ELSEVIER

Political Geography 25 (2006) 361−382

Political Geography

www.elsevier.com/locate/polgeo

Conflicts over shared rivers: Resource scarcity or fuzzy boundaries?☆

Nils Petter Gleditsch [a,b,*], Kathryn Furlong [c], Håvard Hegre [a], Bethany Lacina [d], Taylor Owen [e]

[a] *Centre for the Study of Civil War, International Peace Research Institute (PRIO), Hausmanns gate 7, 0186 Oslo, Norway*

[b] *Department of Sociology and Political Science, Norwegian University of Science and Technology, Norway*

[c] *Department of Geography, University of British Columbia, Canada*

[d] *Department of Political Science, Stanford University, CA, USA*

[e] *University of Oxford, UK*

Abstract

Countries that share rivers have a higher risk of military disputes, even when controlling for a range of standard variables from studies of interstate conflict. A study incorporating the length of the land boundary showed that the shared river variable is not just a proxy for a higher degree of interaction opportunity. A weakness of earlier work is that the existing shared rivers data do not distinguish properly between dyads where the rivers run mainly across the boundary and dyads where the shared river runs along the boundary. Dyads with rivers running across the boundary would be expected to give rise to resource scarcity-related conflict, while in dyads where the river forms the boundary conflict may arise because river boundaries are fluid and fuzzy. Using a new dataset on shared water basins and two measures of water scarcity, we test for the relevance of these

☆ The work reported here was supported by the Research Council of Norway. Earlier versions of the article were presented at the 45th Annual Convention of the International Studies Association, Montreal, 17−20 March 2004, the Fifth Pan-European International Relations Conference, The Hague, 9−11 September 2004, and the 13th Norwegian National Meeting in Political Science, Hurdalssjøen, 5−7 January 2005. We are grateful to Aysegul Aydin, Helga Malmin Binningsbø, Glenn Palmer, and other participants in these meetings for comments and to Kristian S. Gleditsch, Jan Ketil Rød, and Lars Wilhelmsen for help at various stages of our work. Aaron Wolf generously provided us with the International River Basin GIS layers. The codebook for the rivers basin data can be found on www.prio.no/cscw/envi/rivers. The data are found in the same location. Replication data for this article are found on www.prio.no/cscw/datasets.

* Corresponding author. Centre for the Study of Civil War, International Peace Research Institute (PRIO), Hausmanns gate 7, 0186 Oslo, Norway. Tel.: +47 22 54 77 21; fax: +47 22 54 77 01.

E-mail addresses: nilspg@prio.no (N.P. Gleditsch), kathrynf@interchange.ubc.ca (K. Furlong), hhegre@prio.no (H. Hegre), blacina@stanford.edu (B. Lacina), taylor@prio.no (T. Owen).

doi:10.1016/j.polgeo.2006.02.004

two scenarios. Shared basins do predict an increased propensity for conflict in a multivariate analysis. However, we find little support for the fuzzy boundary scenario. Support for a scarcity theory of water conflict is somewhat ambiguous. Neither the number of river crossings nor the share of the basin upstream is significant. Dry countries have more conflict, but less so when the basin is large. Drought has no influence. The size of the basin, however, is significantly associated with conflict. Modernization theory receives some support in that development interacted with basin size predicts less conflict, and we find some evidence here for an environmental Kuznets curve. The importance of basin size suggests a possible 'resource curse' effect for water resources.

Keywords: River basin; Resource scarcity; Boundaries; Conflict

Introduction

Most conflicts are over some type of resource perceived as scarce, at least when territory is counted as a resource (Huth, 1996; Vasquez, 1993). With the decline of ideological conflict after the end of the Cold War some scholars, like Klare (2001a, 2001b), have argued that competition for access to 'vital' resources increasingly drives international relations. According to Klare, the danger of international competition for adequate water resources will grow 'inevitably'. By 2050, the increased demand for water could produce 'intense competition for this essential substance in all but a few well-watered areas of the planet' (Klare, 2001a, p. 57).

In the first large *n* study of water and interstate conflict (Toset, Gleditsch, & Hegre, 2000), we showed that sharing a river increases the probability of a militarized interstate dispute in a pair of countries (a dyad) over and above mere contiguity. We also found water scarcity to be associated with conflict, particularly when a river is shared across rather than along a border. Furlong, Gleditsch, and Hegre (2006) investigated the possibility that these findings might be spurious. Countries with long common boundaries are more likely to have a shared river and also to have more conflict, as argued theoretically by Wesley (1962, p. 388) and empirically by H. Starr (2002). Using a new dataset on international boundaries (Furlong & Gleditsch, 2003), however, we found that the relationship between shared rivers and conflict was not spurious with respect to boundary length.

Here we test another caveat in Toset et al. (2000): most of the dyads with shared rivers in that study had several types of shared rivers, rivers that ran *across* as well as some that ran *along* the boundary. Due to data limitations our earlier studies could only reliably test for the presence, rather than type, of shared rivers. This ambiguity leaves open another challenge to the resource scarcity perspective on conflict: the possibility that rivers cause conflict by forming fuzzy boundaries, i.e., boundaries that are somewhat fluid and shifting over time. In this article, we first review the water wars and fuzzy boundaries conflict scenarios. We then discuss a new dataset based on a more complete set of river basins, and use this dataset to take a fresh look at the relationship between shared rivers and interstate conflict. We find some limited support for the scarcity scenario, little support for the fuzzy boundary scenario, and finally discuss the possibility of a 'resource curse' effect for water resources.

Resource scarcity and conflict: water wars?

The notion of an impending threat of 'water wars' has become quite common in academic and journalistic writing (Irani, 1991; J. R. Starr, 1991; "Water wars", 2001), as well as in political rhetoric. In 1967, just before the Six-Day War between Israel and its Arab neighbors, Prime Minister Levi Eshkol declared that 'water is a question of survival for Israel', and therefore 'Israel will use all means necessary to secure that the water continues to flow' (Biliouri, 1997, p. 5). In the mid-1980s, US intelligence services are said to have 'estimated that there were at least 10 places in the world where war could break out over dwindling shared water' (J. R. Starr, 1991, p. 17). Homer-Dixon (1999, pp. 179–180) argues that war is more likely over non-renewable resources like petroleum and other minerals. But among the renewables, water has the greatest potential for stimulating international war – albeit only under special conditions such as high dependence on water in a downstream country, or a history of antagonism between the two countries. At the World Water Week conference in Stockholm in 2004, William Mitsch, professor of natural resources and environmental science at Ohio State University, was cited as saying that 'we have had oil wars. … Water wars are possible.' With reference to attitudes in the rich countries, Mitsch is reported to have said that 'I don't know what will shake these regions out of complacency other than the fact that there will be droughts, pestilence, and wars that break out of over water rights' (McLoughlin, 2004).

At the global level, water is a finite resource. With an expanding global population, the world run-off per capita has reduced progressively from 40,000 m^3 per person in 1800 to 6840 m^3 in 1995. It is estimated to decline further to 4692 m^3 by 2025 (Beaumont, 1997, p. 358). On a per capita basis, water availability is also enormously skewed geographically. North America has an annual run-off of 17,000 m^3 per capita per year, while Africa has 6000 m^3, and Egypt 50 m^3. Less than 1% of the world's usable freshwater is found in the Middle East or North Africa, although this region is home to 5% of the world's population.

Water distribution is also skewed within countries and cities along lines of class, gender, and race. Stark differences in water access exist in many parts of the world. Many countries with lower water availability today, particularly in Africa, have high rates of population growth, so that water availability may decline especially for those for whom access is already poor. Moreover, increasing standards of living may lead to greater demands for water. In *Global Environmental Outlook 2000*, the United Nations Environment Programme expressed concern about how the increase in freshwater consumption is outpacing population growth, raising the prospect that in 2025 two thirds of the world's population will live in water-stressed conditions (UNEP, 1999, pp. 41–42). An expert survey identified freshwater scarcity and freshwater pollution as two of the four major emerging environmental issues, second only to climate change (UNEP, p. 339).

Writers who foresee growing and increasingly serious global and domestic water scarcities generally proffer an 'ecoscarcity' or 'survivalist' theory of environmental problems. These approaches are linked to the neomalthusian arguments of the 1970s, but steer away from the more absolutist and sometimes authoritarian tendencies associated with those earlier perspectives (see Dobson, 1990). According to Gleick (1993, p. 79) for example, 'Where water is scarce, competition for limited supplies can lead nations to see access to water as a matter of national security', as 'an increasingly salient element of interstate politics, including violent conflict'. The argument extends to cases where states lack control of the source of their water supplies. Many countries are highly dependent on water that originates beyond their borders – over 90% in the case of countries like Egypt, Hungary, and Mauritania (Gleick, p. 100, pp. 103–104). Falkenmark (1990, p. 179), among others, claims that there is a serious risk of international conflict, especially in the Middle East and Africa, between upstream and downstream countries.[1] UNEP (1999, p. 8) also cites

[1] A number of other examples are cited by Wolf (1999b, p. 253).

increasing concern that environmental degradation and resource shortages may cause armed conflict and lists water shortages among such issues. Finally, an authoritative report from the World Water Assessment Program describes mankind as 'facing a serious water crisis' (UNESCO, 2003, p. 4).

On the other hand, not all water-related international violence provides evidence for the scenario of water disputes leading to war. For instance, on 27 August 1965 Jordan bombed an Israeli water pipeline in Kamin and several similar episodes occurred in the following years (Wolf, 2000). In this case, attacking a water pipeline was simply a convenient means of warfare.

Those holding more resource-optimistic views will be classified here under the general rubric of 'eco-modernization' (elsewhere labeled cornucopians, N.P. Gleditsch, 2003, or promethians, Dryzek, 1996). Eco-modernization theorists argue that scarcities are counteracted by innovation, substitution, and flexible pricing of resources, particularly in developed economies. The World Commission on Water for the 21st century, for example, advocates 'full-cost pricing of water with equity' (Serageldin et al., 1995, p. 284). They also frequently hold that cooperation over water resources is more common than conflict (e.g. Lomborg, 2001; Wolf, 1999a). River resources can be shared in a cooperative manner, by means of treaties and joint river administrations. Such arrangements have been in force for decades on the Rhine, the Mekong, and the Danube (Wolf, Natharius, Danielson, Ward, & Pender, 1999, p. 424). A recent example is provided by a long-standing dispute between Namibia and Botswana over the waters to the Okavango River. In 1997, after years of drought, negotiations between the two countries broke down. But instead of initiating violence, the two countries went to the International Court of Justice for dispute settlement (De Villiers, 2003, p. 257).

At the global scale, water is not scarce. However, many areas of the world have water shortages relative to their present needs, and this problem may increase unless changes are made in the patterns of supply or consumption. Securing adequate and plentiful water for human objectives is a political and economic issue rather than one of absolute physical constraints. UNEP (1999, pp. 43–44), while emphasizing the dangers of impending water scarcities, also recognizes that 'good water management can solve many of the problems of pollution and scarcity', citing Israel and Jordan, two of the most water-scarce countries, as examples of successful irrigation strategies.

The presentation here of these dichotomous approaches to water resource issues simplifies the spectrum of environmental approaches. Still, much environmental debate is structured between the two poles presented here: scarcity vs. modernization. According to Harvey (1996, p. 149), Western discourses related to nature have frequently swung between 'cornucopian optimism and triumphalism at one pole and unrelieved pessimism' about natural limits (ecoscarcity/survivalism) at the other. Moreover, within the plethora of environmental discourses and programs, it is only the technological optimism found in eco-modernization that directly challenges the limits discourse driving the ecoscarcity approach (Dryzek, 1996).

Rivers as fuzzy boundaries

Our two earlier large *n* studies of rivers and conflict incidence (Furlong et al., 2006; Toset et al., 2000) use a dataset coded by Toset largely from a 1978 study from the Center for Natural Resources, Energy, and Transport of the Department of Economics and Social Affairs of the United Nations (CNRET, 1978), which attempts to distinguish between three categories of river relations – upstream/downstream, border demarking, and mixed. However, this proved problematic. Only 9% of all coded rivers had a clear upstream/downstream categorization and 39% ended up in a fourth category labeled 'other'. Both studies indicated that the upstream/downstream relationship was the most highly correlated with conflict, but this river type could not be fully separated from the larger and ambiguous 'other' river type configuration. These data limitations have made it difficult to test reliably for the type of shared river (Fig. 1).

This ambiguity, the fuzzy boundary scenario, leaves open a challenge to the water wars hypothesis. Countries sharing large amounts of river boundary may not fight over the direct control of the resource per se, but rather over the political boundary. Rivers are notoriously fickle boundaries. Normally, the boundary follows the Thalweg, the deepest channel in the river. But this is not the only possibility. Some boundaries follow a riverbank, the median line between the banks, or lines drawn between turning points (K. Gleditsch, 1952; Salman, 2000). For opportunistic reasons, two countries could come out in favor of two different legal principles for determining the position of the border. Even after the border has been fixed, erosion can change the banks, the median, or the Thalweg, to the detriment of one country and the benefit of another. Such cases of fuzzy boundaries are quite common, although they do not necessarily lead to conflict. For instance, when the Finnish–Norwegian border was revised in 2002, a number of small sandbanks and islands changed from one country to the other; largest among them was an island of about 1000 m^2. While uninhabited, the island had previously been used as grazing land by neighboring farmers (*Aftenposten*, 2002, January 15, p. 6).

The Sino–Soviet border dispute of 1969 is an instance of a fuzzy boundary leading to conflict. A dispute generally over the boundary line crudely demarcated by the Ussuri river and specifically over the ownership of Chenpao island (*Keesing's*, 2004) led to intense fighting over a period of several months killing 3000 Soviet and Chinese troops (Clodfelter, 2002, p. 700).

A river may also serve as a border but be contested primarily because it is a water resource. For example, during a 1989 conflict between Mauritania and Senegal which took place along the Senegal River, serious interethnic violence claimed approximately 400 lives and led to small border skirmishes between the two nations. Although the Senegal River formed a boundary, the dispute was ultimately one over water resources:

> The trouble began … over competing claims to farming rights on the common border, the Senegal river, where irrigation projects had increased the value of land and made the Mauritanians, traditionally herdsmen, less inclined to allow Senegalese to cultivate both sides of the border. (Bercovitch & Jackson, 1997, p. 240)

In this article we test the fuzzy boundaries and resource wars scenarios by using a new dataset on shared river basins.

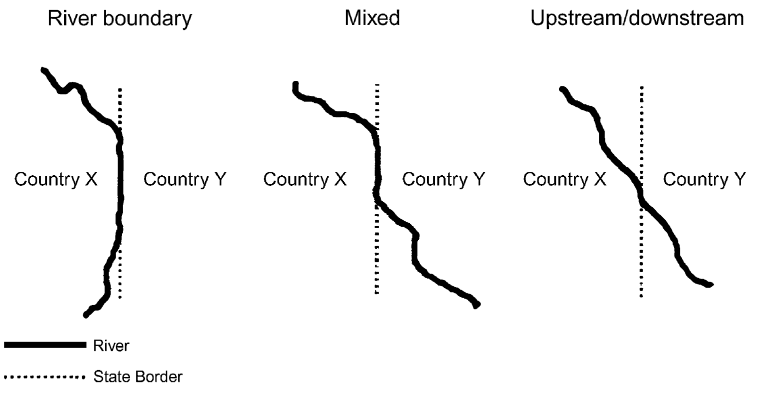

Fig. 1. Typology of shared rivers. Source: Toset et al. (2000, p. 980).

The river basin dataset

Recent work on cooperation and conflict over water resources has focused on river basins rather than on individual rivers (Wolf, 1999a; Yoffe, Wolf, & Giordano, 2003). A watershed is a 'topographically delineated area drained by a stream system – that is, the total land area above some point on a stream or river that drains past that point' (Brooks et al., 1997, p. xiii). A river basin is defined in the same way but includes the entire river and its tributaries. A basin encompasses the entire surface and ground water in what may be quite a large geographical area. The basin is frequently used as a spatial unit for socio-economic management.

Several studies of basins and conflict have pointed to the importance of geographic scale (Ashton, 2002; Sneddon, 2002). They argue that the size of a basin, particularly in the context of the relative national water scarcity, plays a very important role in the potential for conflict escalation. Where Ashton paints a dire picture of African scarcity as a precursor to conflict, Sneddon points out that the geographic importance of certain basins makes them ideal for co-management. Giordano and Wolf (2003) have also shown how seemingly conflict-prone basins have become arenas of cooperation.

The new dataset on shared river basins used here is better suited than the Toset dataset to answer our question about resource competition vs. fuzzy boundaries as sources of conflict. Instead of categorizing individual rivers as either boundary crossing or boundary demarcating, the new dataset recognizes the possibility that rivers within the same basin can be both, that two countries can be both upstream and downstream relative to each other, and that non-contiguous countries can share a river basin – Ethiopia and Egypt provide an important example. Another limitation of the old dataset is that it does not accurately reflect the relative magnitude of the water resource. The importance of the water available in each dyad was only measured by water scarcity in either country and by the number of rivers shared by the dyad. The relevance of water scarcity was discussed in our earlier work, but in this regard the number of rivers crossing the boundary is a very minor improvement on the dichotomous shared river variable. Finally, the earlier dataset was somewhat incomplete. The database used to code the river relations (CNRET, 1978) included little information for either Asia or Africa and left out prominent rivers elsewhere. For example, only seven river crossings and three basins were listed for the Canada–US border, and no rivers east of Quebec were included. We have not found any evidence of a systematic bias in the selection of rivers. Nevertheless, it is unfortunate that the dataset should have large gaps.

We have created a new dataset with four principle ambitions: to include all principal river basins, to clarify the ratio between upstream/downstream and boundary-demarcating rivers, to include data on the magnitude of the water resources, and to include non-contiguous basin-sharing dyads in the dataset.

In order to achieve the level of detail necessary to calculate these new variables, we used a Geographic Information System. We began by doing a systematic test of the Toset dataset with the most comprehensive dataset on transboundary river basins – Aaron Wolf's Transboundary River Basin Registry.[2] We first used their GIS layer for all 250 of the world's basins to

[2] See the Transboundary Fresh Water Dispute Database at Oregon State University on www.transboundarywaters.orst.edu/. The dataset includes 263 existing and two historical basins. It provides very detailed coverage of all international river basins, but some smaller basins are missing. For instance, several hundred kilometers of the Swedish–Norwegian border lack boundary-crossing rivers according to a map in Yoffe et al. (2003, p. 1122). However, this is inaccurate. The possibility of a very small selection bias cannot be discounted, but it is unlikely to have any influence on our results.

determine the number of missing basins in Toset's dataset. Fifty-one basins were missing and many others were named and coded differently, so redoing the data based on new basins was deemed necessary. As we were interested in coding all of the rivers that cross borders within Wolf's river basins we compiled a very detailed rivers layer to cover the area under each of the 250 basins. This was taken from the 1997 *Digital Chart of the World*. Fig. 2 provides an example of the Wolf Basin Layer and the two levels of river detail extrapolated from the *DCW* data.

For each contiguous boundary-crossing river basin we counted the number of river crossings and measured the length of each boundary-demarcating river. We added the non-contiguous river-sharing dyads to the dataset. For all entries, we identified the upstream state, and calculated the percentage and size of basin in both countries.[3]

For the historic boundaries we used a series of GIS layers depicting boundary changes between 1944 and 1996 from O'Loughlin et al. (1998). For the most part, Toset had used historical maps to identify the river-sharing dyads from 1816 to 1944. For instance, when Egypt and Syria joined to form the United Arab Republic, Syria was replaced by Egypt in all Syria/Israel and Syria/Jordan dyads. Where the O'Loughlin et al. data were insufficient to determine the boundary changes, we relied on Toset's reading of the maps.

Differentiating conflict scenarios

Using the newly compiled basin data, we performed regression analysis (with bivariate and multivariate logit models) to investigate the relationship between shared rivers and interstate conflict. Our dependent variable is the same as in Toset et al. (2000), the onset of militarized interstate disputes (MID) with a minimum of one fatality from the Correlates of War project. The reason for limiting ourselves to fatal disputes is to minimize the potential attention bias inherent in data on low-level conflict (N.P. Gleditsch, 1999; Toset et al., p. 984). Our results remain consistent in tests considering fatal and nonfatal disputes, with the exception that the control variable for alliances is significant in some regressions that included nonfatal MIDs. We also perform multivariate analysis of the impact of water variables on MIDs disaggregated by fatality level. These results are discussed below.

We consider system member dyads from 1880 to 2001.[4] We restrict the analysis to dyads that coexist on the same continent, since by definition only these can share a river basin. We coded eight 'continents': North America, South America, Hispaniola (Haiti, Dominican Republic), Africa, Western Eurasia, Great Britain, Eastern Eurasia, and Borneo & New Guinea.[5] Countries that do not share landmass with any other countries (e.g. Australia) were excluded.

[3] For a detailed description of the coding, see www.prio.no/cscw/envi/rivers.

[4] The MID data are now available from 1816 to 2001. However, one of the control variables, the level of economic development, is only available from 1880. The MID data were downloaded from EUGene (Expected Utility Generation and Data Management Program) (see Bennett & Stam, 2003). The most recent MID dataset is described by Ghosn and Palmer (2003). EUGene was also used to download data on years of peace, energy consumption per capita, population, major power status, alliances, and inter-capital distances for the control variables described below.

[5] *North America* includes all countries from Panama northwards, *South America* all countries from Colombia and southwards. Egypt is included only in *Africa*. *Western Eurasia* includes all countries west of Russia and Turkey, *Eastern Eurasia* all countries east of these two countries. Russia and Turkey were coded to belong to both continents. *Hispaniola* includes Haiti and the Dominican Republic. *Borneo & New Guinea* includes Indonesia, Malaysia, and Papua New Guinea.

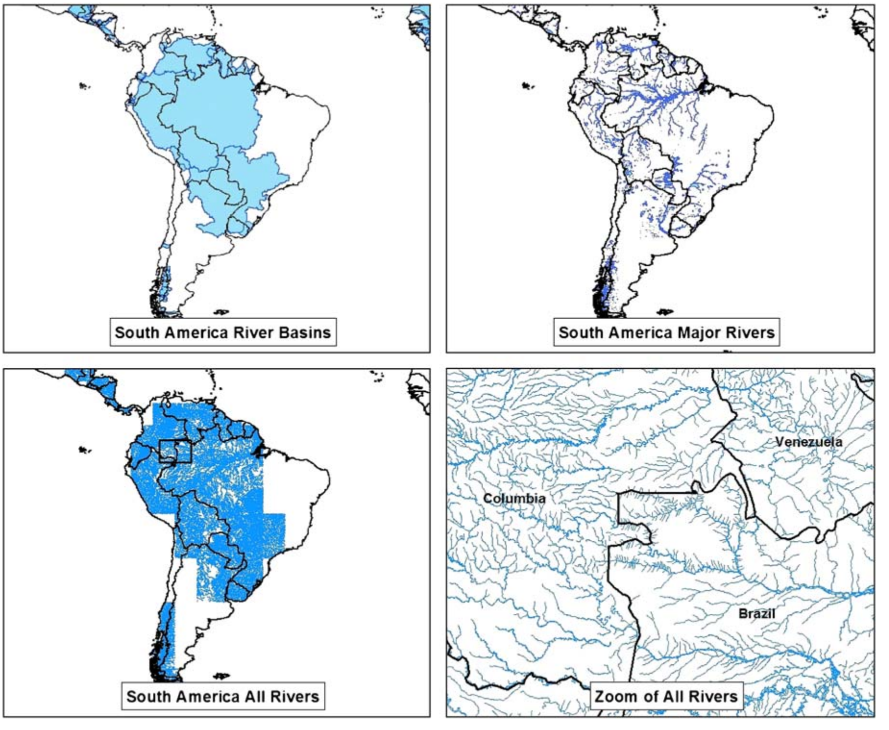

Fig. 2. Four levels of detail for GIS basin measurement, 1997. Source: Maps compiled by Taylor Owen using the 1997 *Digital Chart of the World*.

Our first hypothesis investigates the general relationship between shared rivers and conflict. A dummy variable (Shared basin) notes whether or not the two states in a dyad share a river basin (where they may be contiguous or non-contiguous). The first hypothesis is:

H1: Dyads sharing a river basin have more conflict.[6]

Hypotheses 2 and 3 test the fuzzy boundaries and river crossings scenarios, respectively. Although we use these as alternative scenarios, they are not mutually exclusive. Two countries can have a river boundary as well as a number of river crossings and the new dataset allows us to better sort out the two effects:

H2: Dyads sharing a river boundary have more conflict.
H3: Dyads with more river crossings have more conflict.

The dataset used in our earlier work was limited to immediate neighbors. The dataset now includes non-contiguous dyads sharing a river basin, so we analyze all dyads that are located in

[6] In all the hypotheses, 'conflict' is shorthand for 'violent conflict behavior', the conflict is hypothesized to take place between the two countries in the dyad (rather than between these countries and others), and it is assumed that 'everything else is equal'.

the same continent, with the length of the land boundary in the dyad included as a control variable. Both non-contiguous countries and countries without a river boundary were scored zero on this variable. Hypothesis 2 is tested using the logged length in kilometers of the boundary between contiguous dyads demarcated by a river (river boundary). Hypothesis 3 considers the number of river crossings of a border between two countries, counted using the new GIS rivers database (river crossings).

To investigate concerns for conflict over scarce inequitably distributed resources, we test the following hypotheses:

H4: Dyads that share greater amounts of water resources have more conflict.
H5: Dyads with an unequal distribution of shared water resources have more conflict.

Hypothesis 4 is investigated using a variable for the log of the total size in km^2 of the river basins shared by the dyad (basin size). To test Hypothesis 5 we calculate the log of the area of the parts of the shared basins that are located in the upstream state (basin upstream) as well as the percentage of the total basin area lying in the upstream state (percent upstream).[7] As is evident from the bivariate analysis in Table 1, all of the basin-related variables designed to test Hypotheses 2–5 are significantly associated with conflict. Without multivariate analysis, however, it is not possible to differentiate between the resource scarcity and fuzzy boundaries scenarios.

In place of the water scarcity variable used in our earlier work, we now use a measure of rainfall and a measure of drought. We interact our measures of water scarcity with water resource measures to obtain Hypotheses 6 and 7:

H6: Dyads sharing a river basin have more conflict if one or both of the countries in the dyad have low rainfall.
H7: Dyads sharing a river basin have more conflict if one or both of the countries in the dyad have recently experienced drought.

To test Hypothesis 6 we relied on data from Mitchell and Hulme (2001) for the mean national rainfall over a 30-year period, 1968–1998. We used the non-weighted average for the two countries as our dyadic measure of rainfall. We also created an interaction term with a variable representing the presence of a shared basin.[8] As a second scarcity variable, to test Hypothesis 7, we used the number of droughts. This is not defined biophysically but in terms of the natural disasters each country had experienced per year from 1975 to 2000 (data from EM-DAT, 2001). This variable incorporates the capacity of a country to adapt and mitigate the harmful effects of dry weather. The drought measure is similar to the original water scarcity variable in that it represents a strain which could stimulate conflict. However, the drought variable used can be disaggregated by individual years, whereas the water scarcity variable was assumed to be the same for the entire 30-year period. We transformed this variable into a dummy (drought) that records whether or not one or both countries experienced at least one drought at any time during the past 5 years. Together, the data on mean rainfall over a 30-year period (1968–1998) and the variable for recent

[7] In dyads that share more than one river basin, the upstream state was taken to be the state containing the greater total area of upstream river basin.

[8] We also tried a dichotomous version of this variable which had the value 1 if either of the two states had average rainfall in the bottom 25th percentile of the world range. This variable yielded results similar to the continuous measure.

Table 1
Bivariate analysis of conflict and the independent variables, 1880–2001

Variable	Parameter estimate	Standard error	Odds ratio	*N*
Shared basin (yes/no)	0.83***	0.089	2.3	111,336
River boundary (ln of km)	0.13***	0.021	1.13	111,454
River crossings (number)	0.0095*	0.0040	1.0095	111,454
Basin size (ln of km^2)	0.059***	0.0063	1.0059	111,336
Upstream basin (ln of km^2)	0.070***	0.0082	1.072	111,454
Percent upstream (%)	1.58***	0.28	4.85	111,454
Dry (yes/no)	0.39***	0.060	1.48	127,110
Drought (yes/no, during past 5 years)	−0.32	0.20	0.73	47,369
Middle East and North Africa (yes/no)	−0.047	0.072	0.95	111,454
Sub-Saharan Africa (yes/no)	−0.13*	0.050	0.88	111,454

$*p < 0.05$, $**p < 0.01$, $***p < 0.001$.
Here and in the following tables we report robust standard error estimates, clustering on each dyad (StataCorp, 2003, pp. 270–275).

drought incidents over the last 25 years represent a significant improvement on the single-year water-scarcity variable used in the earlier shared rivers studies.

The scarcity approach to conflict would lead us to expect that resource conflict will be particularly common in regions where resource stress is most pronounced. We test the hypotheses that the Middle East, North Africa, and sub-Saharan Africa experience greater conflict over water resources:

H8: Dyads sharing a river basin have more conflict if one or both of the countries in the dyad are in the Middle East or North Africa.
H9: Dyads sharing a river basin have more conflict if one or both of the countries in the dyad are in sub-Saharan Africa.

We code a dummy variable for dyads with one or both states in the Middle East and North Africa (MENA), and another for dyads with one or both states in sub-Saharan Africa (SSA).[9] These variables were then interacted with the presence of a shared basin. In the bivariate analysis, both the MENA and SSA dummies are negatively related to conflict, although the estimate is significant only for SSA. The ability to test the vulnerability to water wars of these two regions of special interest to theories of scarcity conflict is another advantage over our earlier dataset, which had relatively poor coverage of these areas.

Many developed nations have ample water supply and are not forced to conserve water. But if and when they are water constrained, wealth and modern technology enable them to manage and conserve water resources, avoid wasteful irrigation practices, and to mitigate the humanitarian impact of water scarcity. Therefore, when countries sharing a river basin also have a relatively high level of economic development, we would expect less overall strain on the water resources in the dyad. Thus:

H10: Among dyads that share a river basin, those with lower levels of development will have more conflict.

[9] See Appendix A for regional definitions.

However, it may also be the case that states with relatively little economic activity do not put much stress on their water resources and have little reason to fight over them. This would lead to an environmental Kuznets curve or inverted parabolic relationship, with conflict most likely among states that have developed to the point of straining their resources but have not yet begun to implement water-saving technologies.

H11: Among dyads that share a river basin, those with intermediate levels of development will have more conflict.

To test Hypotheses 10 and 11, we first calculate a variable for the total level of development in a country dyad (dyad development), defined as the log of the total energy consumption of the dyad divided by its total population. In bivariate analysis, dyad development is negatively related to conflict, as was the development term based on the weaker economic link in the dyad. Next, dyad development is interacted with the presence of a shared river basin. We also interact the shared basin variable with the square of dyad development, to test for increasing returns to wealth.

In Table 1 we show the bivariate relationships between the conflict variable and the various independent variables. The results are in line with our expectations, except for the drought variable. We have omitted the control variables from this table, but these results are also generally surprise-free.

A multivariate model for interstate conflict

In Table 2, Model A, we show the results from a multivariate model with just the control variables. The strongest predictor of peace within a dyad is Peace history, a variable generated using a decay function containing the number of previous years without a militarized dispute in the dyad.[10] Variables representing the political make-up of the dyad as compared to a reference dyad of two democracies were the next most important factors in determining conflict; regime type is taken from the Polity IV scale of democracy and autocracy (Marshall & Jaggers, 2003). As has been documented extensively (e.g. in Russett & Oneal, 2001), the political make-up of a dyad tells us a great deal about its propensity for conflict. The regime type with the greatest positive correlation with conflict is that of inconsistent regimes. We define this as a case in which both states have a combined score that is either missing or in the inconsistent range (falls between −5 and +5), or the combination of an autocracy (with a score of −6 or less) and a state with either a missing or inconsistent coding. Our results agree with a number of studies that find that transitional or inconsistent regimes are especially prone to both external and internal violence (Hegre, Ellingsen, Gates, & Gleditsch, 2001; Mansfield & Snyder, 2002). The second most dangerous regime type constellation was that of a single democracy, in which one and only one state is a consistent democracy, defined as having a combined score of 6 or more (its dyadic partner's score may be missing, unconsolidated, or authoritarian). Finally, a dyad of two autocracies is also at greater risk of a fatal military dispute than the reference group, two

[10] The variable was defined as $-(2^{(-\text{years of peace})/\alpha})$, where the half-life parameter α was set to 1 to maximize the log likelihood in Model 1 (see Toset et al., 2000: fn. 14). We also estimated the model using the cubic spline correction for temporal dependence (Beck, Katz, & Tucker, 1998), but found that this did not change the model results and had a lower goodness of fit. Years of peace in the dyad were taken from the COW data downloaded through EUGene (Bennett & Stam, 2003). We used the adjusted values in Werner (2000), which document pre-1816 years of peace in the dyad.

Table 2
Multivariate analysis of conflict and control variables, all dyads, 1880–2001

Variable	Model A		Model B	
	Parameter estimate	Standard error	Parameter estimate	Standard error
Peace history	−3.61***	0.097	−3.65***	0.096
Inconsistent regimes (yes/no)	2.25***	0.34	2.22***	0.35
Single democracy (yes/no)	1.69***	0.33	1.70***	0.33
Two autocracies (yes/no)	1.77***	0.38	1.73***	0.39
Development (ln energy consumption per cap)	−0.011	0.031	−0.018	0.029
Dyad size (ln population)	0.37***	0.067	0.37***	0.068
Major power (yes/no)	0.33	0.18	0.36*	0.17
Alliance (yes/no)	−0.17	0.15		
Distance (ln km)	−0.70***	0.15	−0.71***	0.14
Contiguity	0.20	0.93		
Boundary length (ln km)	0.14	0.11	0.13***	0.023
Post-cold war (yes/no)	0.054	0.16		
System size	0.18	0.17		
Constant	−6.31	1.07	−6.72	0.82
N	104,974		107,710	
Pseudo-R^2	0.38		0.38	

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

democracies. All these findings are in line with the well-known hypothesis of a liberal peace between democratic regimes.

As in our earlier articles, we find no evidence of the level of development as a contributing factor to conflict. Because the level of development is highly correlated with regime type, this non-result is not entirely surprising. By contrast, dyad size, defined as the log of the combined population of the states, is positively related to conflict and highly significant. The presence of one or more major powers within the dyad is also positive, but not highly significant when controlling for dyad size. These findings are explained by the fact that big states and major powers have both more resources and capabilities to pursue military disputes, and more diverse and widespread international interests (see Hegre, 2005).

Other realist factors do not perform as well in our model. The presence of an alliance[11] is not a significant predictor of conflict. As expected (see Buhaug & Gleditsch, 2006), the distance between the capitals of states 1 and 2 significantly reduces the probability of conflict. And, as reported in Furlong et al. (2006) the opportunity for conflict, defined by logged Boundary length, yields a small positive increase in conflict probability. Contiguity – usually a very robust predictor of interstate conflict (Vasquez, 1995) – is not significant in the presence of the distance and boundary length variables. Since distance always is low for contiguous countries and Boundary length is zero for non-contiguous countries, there is not much additional information in the contiguity variable. A dummy variable for the post-cold war period (defined as 1990 or later) is not significant. A system size variable was included to control for the decrease in the risk of conflict in non-neighboring countries resulting from the enormous increase in the number of non-neighboring dyads in

[11] Defined as the presence of an entente or a defense pact between the states. These results did not change when we included neutrality pacts as well.

the international system (Raknerud & Hegre, 1997, p. 391). The variable is not significant here since a higher fraction of same-continent dyads are neighbors, and the statistical problems resulting from an increase in the size of the international system are less serious.

In Model B, the model was reestimated without the insignificant alliance, contiguity, post-cold war, and system size variables.[12] In the absence of contiguity, boundary length significantly increases the risk of militarized dispute. We retained dyad development in the model since it will have a function in later analyses. Model B has a relatively low number of variables, while the pseudo-R^2 is high for a model of this type. Hence, we use Model B as a 'control model' in all subsequent estimations.

Conflict over basins or borders?

In Table 3 we show the result of a series of tests designed to analyze the ambiguities of previous models of the relationship between shared rivers and military disputes. The control variables reported in Table 2 Model B were included in the estimations but are not reported here. Most estimated coefficients and standard errors are close to those reported in Table 2. The notable exception is the Boundary length variable, which is positive but not significant at the 5% level in Models 1 and 4. First, in Model 1, we reaffirm that there is a positive and significant dyadic relationship between sharing a river basin and the onset of conflict. The risk of fatal MIDs is approximately doubled by the presence of a shared basin. The estimated probability of a fatal MID for a typical dyad without a shared river basin is 0.21%. The probability for a dyad with a shared basin is 0.44%.[13]

In order to differentiate between the resource scarcity and the fuzzy boundary scenarios, we then test (in Model 2) the length of the boundary demarcated by a river (river boundary). The variable is not significantly related to conflict when controlling for the overall length of the boundary. Neither is the number of river crossings (Model 3). The conflict proneness of shared basin must derive from something other than the presence of contentious river crossings or potentially fuzzy river boundaries.

Models 4 and 5 test the resource conflict scenario. Both basin size and upstream basin size show a positive and significant relationship to conflict. The substantive effect is similar to that of the shared basin variable: when increasing these variables from the 10th to the 90th percentile, the probability of dispute for the typical dyad increases from 0.21% to 0.42% for basin size, and from 0.22% to 0.35% for upstream basin size. Our results strongly suggest that the size of the basin is more important than either the river boundary length or the number of river crossings. The combined resources present in a basin, including both fresh and groundwater, present a potential source of conflict. While acute conflicts over individual rivers are rare, the presence of a large shared river basin provides a resource worth fighting for. Since we control for both the size of the two countries, major power status, and the length of the border between them, we are reasonably certain that this is not a country size effect – the heightened conflict risk seems to be due to the amount of water resources. It may also be due to resources or the production of goods indirectly based on the availability of water and water transportation,

[12] Including contiguity along with boundary length and distance also caused severe collinearity problems.

[13] The predicted probabilities reported here and below were estimated using Clarify (King, Tomz, & Wittenberg, 2000). The 'typical dyad' was defined as a dyad with one democracy, no unconsolidated regimes, no major powers, and the mean value for the remaining variables.

Table 3
Shared basins, shared borders and conflict: multivariate analysis, all dyads, 1880–2001

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Parameter estimate	Standard error	Parameter estimate	Standard error	Parameter estimate	Standard error	Parameter estimate	Standard error	Parameter estimate	Standard error	Parameter estimate	Standard error
Shared basin (yes/no)	0.73**	0.27										
ln(length of river boundary)			0.048	0.036								
Number of river crossings					0.00089	0.0030						
ln(basin size), km^2							0.052**	0.019				
ln(upstream basin size), km^2									0.046*	0.023		
Percent upstream											0.39	0.42
N	107,584		107,702		107,702		107,584		107,702		107,584	
Pseudo-R^2	0.38		0.38		0.38		0.38		0.38		0.38	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

such as high population densities, fisheries, fertile agricultural areas, or cities or industrial sites located by rivers because of their historical economic importance.

The dependent variable in the analyses reported in Table 3 includes conflicts that vary greatly in terms of magnitude. To investigate whether the association between shared river basins and conflicts apply to all types of conflict, we reestimated the models in Table 3 for all MIDs (including nonfatal ones) and for wars with 1000 or more casualties. The coefficients tend to be higher for the least serious conflicts. The estimate for Shared basin, for instance, is 0.92 for all MIDs, but only 0.34 for wars. The differences between the estimates are not statistically significant in all cases. Still, this finding suggests that water resources are quite important and can lead to serious conflicts between states, but may be less frequently related to large-scale conflicts, or war.

We also tested whether dyads with a high percentage of a shared river basin in the upstream state have a higher risk of conflict than other dyads, but did not obtain significant results (Model 6). This suggests that the absolute size of the available resources rather than the disparity in the distribution is a risk factor for conflict. An upstream state has an incentive to alter the landscape of the basin and siphon off greater water resources (e.g. by means of a dam or extensive irrigation channels), while a downstream state has an incentive to oppose such actions, regardless of where most of the basin currently lies. For example, much of the Nile river basin is located in Sudan, and that nation's use of the water resources affects its downstream riparian neighbor, Egypt. In such cases, the threat of using force (including the bombing of dam projects) may be used by the downstream partner to limit water extraction upstream. The overall size of the basin signifies its importance to Egypt and might make it attractive to use military threats. Four onsets of military disputes between Sudan and Egypt are recorded in the MID dataset. None of them involved any fatalities and the dataset does not contain any information on whether or not these MIDs were related to conflicts over the river water.

In contrast to much of the water scarcity literature, Yoffe et al. (2003) found no significant relationship between water stress and conflict events. In Table 4 we relate fatal disputes to two measures of water stress. The average rainfall variable has a significant, negative estimate. Dry countries seem to have a higher risk of interstate conflict as indicated by Table 1. The interaction term has a positive estimate of the same magnitude and level of significance, however, implying that dyads with low average rainfall have a higher risk of interstate conflict only if they do *not* share a river basin.[14] For dyads that do not share a basin, the predicted probability of fatal dispute for the typical dyad drops from 0.28% to 0.11% when increasing the average rainfall from the 10th to the 90th percentile. For dyads that share a basin, the predicted probability decreases only from 0.54% to 0.53% when altering the rainfall variable correspondingly. This finding may indicate that countries with endemic water scarcity and shared basins have long-term incentives to invest in water management measures and avoid conflict that other basin-sharing dyads do not.

Our socio-political measure of water scarcity, drought, does not yield significant results on its own or for any of the interaction terms with basin variables (Model 8). One explanation may be that the component of drought that relates to a country's ability to cope with a water shortage is already controlled for with several of the other variables included in the regression such as development, democracy, and major power status. Similarly, poor nations, which also tend to be autocratic, are more likely to require international aid in times of drought.[15]

[14] A likelihood ratio test shows that adding the average rainfall and the interaction term to Model 1 reduces the log likelihood by 19 points, which is clearly significant. Inspection of the correlation matrix for the estimates does not indicate that these results are due to collinearity problems.

[15] The correlation between drought and development is −0.14.

Table 4
Water scarcity and shared river basins: multivariate analysis, all dyads, 1880–2001

Variable	Model 7		Model 8	
	Parameter estimate	Standard error	Parameter estimate	Standard error
Shared basin	0.26	0.30	1.17***	0.33
Average rainfall	−0.00080**	0.00028		
Average rainfall*shared basin	0.00081**	0.00031		
Drought			0.22	0.37
Drought*shared basin			−0.34	0.36
N	100,739		47,349	
Pseudo-R^2	0.39		0.39	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Regional impact

In Table 5 we include models testing for the impact of shared water resources in different regions. In Model 9, the Middle East and North Africa dummy is not itself a significant predictor of conflict, and the shared basin variable continues to be positively related to conflict. The interaction term is positive as hypothesized, but not statistically significant. In the case of sub-Saharan Africa (Model 10), the regional dummy on its own indicates that there is less conflict in this region than in the rest of the world. The predicted probability for the typical dyad is 0.12% for the region as compared to 0.24% for the rest of the world. This may seem counterintuitive, but most conflict in this region is internal rather than international. Also, we have controlled for some of the factors that might have predicted conflict here, notably regime type. The interaction term, sub-Saharan Africa*shared basin, has a positive but not significant relationship to dispute onset. While the water scarcity literature suggests that basin-sharing countries in water-scarce regions are probably at higher risk of dispute than basin-sharing countries elsewhere, the relationship here is not significant.

The impact of economic development

Economic development was found to be significantly related to less conflict in the bivariate analysis, but unrelated to conflict in the multivariate analysis, with or without rivers and basin data. This is consistent with what was found in Furlong et al. (2006), but not with the results in Toset et al. (2000). The development variable becomes insignificant when we estimate the model using robust standard errors. Previous studies have obtained mixed results for this variable. Bremer (1992) and Maoz and Russett (1992) find developed dyads to have a lower risk of conflict, but Oneal, Oneal, Maoz, and Russett (1996) find no relationship and Mousseau (2000) finds a positive relationship. The inconclusive results might be due to the high correlation between development and democracy. Some, however, (e.g. Hegre, 2000) have found the democracy variable to be less robust than development when both are included. This puzzle led us in the direction of the argument about the environmental Kuznets curve (Cole, 2003), which suggests that countries at low levels of economic development do not suffer much from pollution or resource scarcity because of their limited economic activity. At very high levels of economic development, the problem of resource scarcity is also smaller, partly because the political

Table 5
Dyad development, regional dummies, and conflict: multivariate analysis, all dyads, 1880–2001

Variable	Model 9		Model 10		Model 11	
	Parameter estimate	Standard error	Parameter estimate	Standard error	Parameter estimate	Standard error
Shared basin	0.69**	0.28	0.62*	0.25	0.64*	0.26
Dyad development					0.059	0.044
Dyad development squared					−0.028	0.035
Dyad development*shared basin					−0.15***	0.051
Dyad development sq. *shared basin					−0.036	0.047
Middle East and North Africa	0.37	0.20				
MENA*shared basin	0.19	0.28				
Sub-Saharan Africa			−0.76*	0.38		
Sub-Saharan Africa*shared basin			0.63	0.38		
N	107,584		107,584		107,584	
Pseudo-R^2	0.38		0.38		0.38	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

priorities change and a clean environment is valued more highly, partly because rich countries can afford to invest in new technology that economizes resource use. The environmental Kuznets curve describes well the pattern of some common forms of pollution, such as SO_2 in cities, but not others, such as greenhouse gas emissions. It underlies the modernization argument that economic development will eventually improve the environment rather than destroy it (Lomborg, 2001; Simon, 1996).

We test this argument here by creating a joint development variable, which measures the total economic activity in the pair of nations (the variable dyad development is defined as the log of the total energy consumption in the dyad divided by its total population) and square it to look for the inverted U suggested by the environmental Kuznets curve. If the environmental Kuznets curve hypothesis fits this dataset, rich and poor countries should be less stressed by resource scarcity and therefore presumably less inclined to fight over it. In Model 11, Table 5 we test this argument by including both the linear and the squared term for economic development[16] and the same two terms interacted with Shared basin. The coefficient for dyad development*-shared basin is significant and negative, supporting Hypothesis 10.

The squared term and the corresponding interaction term are not significant. However, a likelihood ratio test indicates that they are jointly significant at the 0.05 level.[17] Their signs point in the direction of a Kuznets curve relationship in these data: the estimated probability of dispute is plotted as a function of dyad development in Fig. 3. The black line plots the estimated probabilities for dyads that do not share river basins. The grey line plots the

[16] Hibbs (1973) found that a model including a squared economic development term predicted higher levels of internal violence for middle-income countries. The argument that overcoming dire poverty is necessary to organize violent protest, seems reasonable for interstate violence, too, but we are not aware of any empirical application of it.

[17] The likelihood ratio test is not applicable to models using robust estimation of standard errors. The figures reported here are based on an estimation with ordinary standard errors. The squared terms were not individually significant in this model either.

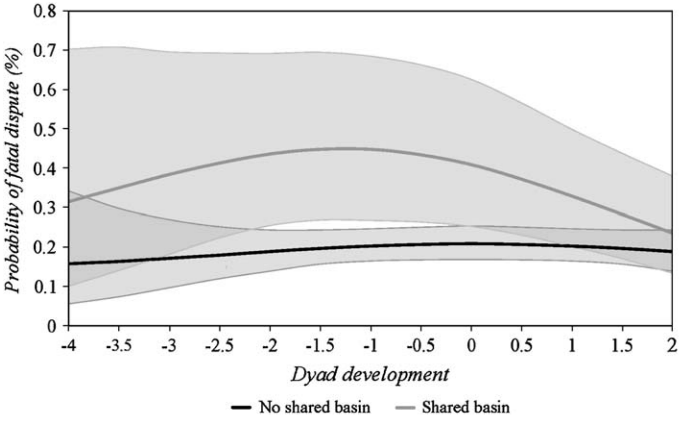

Fig. 3. Estimated probability of fatal dispute by shared basin and dyad development, 1880–2001. The shaded area around each line represents a 90% confidence interval.

probabilities for shared basin dyads. The shaded areas indicate 90% confidence intervals for the two lines.[18] The figure shows that a shared basin does more to increase the estimated risk of dispute at the intermediate level of development than for low and high levels. The confidence bands do not overlap in the middle range, indicating that this difference is statistically significant for this type of dyads.

These results provide clear support for Hypothesis 10: the more developed a dyad, the less is the increased risk resulting from sharing a river basin. This is most likely because wealthier states have the means to cope with resource crises and to make use of advanced water management technology. The support is somewhat more ambiguous for Hypothesis 11. Still, they suggest that the benefits to development may not be linear: the estimated initial increase in the effect of shared basins indicates that resource conflict may accelerate as states develop.

However, the results also indicate that strategies of resource and scarcity management can develop early in the development process and thus mitigate conflict as basin usage intensifies. Namibia provides a good example of such policies. It is the very poorest river-sharing dyads, rather than those at middle income levels, that are most at risk of resource conflicts.

Conclusions

Of the two scenarios invoked to explain the relationship between shared rivers and interstate conflict in the two earlier studies, the fuzzy boundary does not receive much support. A shared basin is positively and significantly related to conflict, while a river boundary is not.

Support for the scarcity view of conflict is somewhat ambiguous. As a first test of the importance of the upstream–downstream relationship, the number of river crossings is not significantly related to conflict. The water scarcity and shared water resource variables did not perform as expected. Drought was not shown to have any effect at all. Dry countries have significantly more conflict, less so when they share a large river basin.

[18] The estimated probabilities and the confidence bands (based on robust standard error estimates) were obtained using Clarify.

Modernization theory receives some support in that shared rivers seem to have less influence on conflict when dyad development is high. This may indicate that wealthier countries can afford to compensate for scarcities by technological substitution or innovation, or that their priorities or challenges are different. The analysis, however, also suggests the existence of an environmental Kuznets curve – shared river basins increase the risk of conflict more for middle-income countries than for low-income countries.

The strongest results are found for the overall importance of a river basin. This does not point clearly in the direction of either of the two scenarios that we posited at the start. It could hint at 'resource curse' argument (Sachs & Warner, 1995): the greater the resource, the more conflict over it. Water is not the kind of lootable resource widely believed to stimulate internal armed conflict (Lujala, Gilmore, & Gleditsch, 2005). But a large river basin can bring other benefits, such as good communications, cheap hydroelectric power, abundant fisheries, and ample opportunities for irrigation. Even if such goods are not the stuff of which wars are made, they may stimulate more serious rivalry over the sharing of the resource than that which arises over trivial shared water resources. This point requires further research. It is also possible that the basin size variable captures other aspects of a dyad's neighborhood – pairs of countries that share a large basin will often be located centrally in large continents. Such countries tend to have many neighbors and there are many opportunities for spillovers from conflicts with other states.

In a comprehensive study on river basins and conflict, Yoffe et al. (2003) created a large global GIS database of biophysical, socio-economic, and geopolitical data to identify basins at risk of political stress. Their project used events data to code a 20-point nominal range of actions (from treaties to war) over water. These data were historically matched with the GIS data using the river basin as the spatial unit of analysis to come up with indicators of possible river stress. From this, 17 basins were identified with 'red flags'. In brief, they found that nations generally cooperate about water (particularly if they cooperate in other areas as well), that the higher the per capita GDP or the lower the population density the greater the cooperation, that water stress is not a significant indicator of dispute, and that neither government type nor climate shows any impact on water disputes. Some of our results are similar, but we find a greater impact of the water variables on conflict. A potential strength in this and similar analyses using their Water Events Database is that the conflict and cooperation events are issue coded.[19] Thus, if conflicts between riparian states occur for reasons other than the shared river, they will be excluded. However, issue coding assumes that the main (or only) issue can be reliably identified for each act or cooperation and conflict, which is not obviously true. Many large *n* studies of ethnic conflict, for instance, avoid classifying each conflict as ethnic or non-ethnic, but relate conflict in general to measures of ethnic fragmentation (Ellingsen, 2000). We follow the same approach here.

Another problem with the studies by Wolf et al. (1999a) is that averaging acts of cooperation and conflict into one dependent variable ignores the possibility that shared rivers might stimulate conflict as well as cooperation. Using the basin as the unit of analysis also impedes comparison with most studies of interstate conflict. Finally, the work done by Wolf et al. is, so far, limited to bivariate analysis.[20]

[19] Another major effort to issue code interstate conflicts is the ICOW project. See Mitchell and Prins (1999) and www.icow.org.

[20] Another problem is that *n* varies greatly in the different bivariate computations.

Our new dataset reinforces the conclusion from the earlier studies that there is some relationship between shared river basins and conflict. But neither the fuzzy boundary scenario nor the resource scarcity argument provides a fully satisfactory explanation for why this is so. The resource curse scenario needs to be investigated more fully.

As in our earlier studies, this article refers mainly to low-level conflict and our results are not to be taken as evidence of impending ‘water wars’. Low-level interstate conflict in no way excludes cooperation; indeed it may be an important incentive for more cooperation. The three-way relationship (shared rivers–conflict–cooperation) also remains to be investigated.

Finally, the impact of shared rivers is not, of course, the last word on how water scarcity may influence armed conflict. Many case studies suggest that water scarcity may contribute to intra-state violence. Investigating such claims is beyond the scope of this article.

Appendix A. Regional definitions

Middle East and North Africa: Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, United Arab Emirates, Yemen (Arab Republic), Yemen (Peoples Republic).

Sub-Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo (Zaire), Cote d’Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea–Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zanzibar, Zimbabwe.

Definitions taken from Mack (2005).

References

Ashton, P. (2002). Avoiding conflicts over Africa’s water resources. *Ambio*, *31*(3), 236–242.

Beaumont, P. (1997). Water and armed conflict in the Middle East – Fantasy or reality? 1997. In N. P. Gleditsch (Ed.), *Conflict and the environment* (pp. 355–374). Dordrecht, Netherlands: Kluwer Academic.

Beck, N., Katz, J. N., & Tucker, R. (1998). Taking time seriously: Time-series–cross-section analysis with a binary dependent variable. *American Journal of Political Science*, *42*(4), 1260–1288.

Bennett, D.S., Stam, A.C. (2003). *EUGene documentation version 3.03*. Pennsylvania State University and Dartmouth College. <www.eugenesoftware.org>.

Bercovitch, J., & Jackson, R. (1997). *International conflict: A chronological encyclopedia of conflicts and their management 1945–1995*. Washington, DC: Congressional Quarterly.

Biliouri, D. (1997, 18–21 March). *Environmental issues as potential threats to security*. Paper presented at the 38th annual convention of the International Studies Association, Toronto.

Bremer, S. A. (1992). Dangerous dyads. Conditions affecting the likelihood of interstate war, 1816–1965. *Journal of Conflict Resolution*, *36*(2), 309–341.

Brooks, K. N., Ffoliott, P. F., Gregersen, H. M., & De Bano, L. F. (1997). *Hydrology and the management of watersheds*. Ames, IO: Iowa State University Press.

Buhaug, H., & Gleditsch, N. P. (2006). The death of distance? The globalization of armed conflict [chap. 8]. In M. Kahler, & B. Walter (Eds.), *Territoriality and conflict in an era of globalization* (pp. 187–216). Cambridge: Cambridge University Press.

Clodfelter, M. (2002). *Warfare and armed conflicts: A statistical reference to casualty and other figures, 1500–2000* (2nd ed.). Jefferson, NC: McFarland.

CNRET (1978). *Register of international rivers*. Oxford: Pergamon, for Centre of Natural Resources, Energy, and Transport of the Department of Economic and Social Affairs of the United Nations.

Cole, M. A. (2003). Development, trade, and the environment: How robust is the environmental Kuznets curve? *Environment and Development Economics*, *8*(4), 557–580.

De Villiers, M. (2003). *Water: The fate of our most precious resource*. Toronto: McClelland & Stewart.

Dobson, A. (1990). *Green political thought: An introduction*. London: Unwin Hyman.

Dryzek, J. S. (1996). *Politics of the earth: Environmental discourses*. Cambridge, MA: Oxford University Press.

Ellingsen, T. (2000). Colorful community or ethnic witches' brew? Multiethnicity and domestic conflict during and after the cold war. *Journal of Conflict Resolution*, *44*(2), 228–249.

EM-DAT: The OFDA/CRED *International Disaster Database* (Data as of December 2001). Data Provider: The OFDA/CRED International Disaster Database, Université Catholique de Louvain. <www.cred.be/emdat>.

Falkenmark, M. (1990). Global water issues facing humanity. *Journal of Peace Research*, *27*(2), 177–190.

Furlong, K., & Gleditsch, N. P. (2003). The boundary dataset. *Conflict Management and Peace Science*, *20*(1), 93–117. The dataset can be downloaded from <www.prio.no/cscw/datasets>.

Furlong, K., Gleditsch, N.P., & Hegre, H., (2006). Geographic opportunity and neomalthusian willingness: Boundaries, shared rivers, and conflict. *International Interactions, 32*(1), in press.

Ghosn, F., & Palmer, G. 2003. Militarized interstate dispute data, version 3.0. <http://cow2.la.psu.edu>.

Giordano, M., & Wolf, A. (2003). Sharing waters: Post-Rio international water management. *Natural Resources Forum*, *27*, 163–171.

Gleditsch, K. (1952). Rivers as international boundaries. *Nordisk Tidsskrift for International Ret*, *22*(1), 15–32.

Gleditsch, N. P. (1999). Do open windows encourage conflict? *Statsvetenskaplig tidskrift*, *102*(3), 333–349.

Gleditsch, N. P. (2003). Environmental conflict: Neomalthusians vs. cornucopians. In H. G. Brauch, P. H. Liotta, A. Marquina, P. F. Rogers, & M. El-Sayed Selim (Eds.), *Security and the environment in the Mediterranean: Conceptualising security and environmental conflicts* (pp. 477–485). Berlin: Springer.

Gleick, P. H. (1993). Water and conflict: Fresh water resources and international security. *International Security*, *18*(1), 79–112.

Harvey, D. (1996). *Justice, nature and the geography of difference*. Cambridge, MA: Blackwell.

Hegre, H. (2000). Development and the liberal peace: What does it take to be a trading state? *Journal of Peace Research*, *37*(1), 5–30.

Hegre, H. (2005, September 8–10). *Gravitating toward war. The gravity model of trade and the liberal peace*. Paper presented to the 3rd general conference of the European Consortium of Political Research, Budapest. <http://folk.uio.no/hahegre/Papers/gravitatingmay2005.pdf>.

Hegre, H., Ellingsen, T., Gates, S., & Gleditsch, N. P. (2001). Toward a democratic civil peace? Democracy, political change, and civil war, 1816–1992. *American Political Science Review*, *95*(1), 33–48.

Hibbs, D. A. (1973). *Mass political violence. A cross-national causal analysis*. New York: Wiley.

Homer-Dixon, T. F. (1999). *Environment, scarcity, and violence*. Princeton, NJ: Princeton University Press.

Huth, P. (1996). *Standing your ground: Territorial disputes and international order 1648–1989*. Ann Arbor, MI: University of Michigan Press.

Irani, R. (1991). Water wars. *New Statesman & Society*, *4*(149), 24–25.

Keesing's. (2004). *Keesing's record of world events/Keesing's contemporary archives*. Washington, DC: Keesing's Worldwide.

King, G., Tomz, M., & Wittenberg, J. (2000). Making the most of statistical analysis: Improving interpretation and presentation. *American Journal of Political Science*, *44*(2), 347–361.

Klare, M. T. (2001a). The new geography of conflict. *Foreign Affairs*, *80*(3), 49–61.

Klare, M. T. (2001b). The new landscape of global conflict. *Resource wars*. New York: Metropolitan.

Lomborg, B. (2001). Resource constraints or abundance? In P. F. Diehl, & N. P. Gleditsch (Eds.), *Environmental conflict* (pp. 125–152) Boulder, CO: Westview.

Lujala, P., Gleditsch, N. P., & Gilmore, E. (2005). A diamonds curse? Civil war and a lootable resource. *Journal of Conflict Resolution*, *49*(4), 538–562.

Mack, A. (Ed.). (2005). *Human security report*. New York and Oxford: Oxford University Press, for the Human Security Centre, University of British Columbia. <www.humansecurityreport.info/>.

Maoz, Z., & Russett, B. (1992). Alliances, wealth, contiguity and political stability: Is the lack of conflict between democracies a statistical artifact? *International Interactions*, *17*(3), 245–267.

McLoughlin, P. (2004). Scientists say risk of water wars is rising. *Environmental News Network*, cited from Reuters, 24 August, <www.enn.com/news/2004-08-24/s_26656.asp>.

Mansfield, E. D., & Snyder, J. (2002). Democratic transitions, institutional strength, and war. *International Organization*, *56*(2), 297–337.

Marshall, M. G., & Jaggers, K. (2003). *Polity IV project. Center for International Development and Conflict Management at the University of Maryland*. <www.cidcm.umd.edu/inscr/polity/>.

Mitchell, S. M., & Prins, B. C. (1999). Beyond territorial contiguity: Issues at stake in democratic militarized interstate disputes. *International Studies Quarterly*, *43*(1), 169–183.

Mitchell, T. D., & Hulme, M. (2001). *Climate data for political areas*. Data Provider: Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre (DDC). <www.cru.uea.ac.uk/cru/data/papers/mitchell2002a.pdf>.

Mousseau, M. (2000). Market prosperity, democratic consolidation, and democratic peace. *Journal of Conflict Resolution*, *44*(4), 472–507.

O'Loughlin, J., Ward, M. D., Lofdahl, C. L., Cohen, J. S., Brown, D. S., & Reilly, D., et al. (1998). The diffusion of democracy, 1946–1994. *Annals of the Association of American Geographers*, *88*(3), 545–574.

Oneal, J. R., Oneal, F., Maoz, Z., & Russett, B. (1996). The liberal peace: Interdependence democracy, and international conflict, 1950–1985. *Journal of Peace Research*, *33*(1), 11–38.

Raknerud, A., & Hegre, H. (1997). The hazard of war: Reassessing the evidence for the democratic peace. *Journal of Peace Research*, *34*(4), 385–404.

Russett, B. M., & Oneal, J. R. (2001). *Triangulating peace: Democracy, interdependence, and international organizations*. New York: Norton.

Sachs, J.D., & Warner, A.M. (1995, December). *Natural resource abundance and economic growth*. NBER Working Paper (W5398). Cambridge, MA: National Bureau of Economic Research.

Salman, S. M. A. (2000). International rivers as boundaries. The dispute over Kasikili/Sedudu Island and the decision of the international court of justice. *Water International*, *25*(4), 580–585.

Serageldin, I., et al. (1995). *Towards sustainable management of water resources*. Directions in Development 14, 910. Washington, DC: World Bank.

Simon, J. L. (1996). *The ultimate resource 2*. Princeton, NJ: Princeton University Press.

Sneddon, C. (2002). Water conflicts and river basins: The contradictions of co-management and scale in northern Thailand. *Society and Natural Resources*, *15*(2), 725–741.

Starr, H. (2002). Opportunity, willingness, and geographic information systems (GIS): Reconceptualizing borders in international relations. *Political Geography*, *21*(2), 243–261.

Starr, J. R. (1991). Water wars. *Foreign Policy*, *82*, 17–36.

StataCorp (2003). *Stata statistical software release 8.0 user's guide*. College Station, TX: Stata Corporation.

Toset, H. P. W., Gleditsch, N. P., & Hegre, H. (2000). Shared rivers and interstate conflict. *Political Geography*, *19*(6), 971–996. The dataset can be downloaded from <www.prio.no/cscw/datasets>.

UNEP (1999). *Global environmental outlook*. Nairobi: UNEP. <www.grida.no/geo2000/ov-e.pdf>.

UNESCO (2003). *Water for people, water for life*. Paris: UNESCO. <www.unesco.org/water/wwap/wwdr>.

Vasquez, J. A. (1993). *The war puzzle*. Cambridge, UK: Cambridge University Press.

Vasquez, J. A. (1995). Why do neighbors fight? Proximity, interaction, or territoriality. *Journal of Peace Research*, *32*(3), 277–293.

Water wars. (2001, 19 May). *New Scientist*, *170*(2291), 3.

Werner, S. (2000). The effect of political similarity on the onset of militarized disputes, 1816–1985. *Political Science Quarterly*, *53*(2), 343–374.

Wesley, P. J. (1962). Frequency of wars and geographical opportunity. *Journal of Conflict Resolution*, *6*(4), 387–389.

Wolf, A. T. (1999a). The transboundary freshwater dispute database project. *Water International*, *24*(2), 160–163.

Wolf, A. T. (1999b). 'Water wars' and water reality: Conflict and cooperation along international waterways. In S. Lonergan (Ed.), *Environmental change, adaptation, and human security* (pp. 251–265). Dordrecht: Kluwer Academic.

Wolf, A. T. (2000). *International water event database*. Retrieved January 20, 2005, from <http://www.transboundary-waters.orst.edu/projects/events/>.

Wolf, A. T., Natharius, J. A., Danielson, J. J., Ward, B. S., & Pender, J. K. (1999). International river basins of the world. *Water Resources Development*, *15*(4), 387–427.

Yoffe, S., Wolf, A. T., & Giordano, M. (2003). Conflict and cooperation over international freshwater resources: Indicators of basins at risk. *Journal of the American Water Resources Association*, *39*(5), 1109–1125.