JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
OCTOBER AMERICAN WATER RESOURCES ASSOCIATION 2003

CONFLICT AND COOPERATION OVER INTERNATIONAL FRESHWATER RESOURCES: INDICATORS OF BASINS AT RISK[1]

Shira Yoffe, Aaron T. Wolf, and Mark Giordano[2]

ABSTRACT: In this paper we seek to identify historical indicators of international freshwater conflict and cooperation and to create a framework to identify and evaluate international river basins at potential risk for future conflict. We derived biophysical, socioeconomic, and geopolitical variables at multiple spatial and temporal scales from GIS datasets of international basins and associated countries, and we tested these variables against a database of historical incidents of international water related cooperation and conflict from 1948 to 1999. International relations over freshwater resources were overwhelmingly cooperative and covered a wide range of issues, including water quantity, water quality, joint management, and hydropower. Conflictive relations tended to center on quantity and infrastructure. No single indicator – including climate, water stress, government type, and dependence on water for agriculture or energy – explained conflict/cooperation over water. Even indicators showing a significant correlation with water conflict, such as high population density, low per capita GDP, and overall unfriendly international relations, explained only a small percentage of data variability. The most promising sets of indicators for water conflict were those associated with rapid or extreme physical or institutional change within a basin (e.g., large dams or internationalization of a basin) and the key role of institutional mechanisms, such as freshwater treaties, in mitigating such conflict.

(KEY TERMS: international river basins; conflict; cooperation; event data; geographic information systems; water resources geography; indicators.)

Yoffe, Shira, Aaron T. Wolf, and Mark Giordano, 2003. Conflict and Cooperation Over International Freshwater Resources: Indicators of Basins at Risk. Journal of the American Water Resources Association (JAWRA) 39(5):1109-1126.

INTRODUCTION

Issues of water and international conflict have appeared with increasing frequency in both the policy literature and popular press (Westing, 1986; Elliott, 1991; Gleick, 1993; Homer-Dixon, 1994; Remans, 1995; Butts, 1997; Elhance, 1999). This literature often stresses various indicators for conflict, including proximity, government type, aridity, and rapid population growth. Yet despite the number of case studies analyzing and comparing water related conflict in various international river basins, little global scale or quantitative evidence has been compiled. Existing work often consists of case studies from the most volatile basins and excludes examination of cooperation, spatial variability, and precise definitions of conflict.

In the Basins At Risk (BAR) project, we addressed the gaps in the literature on international freshwater resources by providing a quantitative, global scale exploration of the relationship between freshwater and conflict. We considered the full spectrum of interactions, using precise definitions of cooperation and conflict, and our approach incorporates a spatial perspective. In essence, we asked whether the theories and claims are supported by historical evidence. We also considered another hypothesis, that the likelihood and intensity of conflict within a basin increase as the magnitude or amount of physical or institutional change exceeds the capacity within the basin to absorb that change.

The BAR project had three objectives: (1) to identify historical indicators of international freshwater conflict and cooperation; (2) to use these indicators to create a framework to identify and evaluate international river basins at potential risk for future freshwater conflict; and (3) to enhance understanding of

[1]Paper No. 02036 of the *Journal of the American Water Resources Association*. **Discussions are open until April 1, 2004.**

[2]Respectively, Diplomacy Fellow, American Association for the Advancement of Science; Associate Professor of Geography, Department of Geosciences, Oregon State University, 104 Wilkinson Hall, Corvallis, Oregon 97331; and Senior Researcher, International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka (E-Mail/Yoffe: SYoffe@mfire.com).

the driving forces that may cause water to become a focus of conflict or cooperation.

It is hoped that such information can contribute to the development of international management approaches to enhance cooperation and mitigate potential conflict over international freshwater resources.

METHODS

Our approach consisted of three main elements: (1) creation of an event database documenting historical water relations, including a methodology for identifying and classifying events by their intensity of cooperation and conflict; (2) construction of a geographic information system (GIS) dataset of countries and international basins, both current and historical, and creation of associated indicator variables (biophysical, socioeconomic, political); and (3) formulation and testing of hypotheses about factors associated with water conflict.

The BAR Water Event Database

In the BAR Water Event Database we compiled all reported instances of conflict or cooperation over international freshwater resources in the world from 1948 to 1999. For each event, we documented the international river basin in which it occurred, the countries involved, the date, the level of intensity of conflict or cooperation, and the main issue associated with each event (Table 1) (Yoffe and Larson, 2002). This information was compiled in a relational database to allow for analyses at an array of spatial and temporal scales.

We defined water events as instances of conflict and cooperation that occur within an international river basin, involve the nations riparian to that basin, and concern freshwater as a scarce or consumable resource (e.g., water quantity, water quality) or as a quantity to be managed (e.g., flooding or flood control, water levels for navigational purposes).

Incidents that did not meet the above criteria were not included as events in the analyses (e.g., use of water as a weapon, victim, or target of warfare; navigation or construction of ports; boundary or territorial disputes such as control over river islands; purchasing and selling of hydroelectricity; involvement of a third party, that is, a nonbasin country; and issues internal to a country).

We chose the time period 1948 to 1999 for its relevance to potential future instances of cooperation and conflict and for data manageability and availability. The spatial coverage is global and considers all international river basins.

We gathered event data from political science datasets – the International Crisis Behavior Project (Brecher and Wilkenfeld, 2000), the Conflict and Peace Databank (Azar, 1980), the Global Event Data System (Davies, 1998), and the Transboundary Freshwater Dispute Database (Wolf, 1999) – as well as historical analyses and case studies of international river basins. In addition, we conducted our own primary searches of several electronic news databases – Foreign Broadcast Information Service, World News Connection, Lexis-Nexis Academic Universe – from which we obtained about half of our event data.

Incidents of conflict and cooperation over freshwater were considered in two basic formats: *interactions*, in which incidents are broken out by the country pairs (dyads) and basins involved; and *events*, in which one entry is provided for each incident in a basin regardless of the number of country pairs involved.

The BAR Water Event database contains approximately 1,800 events, which can be broken out into approximately 3,300 country pair interactions. The data include events for 124 countries and for 122 out of 265 current and historical international basins.

The Historical GIS

We created a GIS dataset to delineate all current and historical international basins and their riparian countries from 1948 to 1999 (Fiske and Yoffe, 2002). A GIS is a computerized system that enables storage, management, analysis, modeling, and display of spatial and associated data. The GIS allowed us to conduct analyses at a range of spatial scales including country, region, and basin/country polygon (a country's territorial share of an international basin). The key unit of analysis, however, was the international river basin, which comprises all the land that drains through a given river and its tributaries into an ocean or an internal lake or sea and includes territory of more than one country. The term "riparian" here refers to countries whose territory includes part of an international river basin.

BAR's GIS includes 263 current international basins and two historical basins. This historical GIS enabled incorporation of both temporal and spatial variability into our analyses. It allowed us to derive data including population, climate, and water availability at the basin level or other scales and to explore correlations between these variables and the event data. This ability to explore factors associated with events – to ask why an event occurred – is a powerful feature of the BAR Event Database and directly

TABLE 1. Example of Events in BAR Water Event Database.

Date	Basin	Countries Involved	BAR Scale	Event Summary	Issue Type
December 5, 1973	LaPlata	Argentina; Paraguay	4	Paraguay and Argentina agree to build 1B dam, and hydroelectric project.	Infrastructure
January 1, 1976	Ganges	Bangladesh; India; United Nations	-2	Bangladesh lodges formal protest against India with United Nations, which adopts consensus statement encouraging parties to meet urgently, at level of minister, to arrive at settlement.	Quantity
July 3, 1978	Amazon	Bolivia; Brazil; Colombia; Ecuador; Guyana; Peru; Suriname; Venezuela	6	Treaty for Amazonian Cooperation.	Economic Development
April 7, 1995	Jordan	Israel; Jordan	4	Pipeline from Israel storage at Beit Zera to Abdullah Canal (East Ghor Canal) begins delivering water stipulated in Treaty (20 mcm summer, 10 mcm winter). The 10 mcm replaces the 10 mcm of desalinated water stipulated Annex II, Article 2d until desalinization plant complete. (Note mcm = million cubic meters.)	Quantity
June 1, 1999	Senegal	Mali; Mauritania	-3	Thirteen people died in communal clashes in June 1999 along Mauritania and Mali border. Conflict started when herdsmen in Missira-Samoura village in West Mali refused to allow Mauritania horseman to use watering hole; horseman returned with clansmen, attacking village on June 20, 1999, causing two deaths; in retaliation that followed, 11 more died.	Quantity

addresses past criticisms concerning the utility of event datasets (Lanphier, 1975; Andriole and Hopple, 1984; Laurance, 1990).

The BAR Scale of Intensity of Conflict and Cooperation

Each event was coded by its intensity of conflict or cooperation. We created a 15-point "BAR Scale" whose numbers range from +7, the most cooperative event (voluntary unification into one nation over water), to -7, the most conflictive (formal declaration of war over water); 0 represents neutral or nonsignificant acts (Table 2). While based on the International Cooperation and Conflict Scale developed by Edward Azar (1980), the BAR Scale incorporates water specific considerations and terminology (Yoffe and Larson, 2002).

Before conducting our statistical analyses, we applied an exponential transformation to the BAR Scale values (Table 2). Exponential and other transformations of data are common in event data analyses, and a comparison of results using other mathematical transformations offers an area for additional research. We chose an exponential transformation to provide a numerical representation of the greater significance of the extremes of the BAR Scale and of the transition from, for example, small scale military acts to extensive war acts (Categories -5 and -6) as compared to the transition from mild to strong verbal hostility (-1 to -2). Having chosen our transformation, we calculated conflict/cooperation at a range of spatial and temporal scales (e.g., basin, country, year, etc.). We then averaged these values for our response variable. In analyses comparing data by year, the response variable was the average value of conflict/cooperation for all events in that year. In analyses spanning the entire time period of our study, the response variable was the average of the annual averages. The graphs accompanying this paper show the results of analyses back transformed to the 15-point (+7 to -7) BAR Scale.

RESULTS AND DISCUSSION

Are the theories and claims linking water to international conflict supported by historical evidence? If not, what is water's role in international relations? What basins are at potential risk for future conflict over international freshwater resources? The

TABLE 2. Water Event (BAR) Intensity Scale.

COPDAB Scale	Recentered BAR Scale	Anti-Logged Recentered Scale	Event Description
15	-7	-198.3	*Formal Declaration of War.*
14	-6	-130.4	Extensive War Acts causing deaths, dislocation, or high strategic cost.
13	-5	-79.4	Small scale military acts.
12	-4	-43.3	Political/military hostile actions.
11	-3	-19.8	Diplomatic/economic hostile actions. *Unilateral construction of water projects against another country's protests; reducing flow of water to another country, abrogation of a water agreement.*
10	-2	-6.6	Strong verbal expressions displaying hostility in interaction. *Official interactions only.*
9	-1	-1.0	Mild verbal expressions displaying discord in interaction. *Both unofficial and official, including diplomatic notes of protest.*
8	0	0.0	Neutral or nonsignificant acts for the international situation.
7	1	1.0	Minor official exchanges, talks, or policy expressions – mild verbal support.
6	2	6.6	Official verbal support of goals, values, or regime.
5	3	19.8	Cultural or scientific agreement or support (nonstrategic). *Agreements to set up cooperative working groups.*
4	4	43.3	Nonmilitary economic, technological, or industrial agreement. *Legal, cooperative actions between nations that are not treaties; cooperative projects for watershed management, irrigation, poverty alleviation.*
3	5	79.4	Military economic or strategic support.
2	6	130.4	Major strategic alliance (regional or international). *International Freshwater Treaty.*
1	7	198.3	Voluntary unification into one nation.

Note: *Italics* indicate water specific terminology that were not part of Azar's original scale descriptions.

following sections describe historical patterns in international conflict and cooperation over freshwater resources and the hypotheses and statistical analyses from which we derive our framework for identifying basins at risk.

Overall Patterns

We found no events at the extremes of the intensity scale – no formal declaration of war over water and no countries voluntarily unifying into one nation over water. For the years 1948 to 1999, cooperation over water, including the signing of treaties, far outweighed conflict over water and violent conflict in particular (Figure 1). Of 1,831 events, 28 percent were conflictive (507 events), 67 percent were cooperative (1,228), and the remaining 5 percent were neutral or nonsignificant. More than half of all events (57 percent) represented verbal exchanges, either mildly conflictive or cooperative. Interactions follow the same pattern, with 17 percent conflictive, 78 percent cooperative, 5 percent neutral, and verbal exchanges accounting for 54 percent of total interactions.

Four issues – water quantity, infrastructure, joint management, and hydropower – dominated the events. Cooperative events concerned a slightly wider range of issues than did conflictive events, with a more dramatic difference at the extremes of the scale. International freshwater treaties, the most cooperative event in our dataset (BAR Scale +6), covered a wide range of issue areas, with emphasis on water quality and quantity, hydropower, joint management, and economic development. The most extremely conflictive events in our database, extensive military acts (BAR Scale -6), concerned quantity and infrastructure exclusively, two closely related issue areas.

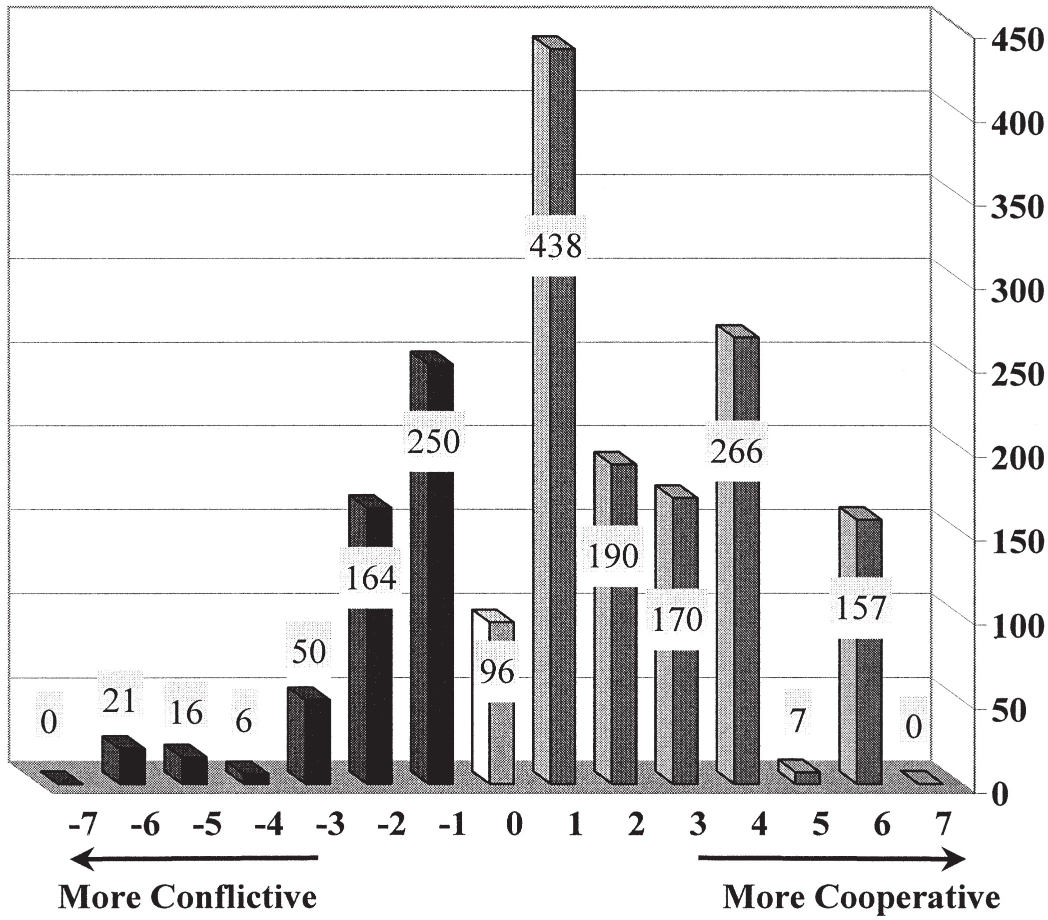

Figure 1. Total Number of Events by BAR Intensity Scale.

In comparing events to interactions, we found that events involving high levels of conflict (BAR Scale -3 to -7) occurred most often between individual dyads (i.e., only one country pair was involved). In contrast, highly cooperative events (BAR Scale +3 to +7) often involved multiple dyads. For example, the 157 international freshwater treaties (BAR Scale +6) involved 490 dyadic interactions (an average of approximately three country pairs per treaty), while all of the 21 events categorized as extensive war acts (BAR Scale -6) were bilateral conflicts. A large portion of the multilateral freshwater treaties emphasized economic development, joint management, and water quality, whereas bilateral agreements tended to concern water quantity and hydropower. Overall, joint management, water quality, and economic development were more prevalent and infrastructure concerns less so in events involving multiple country pairs. It may be that countries find more difficulty in reaching multilateral agreements on water quantity, while areas such as economic development, joint management, and water quality offer more opportunities for mutual benefit. Such differences point to areas where one approach (e.g., multilateral versus bilateral) may be more appropriate for development of institutional mechanisms to facilitate negotiation and management of international freshwater resources.

Temporal and Spatial Coverage of the Event Data

Although we used a wide range of data sources to achieve as broad a temporal and spatial coverage as possible, event data coverage was not consistent for all countries or for all years. Despite appearances in Figure 2, which shows the number of cooperative, conflictive, and total events by year, conflict, or cooperation over water has not necessarily been increasing over time. Rather, identification of water events for earlier periods is less comprehensive because the relative lack of contextual information in the datasets we used made positive identification of water specific events difficult. The skew toward later years in the

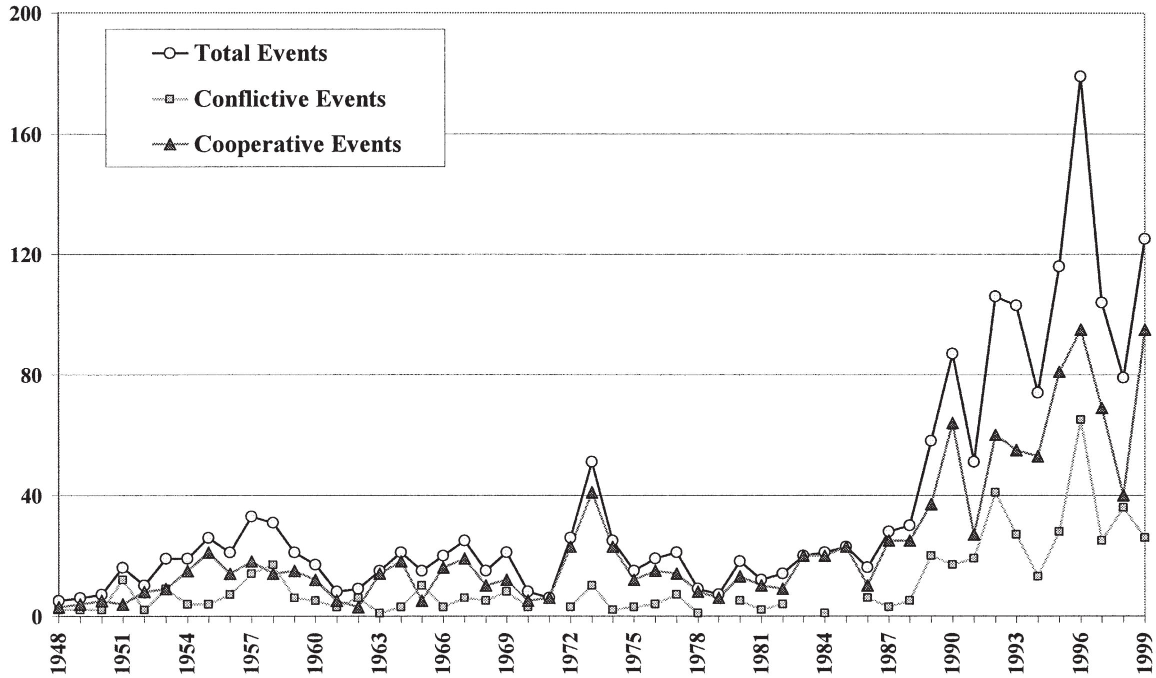

Figure 2. Distribution of Cooperative, Conflictive, and Total Events by Year.

temporal distribution also reflects intensity of effort, in large part because of the availability of electronic news databases with searchable text or summaries for the later years in our study period. The pattern of temporal distribution may also reflect a growing importance of water and environmental issues in general in news reporting. Although we found many more cooperative events toward the later years of our study, cooperative events did not increase significantly as a percentage of total events recorded.

From a regional perspective, the majority of events in the BAR Water Event Database are associated with basins in North Africa and the Middle East, sub-Saharan Africa, and Eastern Europe, followed by Southeast and South Asia and South America (Figure 3). For all but one of these regions, the average BAR Scale is cooperative (Figure 4). The Middle East/North Africa region shows the lowest level of cooperation, while Western Europe represents the highest. In terms of number of events, therefore, the water event data are somewhat weighted toward the least cooperative region. Despite this bias, we found that the majority of international relations over freshwater resources were cooperative. Moreover, the most conflictive basins (those with the greatest number of conflictive events) were also among the most cooperative. The basins with the highest number of events were the Danube, Ganges-Brahmaputra-Meghna, Jordan, La Plata, Tigris-Euphrates, and Mekong. A comparison of the number of events per basin region with the number of interactions reveals that multilateral relations were most prevalent in Eastern Europe, Southeast Asia, the Soviet Union/FSU, and East Asia, as compared with other study regions (Figure 3).

Hypotheses and Analyses for Developing Framework to Identify Basins at Risk

We tested a set of hypotheses relating the level of international conflict/cooperation over water to a set of quantifiable independent variables cited in the literature or formulated by our research group. For the majority of our analyses, we chose to use linear regression as our main statistical tool because it offered a concise summary of the mean of the response variable as a function of an explanatory variable. Linear regression models were compared to assess the relative strength of various independent variables in explaining the variability in the event data. Other univariate statistical analyses employed two-sample t-tests. We also considered indicators based on qualitative assessments of the empirical data (graphical comparison of average BAR Scale values) where statistical analyses were not feasible or appropriate. Table 3 lists the majority of hypotheses considered. The results of the hypotheses are discussed below. Further detail regarding the hypotheses and datasets we used may be found in Yoffe (2002).

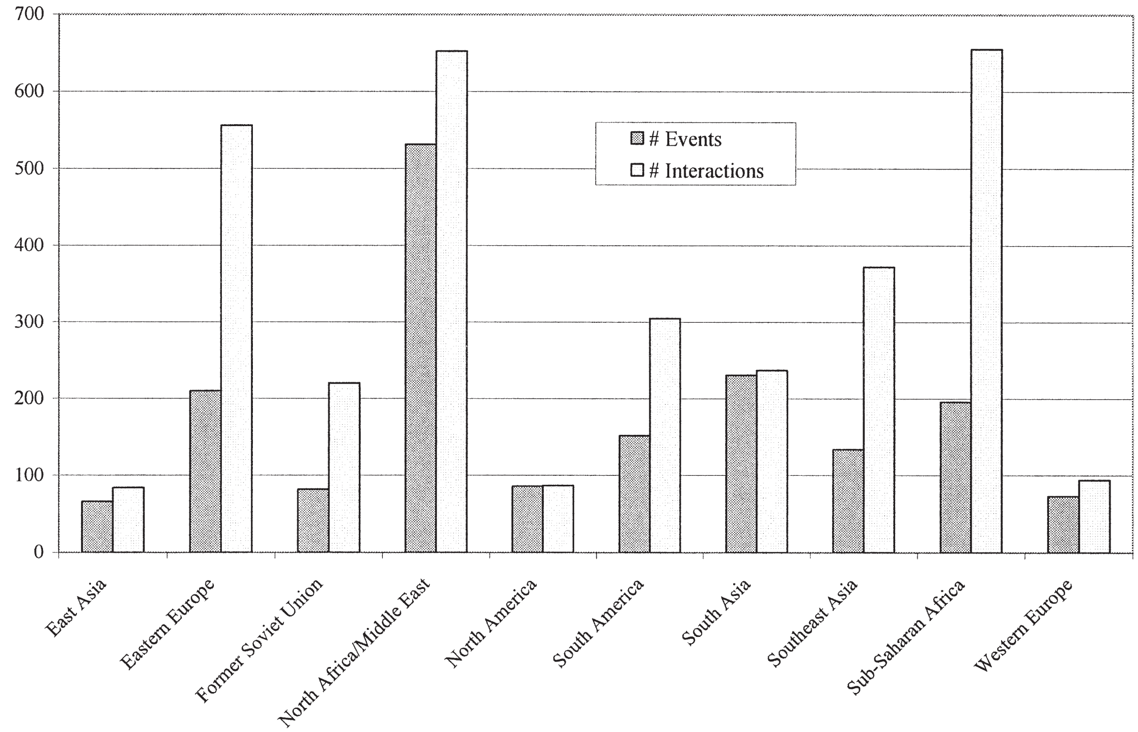

Figure 3. Number of Events and Interactions Per Basin Region.

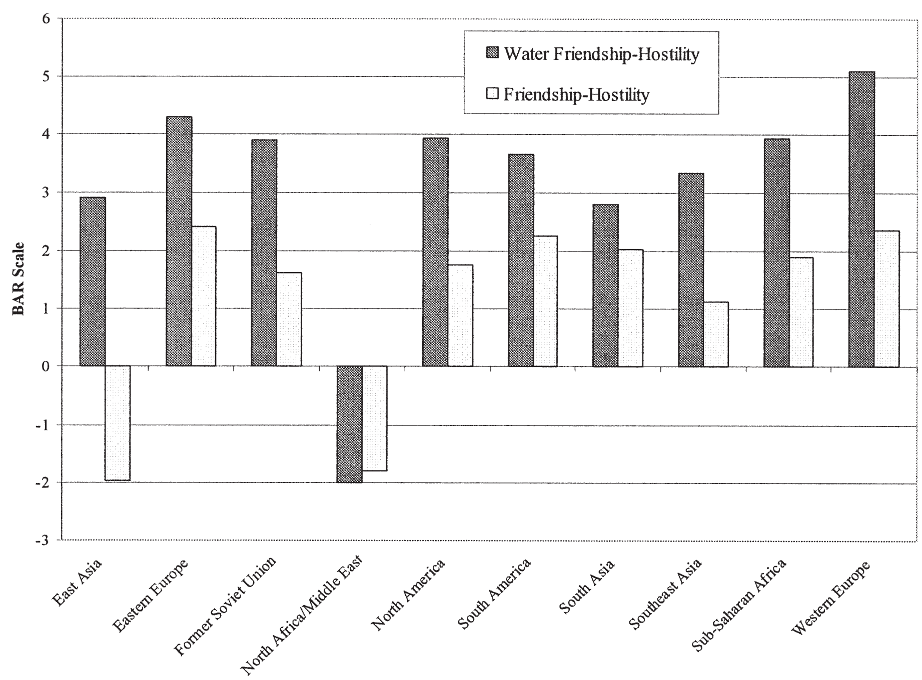

Figure 4. Average BAR Scale Values and Friendship-Hostility Index, by Country Region.

TABLE 3. Hypotheses Considered and Results.

Indicator	Relationship of Interest	Result			
		n	R^2	Coefficient	P-Value*
	Linear Regression				
GDP	GDP vs. country ABS	115	0.01	0.00	0.43
GDP/Capita	**GDP/capita vs. country ABS**	**114**	**0.05**	**5.11**	**0.01**
Population Density (no. people/km^2)	**Population density vs. country ABS**	**123**	**0.03**	**-0.02**	**0.04**
	Population density vs. basin ABS	**121**	**0.04**	**-0.30**	**0.04**
	Population density vs. basin/country polygon ABS	**344**	**0.02**	**-0.19**	**0.00**
Overall Relations	**Friendship/Hostility vs. country ABS**	**130**	**0.12**	**1.74**	**0.00**
Relative Power	**Ratio of GDP/capita vs. dyad ABS**	**304**	**0.02**	**-1.78**	**0.03**
	Ratio of population densities vs. dyad ABS	**490**	**0.02**	**6.70**	**0.00**
Rate of Population Growth	National pop. growth rate (1950 to 1999) vs. country ABS	126	0.02	-11.77	0.08
	National pop. growth rate (1950 to 1999) vs. average country Friendship/Hostility	**169**	**0.07**	**-3.24**	**0.00**
No. of Dams	No. of dams vs. basin ABS	82	0.00	-1.57	0.58
	No. of dams vs. basin/country polygon ABS	155	0.02	0.00	0.12
Dam Density (no. dams/km^2)	Dam density vs. basin ABS	82	0.02	-3.93	0.16
	Dam density vs. basin-country polygon ABS	155	0.01	-0.00	0.16
Basin Area	**Basin area in km^2 vs. basin ABS**	**122**	**0.03**	**3.47**	**0.04**
No. of Basin Countries	No. of countries sharing a basin vs. basin ABS	122	0.01	1.39	0.38
Water Stress	Freshwater availability/capita vs. basin ABS	86	0.01	6.56	0.51
Social Water Stress	Capacity adjusted water/capita vs. basin ABS	85	0.04	5.66	0.06
Human Dev. Index (HDI)	Country HDI vs. country ABS	119	0.01	19.39	0.29
	Average of riparian country HDIs vs. basin ABS	121	0.01	-24.87	0.37
Agric. as Percentage of GDP	Percentage of GDP in agriculture vs. country ABS	63	0.01	-0.22	0.35
Percentage of Labor Force	Percentage of country labor force in agriculture vs. country ABS	126	0.00	-0.08	0.47
Hydropower	Hydropower as percentage of electricity production vs. country ABS	98	0.04	-0.06	0.06
	Two-Sample T-Test				
Freshwater Treaties	ABS of nontreaty dyads (2.6) vs. ABS of dyads with treaties for years before first treaty signed (2.5)	388			0.34
Adjacency	ABS of basin dyads sharing a border (3.8) vs. ABS of basin dyads not sharing border (3.3)	3,332			0.00
Riverine Contiguity	ABS of riparian countries with river as border (4.0) vs. ABS or riparian countries w/out river as border (3.9)	390			0.31

No Statistical Test Conducted Due to Structure of Data

Indicator	Relationship of Interest	Graphical Comparison of ABS
Dam Density and Freshwater Treaties	Series of comparisons of high dam density and low dam density basins with and without treaties	High dam density basins more conflictive than low dam density basins except in presence of freshwater treaties.
Freshwater Treaties	Basin AABS in three years before a treaty was signed vs. three years after treaty signature	Three years preceding treaty, ABS no different than in normal years. Three years following treaty, ABS higher than in normal years.
Climate	Predominant climate type in basin (based on area percentage) vs. basin ABS	ABS of arid basins similar to that of basins in most other climate zones.
Precipitation	Annual basin precipitation vs. basin AABS	Most cooperative years were those in which rainfall close to average basin precipitation. Very dry years marginally more cooperative than wet/very wet years.

*Tests with results in which the p-value considered significant at < 0.05 are in bold.

GDP and Population

We considered Gross Domestic Product (GDP) and GDP per capita at the country scale and population and population density (people/km^2) at the basin and country scales. Only GDP per capita and population density showed an association with conflict over water. We found that rich countries and those with lower population densities tended to be more cooperative over water than poorer, more densely populated countries. Despite their statistical significance, however, these factors explain only a small percentage of the variability in the data (r-squared values < 0.10).

Overall Relations

The overall level of friendship or hostility among riparian countries was significantly associated with cooperation or conflict over water. Countries that cooperate in general also cooperate over water, and countries with overall unfriendly relations are also unfriendly over water issues. At the regional scale, we did not see such a correlation between international relations over water and all other international relations (friendship/hostility). We did find, however, that at the regional level countries appear to have friendlier relations over water than they do overall (friendship/hostility). This result may indicate that nonwater issues provide a greater source of regional tensions than water issues. Although the Middle East/North Africa region presents an exception, it should be noted that the water event data are based on public reports of interactions and therefore underrepresent nonpublic cooperation, such as the secret "picnic table talks" between Israel and Jordan on the Jordan River. At the country level, the relationship is much less clear, perhaps because freshwater resources are largely dealt with as a bilateral concern.

We also considered population growth rates and conflict over water as well as overall conflict. Countries with more rapidly growing populations tended to be more internationally conflictive overall but not more conflictive over water resources. These findings suggest that the drivers of water conflict and cooperation are not the same as for overall conflict and cooperation.

Relative Power

A general indicator of international conflict cited in the political science/geography literature is "relative power." Theorists exploring geography as a source of conflict consider distribution of power (Mandel, 1980) or the change in the relative power of states (Prescott, 1965; Garnham, 1976) as indicators of the frequency or likelihood of territorial disputes. Authors have offered various ways to measure relative power. Garnham (1976), for example, measured power parity using four indicators of national power: geographical area, population size, fuel consumption, and steel production. These indicators are assumed to correlate with a nation's capability to create and mobilize military forces. Garnham found that international war was more likely to occur between nation/states of relatively equal national power, in terms of population parity.

We tested a series of possible measures of relative power between countries, including the ratio of GDP per capita between basin/dyads and the ratio of their population densities. We found that dyads with greater differences in their per capita GDPs were associated with greater conflict over water. In contrast, basin/dyads with greater differences in their population densities were associated with greater cooperation over their shared freshwater resources. However, these indicators explain only a small percentage of the variability in the data.

Infrastructure Development and Institutional Mechanisms

The majority of indicators discussed in this paper relate to existing theoretical claims regarding causes of international conflict or, more specifically, geography or water's relationship to international conflict. We also considered our own hypothesis – the likelihood and intensity of conflict within a basin increases as the magnitude or amount of change in physical or institutional systems exceeds the capacity to absorb that change.

An extreme change in the physical systems of a basin might result from the construction of a large dam or water development project. We tested number of dams and density of dams (dams/1,000 km^2) against the BAR Scale; neither proved significant. In and of themselves, dams did not appear to provide a useful indicator for conflict over water, yet many of the conflictive events in the database concerned infrastructure development issues. We then considered the relationship of dams to freshwater treaties. We divided basins into two groups: those with a high density of dams and those with a low density of dams. We also identified basins with and without treaties. We then did a series of comparisons (Table 4) and found that overall and in basins without treaties, lower dam density basins tended to exhibit slightly less conflict. In basins with treaties, the relationship was reversed; lower dam density basins exhibited

TABLE 4. Dam Density and Freshwater Treaties.

Basin Setting	BAR Scale	Percent Difference
Basins With Low Dam Density	4.2	
Basins With High Dam Density	3.7	-12
Basins Without Treaties and Low Dam Density	2.8	
Basins Without Treaties and High Dam Density	2.5	-12
Basins With Treaties (value of first treaty excluded) and Low Dam Density	3.8	
Basins With Treaties (value of first treaty excluded) and High Dam Density	4.2	11
Basins With Treaties (value of first treaty excluded) and High Dam Density	4.2	
Basins Without Treaties and High Dam Density	2.5	-41

slightly more cooperation. In all these instances, however, the relationship was not significant. We then compared high dam density basins with treaties to those without treaties. In high dam density basins, treaties mitigate conflict. High dam density basins with treaties showed significantly higher levels of cooperation than did nontreaty basins (41 percent difference; average BAR Scale of +4.2 in treaty basins versus +2.5 in nontreaty basins). Moreover, this difference was not because pairs of countries with treaties started out as inherently more cooperative than pairs of countries without treaties. In fact, average water relations between dyads in the three years before a treaty was signed were somewhat more conflictive than in general. Nonetheless, once a freshwater treaty was signed, cooperation increased and, over time, additional treaties often were signed.

Rapid change in the institutional systems of a basin might include internationalization of that basin. Internationalized basins are those basins whose management institutions were developed under a single jurisdiction that was then fragmented when the jurisdiction was divided among two or more nations. We found that basins in regions experiencing internationalization, such as the Middle East/North Africa and South Asia during the breakup of the British empire and Eastern Europe and Central Asia during the fall of the Soviet Union, showed much higher levels of conflict compared to other parts of the world during the same time period.

Adjacency/Spatial Proximity

Pairs of countries within an international river basin that also shared a border cooperated more over water than pairs of countries that shared a basin but not a border. This result contrasts with theories of geography and war. States are expected to exhibit more conflict with neighboring states than with others because: (1) it is less difficult to wage war against closer countries than against more distant nations (Russett, 1967; Garnham, 1976; Most and Starr, 1989; Vasquez, 1995); (2) multiple shared borders create uncertainty, which contributes to conflict (Richardson, 1960; Midlarsky, 1975; Diehl, 1991); and (3) countries closer together are more likely to have conflicting interests because of their proximity (Bremer, 1992).

Several studies have found a relationship between proximity and violent international conflict, war in particular (Gleditsch and Singer, 1975; Garnham, 1976; Gochman, 1991; Gleditsch, 1995). These studies, however, focused on wars or militarized international disputes rather than a spectrum of conflict types and did not consider the specific issue under dispute. Vasquez (1995) contends the reason proximity is associated with international conflict is that war arises "from specific territorial disputes that have been unable to be resolved by other means . . .Wars are clustered among neighbors because neighbors have territorial disputes" (p. 281). Many of the quantitative studies linking proximity to war concern territory or fail to distinguish the issues over which the war is fought. Toset and Gleditsch (2000) consider the relationship between militarized interstate disputes and water scarcity, as well as proximity, shared rivers, and other factors. Their study found that contiguity was significant but freshwater availability per capita was not. Toset and Gleditsch (2000) explored militarized interstate disputes only, and they noted that it may be unreasonable to expect disputes over water to escalate to armed conflict. Even their study, however, does not distinguish the issues over which the conflicts were fought or in particular whether the conflicts concerned shared rivers or freshwater as a resource.

Since the BAR water events specifically exclude issues where the concern is over territory or rivers as borders, we did not expect to find a correlation between proximity and conflict over international freshwater resources. In the political geography literature, the importance of shared borders lies in interaction opportunities and the role of uncertainty. Our finding highlights that shared borders, in and of themselves, represent opportunities for cooperation as well as conflict. This finding fits with more recent literature, which speculates that the effects of geography on the likelihood of war are not uniform and considers coexistence and cooperation, rather than conflict, across international boundaries (Barnard, 1994; Blake, 1994; Gradus, 1994).

We infer that for water issues, shared borders in shared basins offer opportunities for tradeoffs and cooperative interactions between states because of the geographic proximity and other, nonwater, relations the states may share. In situations where states share a river but not a border, there may be fewer opportunities for such cooperative interactions. If uncertainty associated with multiple borders increases the potential for international conflict, then perhaps shared river systems, which serve to expand a country's physical connections beyond its immediate neighbors, contribute to such conflict when other opportunities for cooperative interactions, such as a shared border, are lacking.

Climate, Precipitation, Water Availability

Two factors often cited as indicators of water conflict are climate and water availability. In a modified form of environmental determinism, authors cite such factors as aridity and population growth as key contributors to potential "water wars," because scarcity of water is seen as contributing to instability and conflict (Elliott, 1991). Such thinking is prevalent in environmental security literature, which links environment and natural resource issues with violent conflict and national security concerns (Ullman, 1983; Westing, 1986; Gleick, 1989; Myers, 1989; Tuchman Mathews, 1989; Homer-Dixon, 1991).

We found no relationship between climate and water conflict/cooperation in a basin. Arid regions were not found to be substantially less cooperative than other climate zones, excepting humid mesothermal regions. This latter climate zone includes the basins of Western Europe, in which other factors (e.g., overall friendly relations, relatively high GDP) may facilitate cooperation.

In addition to overall climate, we considered precipitation as an explanatory factor. For the 11 basins for which annual precipitation data were available for the years 1948 to 1999, we found that the most cooperative years were those in which rainfall was close to average and that very dry years were marginally more cooperative than wet or very wet years (Figure 5). Although 11 basins do not provide enough data for a broad assessment, Figure 5 does illustrate the wide range of variation in precipitation patterns from basin to basin. It may be that it is not the overall climate or average precipitation levels that provide an indicator of conflict, but the occurrence of extremes or the level of uncertainty concerning available water resources in a basin.

Although environmental security literature identifies few numerical measures of water as a potential indicator of international conflict, Falkenmark's (1989) Water Stress Index (WSI) offers a measure widely cited in water resources management. This index divides the volume of available water resources for each country by its population. We also considered Ohlsson's (1999) Social Water Stress Index (SWSI), which is basically Falkenmark's WSI weighted by a measure of a country's adaptive capacity (the Human Development Index of the U.N. Development Programme, UNDP). Both the WSI and SWSI are usually derived and applied at the country level. We considered these measures at the basin scale. Water availability by basin, both with and without an adjustment for institutional capacity, failed to show significant association with cooperation/conflict over freshwater resources.

Although the SWSI incorporates the Human Development Index (HDI), for our purposes it provided only a partial picture of water related institutional capacity because it is not water specific. The HDI itself is not significantly associated with conflict/cooperation over water. We considered testing percentage of population with access to freshwater or sanitation services, incidence of water related disease, water quality/water pollution trends, and/or efficiency of existing water uses and water delivery systems. Current, global scale data for these variables, however, were either unavailable or did not allow for cross country comparisons.

Resource Dependence for Agricultural and Energy Needs

We also considered other indicators that might provide measures of a country's dependence upon freshwater resources, such as hydropower, potential irrigation, and the proportion of the economy in agriculture. We found that dependence upon water in terms of agricultural or energy needs was not associated with conflict/cooperation over water. Our findings differ from Gleick (1993), one of the few authors who identifies indices of vulnerability that might suggest "regions at risk" for international water conflicts. Gleick's indices are: (1) ratio of water demand to

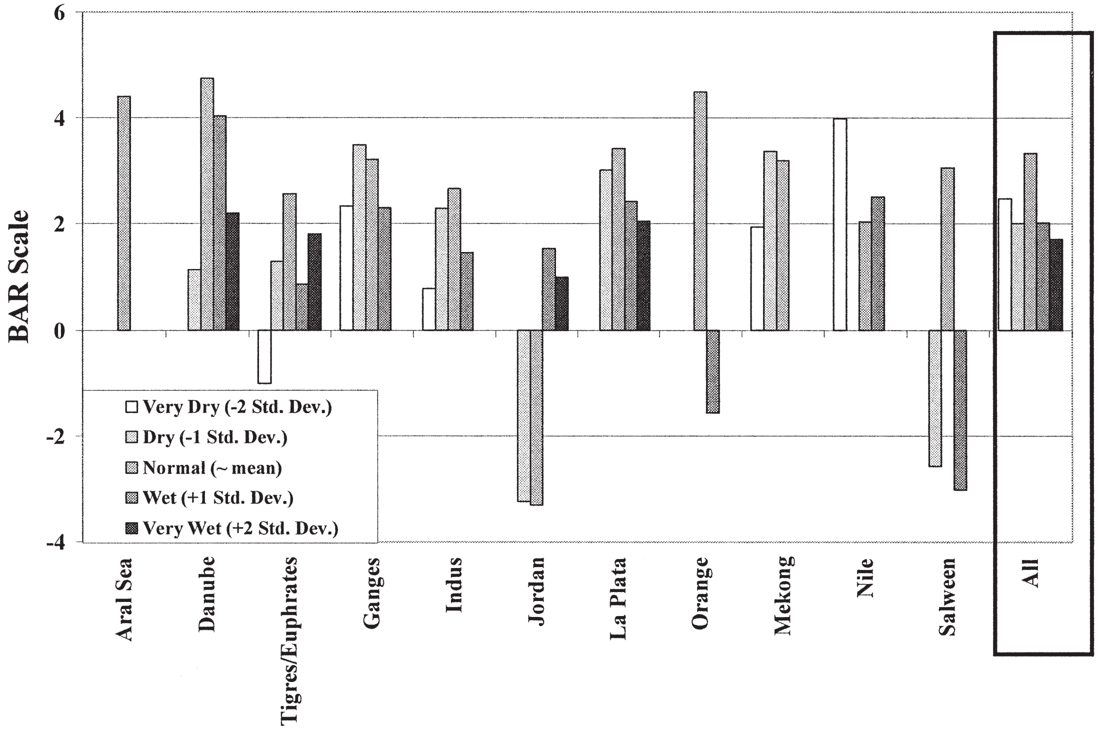

Figure 5. Annual Precipitation in Select Basins Versus BAR Scale.

supply; (2) water availability per person (Falkenmark's WSI); (3) fraction of water supply originating outside a nation's borders; and (4) dependence on hydroelectricity as a fraction of total electrical supply. Gleick's (1993) indicators concern the nation as the unit of analysis and were not quantitatively tested. We tested the first two indicators. For water supply originating in other countries and potential irrigation as a measure of water demand, the scale of available data was too coarse to be useful. Our findings indicate that, at the global scale, no one indicator of water resource availability is likely to provide a useful measure of the potential for conflict over freshwater resources within a basin.

Government Type

In addition to relative power, discussed above, political geography and political science theory consider the role of government type in overall international conflict. In general, these theories do not directly address resource related issues, but they do deal specifically with indicators of international conflict. Our findings suggest that government regime type is not a useful indicator for international conflict over freshwater resources. The current political science wisdom concerning regime type and international conflict is that democracies are not more peaceful than other regime types, although they tend not to fight other democracies (e.g., Gleditsch, 1995). Also, societies in uneven transition between democracy and autocracy are considered more likely to be involved in international conflict, as are highly undemocratic countries (Gleditsch and Ward, 2000).

We found that governments experiencing disruption or transition (i.e., regimes with a mix of autocratic and democratic tendencies) were no more bellicose over water than other regime types and that countries at the democratic end of the spectrum tended to exhibit less cooperation over water than did other regime types, with the exception of countries at the democratic extreme. In comparing levels of water conflict between country pairs by their type of government regime, we found little discernible trend, except that the few sets of neighbors with the highest possible heterogeneity (greatest difference in type of government regime) seemed to have the worst relations. These differences between our findings and current political science theory may reflect the fact that the theories are based on research concerned specifically with international war rather than with a spectrum of conflict as we have considered. Moreover, these studies rarely take into account what the conflicts are about (e.g., territory, ideology, control of resources). Since countries historically have exhibited greater cooperation than violent conflict over shared freshwater resources, political science theories that hold true for war in general might not hold true for conflicts where water is concerned.

Basins at Risk

Based on an assessment of our global-scale analyses, discussed in following sections, we created a framework to identify basins at risk for future conflict over freshwater resources. We systematically selected those basins that had a confluence of what we identified as indicators, based on the results of our statistical and empirical analyses and our own qualitative judgment – basins with

- high population density (>100 people/sq km),
- low per capita GDP (< $765/person – 1998 World Bank lowest income country definition),
- overall unfriendly relations (BAR Scale < -1.0),
- politically active minority groups that might lead to internationalization,
- proposed large dams or other water development projects, and
- limited or no freshwater treaties.

In addition, we identified basins with ongoing international water conflicts.

Basins experiencing both high population density and average low per capita GDP include the Ca (Laos and Vietnam), Cross (Cameroon and Nigeria), Drin (Albania, Macedonia, and Serbia and Montenegro), Fenney (India, Bangladesh), Ganges-Brahmaputra-Meghna (India, Bangladesh, Bhutan, Nepal, Burma, China), Han (North and South Korea), Indus (India, Pakistan, China, Afghanistan), Irrawaddy (India, Burma, China), Karnaphuli (Bangladesh, India), Red (China, Laos, Vietnam), Saigon (Cambodia, Vietnam), Song Vam Co Dong (Cambodia, Vietnam), and Yalu (China and North Korea). Of these, only the Ganges, Indus, and Song Vam Co Dong have international freshwater agreements, and only the Song Vam Co Dong agreement includes all the riparian countries. See Yoffe (2002, Appendix 13) for tables listing basins and countries by the above mentioned factors, as well as the historically (1948 to 1994) most overall conflictive pairs of countries (BAR Scale ≤ -1.0) and the basins they share.

Regarding the potential for internationalization, we have information on current international basins that might experience further internationalization because of the presence of politically active minority groups with assertive nationalist aspirations (Yoffe, 2002). These basins include the Salween (Shan, Karen, and other groups), Tigris-Euphrates (Kurds), Jordan (Palestinians), Indus (Kashmiri), Ganges (Chittagong Hill peoples), Kura (Nagorno-Karabahk), Ili and Tarim (Uighers in northwest China who want a separate East Turkestan State), Chiloango (Cabindans in Angola), Nile (Nuba in Sudan), Awash, Juba-Shibeli, and/or Nile (Oromos in Ethiopia), and Ebro and Bidasoa (Basques in Spain). The conflicts involving the Abkhaz in Georgia, Chechens in Russia, Moros in Philippines, and East Timorese in Indonesia fall outside existing international basins.

In terms of physical change, basins in which large development projects are planned include, but are not limited to, the Amazon, Asi-Orontes, Ganges, Incomati, Indus, Irrawady, Kunene, La Plata, Mekong, Niger, Nile, Okavango, Orinoco-Caroni, Po, Salween, Senegal, Song Vam Co Dong, Tigris, Volta, and Zambezi. Data on future development projects were compiled from multiple sources, including news reports and websites on tender requests and construction bids.

Of the above basins, only the Amazon, Incomati, Kunene, Niger, Okavango, Orinoco-Caroni, and Song Vam Co Dong have freshwater treaties that involve all the riparian parties. The provisions and strength of these treaties vary greatly, however. For example, the Okavango basin agreements that include all the basin riparian parties are general, multicountry Southern African Development Community protocols regarding shared watercourse systems rather than specific agreements on quantity, quality, or infrastructure issues unique to the Okavango. Although minutes on cooperation in water conservancy were signed between Cambodia and Vietnam on the Song Vam Co Dong, these minutes do not necessarily address development project concerns. Such realizations speak to the need to explore basins individually to determine their propensity for conflict.

When all the various factors described above are pulled together, the following basins are worth further investigation as to the potential for future conflict over freshwater resources (see Wolf *et al.,* 2003, for an earlier discussion of basins at risk). We divide these basins at risk into three categories (Figure 6, Table 5). The first category, basins negotiating current conflicts, includes the Aral Sea, Jordan, Nile, and Tigris-Euphrates. While each of these basins has a treaty associated with it, none of those treaties includes all of the basin riparian countries. These basins are well known "hot spots," where the potential for continued disputes, at least in the immediate future, is considered high. The second category is basins in which factors point to the potential for future conflict and in which upcoming development projects or other stresses upon the water system have raised protests among the riparian countries. The third category is similar to the second in that there is a confluence of factors that indicate the potential for future conflict. Unlike Category 2 basins, however,

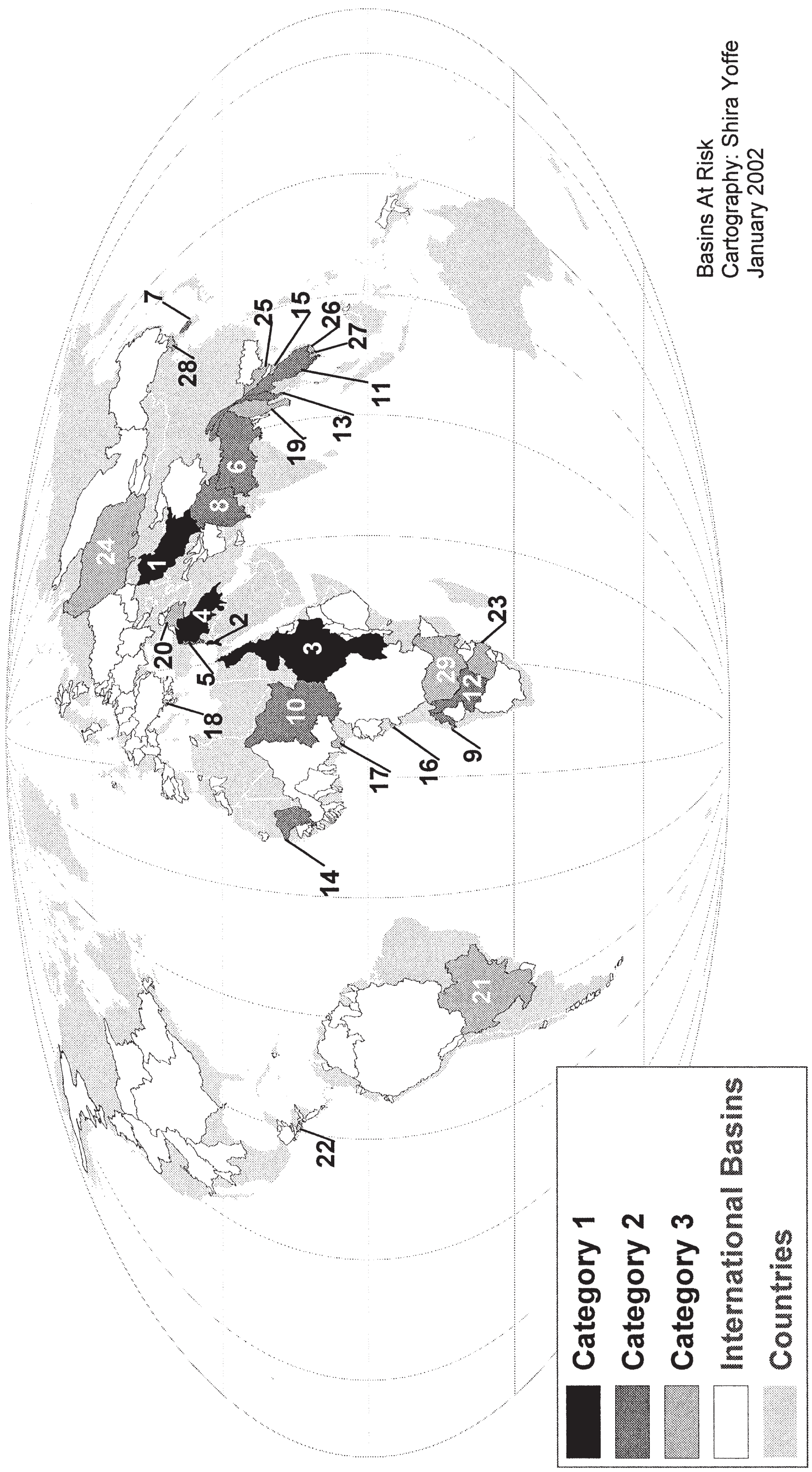

Figure 6. Basins At Risk – Categories 1, 2, and 3.

TABLE 5. Basins At Risk – Basin Map Number, and Basin Riparian Countries.

Basin No.	Basin Name	Basin Riparian Countries
		CATEGORY 1 – Negotiating Current Conflicts
1	Aral Sea	Afghanistan, China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
2	Jordan	Israel, Jordan, Lebanon, Palestinians, Syria
3	Nile	Burundi, Congo (Kinshasa), Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda
4	Tigris-Euphrates	Iran, Iraq, Jordan, Saudi Arabia, Syria, Turkey
		CATEGORY 2 – Indicators and Protests over Water
5	Asi/Orontes	Lebanon, Syria, Turkey
6	Ganges-Brahmaputra-Meghna	Bangladesh, Bhutan, Burma, China, India, Nepal
7	Han	North and South Korea
8	Indus	Afghanistan, China, India, Pakistan
9	Kune	Angola, Namibia
10	Lake Chad	Algeria, Cameroon, Central African Republic, Chad, Libya, Niger, Nigeria, Sudan
11	Mekong	Burma, Cambodia, China, Laos, Thailand, Vietnam
12	Okavango	Angola, Botswana, Namibia, Zimbabwe
13	Salween	China, Burma, Thailand
14	Senegal	Guinea, Mali, Mauritania, Senegal
		CATEGORY 3 – Indicators Only
15	Ca	Laos and Vietnam
16	Chiloango	Angola, Congo (Kinshasa), Congo (Brazzaville)
17	Cross	Cameroon, Nigeria
18	Drin	Albania, Macedonia, Serbia & Montenegro
19	Irrawaddy	Burma, China, India
20	Kura-Araks	Armenia, Azerbaijan, Georgia, Iran, Turkey
21	La Plata	Argentina, Bolivia, Brazil, Paraguay, Uruguay
22	Lempa	El Salvador, Guatemala, Honduras
23	Limpopo	Botswana, Mozambique, South Africa, Zimbabwe
24	Ob	China, Kazakhstan, Russia
25	Red	China, Laos, Vietnam
26	Saigon	Cambodia, Vietnam
27	Song Vam Co Dong	Cambodia, Vietnam
28	Yalu	China, North Korea
29	Zambezi	Angola, Botswana, Congo (Kinshasa), Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe

there is no evidence of existing tensions in public policy or news fora. When viewing all the categories together, what stands out is that most basins at risk are in southern Asia and central and southern Africa.

In this section, we have discussed a series of possible indicators, derived from a broad and highly variable set of data, for basins that show a high degree of individuality. Categorizing a basin as "at risk" does not presume to identify basins in which acute conflict will occur but to point to basins worth more detailed investigation. In such investigations, particular attention should be paid to the indicators discussed above as well as to more detailed assessment of

- the existence, strength, and provisions of existing international water treaties or other relevant, basin level institutional mechanisms, as well as the level of development of water institutions within individual riparian countries;
- the quality of governance within the basin and conditions such as high population density and low per capita GDP that may hamper a government's ability to cope with change; and
- the uncertainties associated with the basin's water regime, such as climatic variability and institutional adaptability to extreme fluctuations in water availability.

The above sets of indicators represent an intermediate step between the specific comparisons associated with case studies and the broad quantitative assessments that base predictive indicators solely on statistical results. Although some indicators proved statistically significant, individually they explained only a small percentage of the variability in the event data. Moreover, no formal multivariate analyses were conducted, as the data sets lie at different spatial scales. The framework represents a qualitative assessment of the relative importance of our statistical and empirical findings, given our knowledge of transboundary freshwater resources and the constraints of the data sources used.

CONCLUSION

Historically, international cooperation over freshwater resources as a resource has far outweighed international conflict. Where acute conflict over water has occurred, it concerned quantity and infrastructure, two issues closely related. These instances of acute conflict involved only bilateral interactions. Cooperation, on the other hand, was often multilateral and more likely to involve joint management, water quality, and economic development issues rather than the bilateral concerns of water quantity and infrastructure. Such differences highlight issues that may be appropriate for development of multilateral, as opposed to bilateral, institutional mechanisms to facilitate negotiation and management of freshwater resources. Regionally, countries exhibited greater cooperation over water as compared to their overall international relations, indicating that countries in conflict over other concerns may still find common interest in cooperation with regard to their shared water resources.

Most of the commonly cited indicators linking freshwater to conflict proved unsupported by the data. Spatial proximity, government type, climate, basin water stress, dams and infrastructure development, and dependence on freshwater resources for agricultural or energy needs showed no significant association with conflict over freshwater resources. In fact, no one indicator in itself proved relevant. Even factors that showed a statistically significant association with conflict or cooperation over freshwater resources explained only a small percentage of the variability in the data.

The relevant indicators appear to be rapid or extreme changes in physical or institutional settings within a basin – large dams and/or internationalization – and the presence of institutional mechanisms, international freshwater treaties in particular, that mitigate uncertainty. Broadly defined, institutions and institutional infrastructure matter, perhaps because institutions provide a mechanism for mitigating or managing the uncertainty that theorists associate with a propensity toward international conflict. Institutions are also important because they reflect a country's ability to understand and cope with stresses upon water resource systems.

Although no one indicator was sufficient to identify a basin at potential risk, we took those indicators that showed some association and qualitatively created a framework to identify basins at potential risk for future conflict. The majority of these basins are in southern Asia and central and southern Africa. Identifying a basin at risk does not presume that conflict will occur in that basin but points to regions worth more detailed study in terms of water resource institutions, water resource needs, and the ability of riparian countries to work together and to cope with changes or stresses upon a basin's water institutions and hydrological systems.

In the future, there will be international conflicts over water, and it may be that such conflicts will increase given increasing populations or other stresses upon the resource. The question is how and at what level of intensity such conflicts will be dealt with by the parties concerned.

This study is a first step in what is hoped to be continued exploration of conflict and cooperation over freshwater resources, using the database we have created. Other issues that may play a role and are worth further analysis include the possible relationship of intranational water conflict to water disputes at the international level, the influence of nonriparian countries or entities (e.g., World Bank) on water conflict and cooperation within a basin, and whether basins with greater annual or interannual variability in precipitation show higher propensity for conflict than do basins with more predictable climatic patterns.

This last question also plays into analyses regarding institutions and infrastructure, as both provide mechanisms for managing variability in water supply and demand. Overall, it may not be the trends, such as population growth or average climate, but the discontinuities, such as extreme climatic events or sudden institutional change, that provide relevant indicators of international water conflict or cooperation.

The Basins At Risk project offers a wealth of data and resources for further research and comparative analyses. We hope that others will make use of the data we have gathered. The statistical analyses and numerical data developed through the BAR project are available through the Transboundary Freshwater Dispute Database website at http://www.transboundarywaters.orst.edu.

ACKNOWLEDGMENTS

Spanning three years, the Basins At Risk project involved the efforts of more than ten faculty and student researchers at Oregon State University. The authors would like to acknowledge the insights, assistance, and support of Dr. Julia Jones, Dr. Jon Kimerling, Dr. Phil Jackson, Dr. Chuck Rosenfeld, Dr. Dawn Wright, Case Bowman, Kuuipo Burleigh, Becci Dale, Meredith Giordano, Greg Fiske, Jeanne Hoadley, Kelli Larson, Kyoko Matsumoto, Marc Rothgery, Brian Ward, and Daniel Wise. In addition, the authors would like to extend their thanks to George Taylor, Oregon State climatologist, and his assistants Nathaniel De Young and Melanie Mitchell; Mark Levy, CIESIN; Jake Brunner and Kirsten Thompson, WRI; Petra Doell, University of Kassel, Germany; Glenda Pearson, University of Washington Library; David B. Kynoch, President, Pacific Northwest GIS Consulting, Inc.; Dr. Michael D. Ward, Department of Political Science, University of Washington (Seattle); Balazs Fekete, Complex Systems Research Center, University of New Hampshire; Dr. Jerome E. Dobson, Oak Ridge National Laboratory; Joe Toth and Carrie Ottow, Oregon State University Valley Library; Brian Smith; Jeff Danielson and Kent Lethcoe, EROS Data Center; Global Event Data System, University of Maryland; National Geographic; and the National Science Foundation Graduate Research Traineeship (GRT) Fellowship in Landscape Studies.

LITERATURE CITED

Andriole, S. J. and G. W. Hopple, 1984. The Rise and Fall of Event Data: From Basic Research to Applied Use in the U.S. Department of Defense. International Interactions 10(3-4):239-309.

Azar, E. E., 1980. The Conflict and Peace Data Base (COPDAB). Journal of Conflict Resolution 24(1):143-152.

Barnard, W. S., 1994. From Obscurity to Resurrection: The Lower Orange River as International Boundary. *In:* Political Boundaries and Coexistence, W. A. Galluser, M. Bürgin, and W. Leimgruber (Editors). Proceedings of the IGU-Symposium in Basle, Switzerland. Peter Lang, New York, New York, pp. 125-134.

Blake, G., 1994. International Transboundary Collaborative Ventures. *In:* Political Boundaries and Coexistence, W. A. Galluser, M. Bürgin, and W. Leimgruber (Editors). Proceedings of the IGU-Symposium in Basle, Switzerland. Peter Lang, New York, New York, pp. 359-371.

Brecher, M. and J. Wilkenfeld, 2000. A Study of Crisis. University of Michigan Press, Ann Arbor, Michigan.

Bremer, S. A., 1992. Dangerous Dyads: Conditions Affecting the Likelihood of Interstate War, 1816-1965. Journal of Conflict Resolution 36(2):309-341.

Butts, K., 1997. The Strategic Importance of Water. Parameters Spring, pp. 65-83.

Davies, J. L., 1998. The Global Event-Data System: Coders' Manual (August Revision). Center for International Development and Conflict Management and Department of Government and Politics, University of Maryland, College Park, Maryland. *Available at* http://geds.umd.edu/geds/.

Diehl, P. F., 1991. Geography and War: A Review and Assessment of the Empirical Literature. International Interactions 17(1):11-27.

Elhance, A. P., 1999. Hydro-Politics in the Third World: Conflict and Cooperation in International River Basins. United States Institute of Peace Press, Washington, D.C.

Elliott, M., 1991. Water Wars. Geographical Magazine, pp. 28-30.

Falkenmark, M., 1989. The Massive Water Scarcity Now Threatening Africa – Why Isn't It Being Addressed? Ambio 18(2):112-118.

Fiske, G. and S. Yoffe, 2002. Use of GIS for Analysis of Indicators of Conflict and Cooperation Over International Freshwater Resources. *In:* Basins at Risk: Conflict and Cooperation Over International Freshwater Resources, S. B. Yoffe (Editor), Chapter 3. *Available at* http://www.transboundarywaters.orst.edu/projects/bar/BAR_chapter3.htm. *Accessed on* July 14, 2003.

Garnham, D., 1976. Dyadic International War 1816-1965: The Role of Power Parity and Geographical Proximity. Western Political Quarterly 29:231-242.

Gleditsch, K. S. and M. D. Ward, 2000. War and Peace in Space and Time: The Role of Democratization. International Studies Quarterly 44(1):1-30.

Gleditsch, N. P., 1995. Geography, Democracy, and Peace. International Interactions 20(4):297-323.

Gleditsch, N. P. and J. D. Singer, 1975. Distance and International War, 1816-1965. Proceedings of the International Peace Research Association Fifth General Conference, Oslo. International Peace Research Association, pp. 481-506.

Gleick, P., 1989. The Implications of Global Climatic Changes for International Security. Climatic Change 15(1/2):309-325.

Gleick, P., 1993. Water and Conflict: Fresh Water Resources and International Security. International Security 18(1):79-112.

Gochman, C. S., 1991. Interstate Metrics: Conceptualizing, Operationalizing, and Measuring the Geographic Proximity of States Since the Congress of Vienna. International Interactions 17:93-112.

Gradus, Y., 1994. The Israel-Jordan Rift Valley: A Border of Cooperation and Productive Coexistence. *In:* Political Boundaries and Coexistence, W. A. Galluser, M. Bürgin, and W. Leimgruber (Editors). Proceedings of the IGU-Symposium in Basle, Switzerland. Peter Lang, New York, New York.

Homer-Dixon, T. F., 1991. On the Threshold: Environmental Changes as Causes of Acute Conflict. International Security 16(2):76-116.

Homer-Dixon, T. F., 1994. Environmental Scarcities and Violent Conflict: Evidence From Cases. International Security 19:5-40.

Lanphier, V. A., 1975. Foreign Relations Indicator Project (FRIP). Theory and Practice of Events Research: Studies in Inter-Nation Actions and Interaction, E. Azar and J. D. Ben-Dak (Editors). Gordon and Breach, New York, New York, pp. 161-174.

Laurance, E. J., 1990. Events Data and Policy Analysis: Improving the Potential for Applying Academic Research to Foreign and Defense Policy Problems. Policy Sciences 23:111-132.

Mandel, R., 1980. Roots of Modern Interstate Border Disputes. Journal of Conflict Resolution 24:427-454.

Midlarsky, M., 1975. On War. Free Press, New York, New York.

Most, B. A. and H. Starr, 1989. Inquiry, Logic, and International Politics. University of South Carolina Press, Columbia, South Carolina.

Myers, N., 1989. Environment and Security. Foreign Policy 74(Spring):23-41.

Ohlsson, L., 1999. Environment, Scarcity, and Conflict: A Study of Malthusian Concerns. Department of Peace and Development Research, Goteborg University, Goteborg, Switzerland.

Prescott, J. R. V., 1965. The Geography of Frontiers and Boundaries. Aldine, Chicago, Illinois.

Remans, W., 1995. Water and War. Humantäres Völkerrecht 8(1).

Richardson, L., 1960. Statistics of Deadly Quarrels. Boxwood, Pittsburgh, Pennsylvania.

Russett, Bruce M., 1967. International Regimes and the International system. Rand McNally, Chicago, Illinois.

Toset, H. W. and N. Gleditsch, 2000. Conflict and Shared Rivers. Journal of Political Geography 19(8):971-927.

Tuchman Mathews, J., 1989. Redefining Security. Foreign Affairs 68(2):162-77.

Ullman, R. H., 1983. Redefining Security. International Security 8(1):129-153.

Vasquez, J. A., 1995. Why Do Neighbors Fight? Proximity, Interaction, or Territoriality." Journal of Peace Research 32(3):277-293.

Westing, A. (Editor), 1986. Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action. Oxford University Press, New York, New York.

Wolf, A. T., 1999. The Transboundary Freshwater Dispute Database Project. Water International 24(2):160-163.

Wolf, Aaron T., Shira B. Yoffe, and Mark Giordano, 2003. International Waters: Identifying Basins at Risk. Water Policy 5(1):29-60.

Yoffe, S. B., 2002. Basins at Risk: Conflict and Cooperation Over International Freshwater Resources. Dissertation, Department of Geosciences. Corvallis, Oregon State University. *Available at* http://www.transboundarywaters.orst.edu/projects/bar/. *Accessed on* July 14, 2003.

Yoffe, S. and K. Larson, 2002. Basins at Risk: Water Event Database Methodology. *In:* Basins at Risk: Conflict and Cooperation Over International Freshwater Resources, S. B. Yoffe (Editor), Chapter 2. *Available at* http://www.transboundarywaters.orst.edu/projects/bar/BAR_chapter2.htm. *Accessed on* July 14, 2003.