected the data. HJB cleaned and managed

the data. AYR and LBF conducted the analyses. LBF drafted the manuscript with help from AYR. AW, AB, SY, and DMA provided critical feedback on the manuscript. All authors provided feedback, editing, and approved the final version of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

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