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Wyoming Department of Environmental Quality

Occurrence of Fecal Coliform Bacteria in Selected Streams in Wyoming, 1990-99

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ABSTRACT

The U.S. Geological Survey (USGS), in cooperation with the Wyoming Department of Environmental Quality (WDEQ), is collecting water samples for analysis of fecal coliform bacteria at 18 stream sites as part of a statewide network. Contamination by bacteria of fecal origin in streams where contact recreation is a designated water use is a concern because of potential public-health risk from the presence of enteric pathogens. Fecal coliform concentrations are temporally and spatially variable in Wyoming streams—concentrations ranged from less than 1 to 45,000 colonies per 100 milliliters of water during 1990-99. Fecal coliform concentrations were less than the water-quality criterion of 400 colonies per 100 milliliters in 83 percent of the samples, indicating fecal coliform contamination is not a widespread problem in these Wyoming streams. However, 14 of the 18 monitoring sites had at least one sample in which the fecal coliform concentration exceeded 400 colonies per 100 milliliters at some time during the 10-year period. Fecal coliform concentrations generally are higher during April through September than during October through March. The higher concentrations coincide with the time period when the public-health risk is higher because summer months are when contact recreation use is more likely occurring. Fecal coliform concentrations were positively correlated with discharge and stream temperature and generally were negatively correlated with pH, specific conductance, and dissolved oxygen.

INTRODUCTION

The Clean Water Act (CWA) establishes a process for States to develop information on water quality. It requires States to designate uses for each surface-water body in the State and adopt water-quality criteria that protect those uses (Public Law 92-500). In even numbered years, the State of Wyoming reports to the U.S. Environmental Protection Agency (USEPA) the status of its waters through the 305(b) Water Quality Assessment. Waters that do not meet water-quality criteria for their designated use are listed as required under section 303(d) of the CWA. In Wyoming, streams placed on the section 303(d) list as not fully meeting their designated uses must either show at least two exceedences of a numeric water-quality standard within a single 3-year period in the previous 5 years, or clearly exhibit the failure to achieve State narrative water-quality standards (J. Smith, Wyoming Department of Environmental Quality, written commun., 2000). The State of Wyoming assessed nearly 3,000 stream miles for the 305(b) report for 2000 (Wyoming Department of Environmental Quality, 2000). In general, Wyoming streams fully support their designated use. Impairments identified for Wyoming streams on the 303(d) list for 2000 include: fecal coliform bacteria, trace metals, nutrients, salinity, physical degradation, and oil deposits (Wyoming Department of

Environmental Quality, 2000). Fecal coliform bacteria was the most commonly listed impairment in 2000—the State assessed about 250 miles of stream as being impaired for contact recreation use.

Bacteriological analyses are used to assess the sanitary quality of water because the presence of certain bacteria is an indicator of the presence of fecal material from warm-blooded animals (U.S. Environmental Protection Agency, 1976). High concentrations of fecal indicator bacteria in waters where humans have recreational contact may present a risk of infection from other pathogenic microorganisms. Indicator bacteria, like fecal coliform, do not necessarily cause illness but are found in association with pathogenic microorganisms. High levels of indicator bacteria can indicate the possible presence of pathogens that cause such waterborne diseases as gastroenteritis, bacillary dysentery, typhoid fever, and cholera (Myers and Sylvester, 1997). The origin of bacterial contamination can be from point or nonpoint sources. Point sources are from single locations, like the end of a pipe. The primary point source of bacterial contamination is sewage-treatment-plant outfalls. Nonpoint sources are diffuse in nature and include:

- Agricultural—animal waste, application of manure and biosolids to fields, crop irrigation from contaminated storage ponds;
- Urban/Residential—failed septic systems, pet waste, landfill leakage;
- Recreational—direct discharge of water-craft sewage; and
- Wildlife waste (Wilhelm and Maluk, 1998).

Historically, the USEPA studies determined that statistically significant swimming-associated gastrointestinal illness may occur when concentrations of fecal-coliform indicator bacteria are 400 colonies per 100 milliliters of water (cols/100 mL) or higher (U.S. Environmental Protection Agency, 1986).

As part of a program to monitor long-term water quality in Wyoming, the U.S. Geological Survey (USGS), in cooperation with the Wyoming Department of Environmental Quality (WDEQ), monitors fecal coliform indicator bacteria at 18 sites statewide on major rivers and their tributaries (table 1). The purpose of this report is to describe the occurrence of fecal coliform in streams in Wyoming for the period 1990-99. This report summarizes data by water year which is the period from October of the previous year to September of the specified year. Seasonal variations are summarized for eight sites that are identified

Table 1. Fecal coliform bacteria sampling sites in Wyoming during 2000

Site no. (fig. 1)	USGS station no.	Station name	Latitude	Longitude
1	06232600	Popo Agie River at Hudson Siding, near Lander, Wyo.	42°51′59″	108°41′04″
2	06235500	Little Wind River near Riverton, Wyo.	42°59′51″	108°22′29″
3	06264700	Bighorn River at Lucerne, Wyo.	43°44′10″	108°09′38″
4	06274300	Bighorn River at Basin, Wyo.	44°23′00″	108°02′08″
5	06276500	Greybull River at Meeteetse, Wyo.	44°09′20″	108°52′35″
6	06284500	Bitter Creek near Garland, Wyo.	44°45′13″	108°35′29″
7	06302200	Big Goose Creek above Park Creek, near Sheridan, Wyo.	44°44′35″	107°07′45″
8	06304500	Little Goose Creek at Sheridan, Wyo.	44°48′10″	106°57′10″
9	06305500	Goose Creek below Sheridan, Wyo.	44°49′25″	106°57′40″
10	06320210	Clear Creek above Kumor Draw, near Buffalo, Wyo.	44°23′21″	106°37′23″
11	06426500	Belle Fourche River below Moorcroft, Wyo.	44°19′19″	104°56′24″
12	06428050	Belle Fourche River below Hulett, Wyo.	44°42′04″	104°35′07″
13	06669050	Wheatland Creek below Wheatland, Wyo.	42°05′05″	104°57′02″
14	06756060	Crow Creek near Archer, Wyo.	41°07′35″	104°39′04″
15	09222000	Blacks Fork near Lyman, Wyo.	41°27′08″	110°10′20″
16	09224050	Hams Fork near Diamondville, Wyo.	41°45′06″	110°31′57″
17	10038000	Bear River below Smiths Fork, near Cokeville, Wyo.	42°07′34″	110°58′23″
18	13027500	Salt River above reservoir near Etna, Wyo.	43°04′47″	111°02′12″

on the 303(d) list for 2000 for fecal coliform. The State of Wyoming water-quality criterion for fecal coliform bacteria for a water body is not a single number; the criterion depends on the class of water, time of year, and location relative to sewage-treatment-plant outfalls (Wyoming Department of Environmental Quality, 1990). The criterion of 400 cols/100 mL applies to most surface waters in the State during May through September. For this report, 400 cols/100 mL of fecal coliform is used for consistency across sites and sampling periods.

FECAL COLIFORM MONITORING

During water year 2000, the USGS is collecting water samples for analysis of fecal coliform bacteria at 18 sites that are part of the statewide WDEQ monitoring network (fig. 1). Samples are collected on a quarterly basis (October-December, January-March, April-June, and July-September) under varying hydrologic conditions. Within the larger statewide monitoring network, the constituents to be monitored at each site are selected to provide basic statewide water-quality data and to monitor possible water-quality concerns at that site, as determined by land-use information and historical water-quality records. Of the 18 sites being monitored for bacteria, 9 are included on the 303(d) list for 2000 with fecal coliform listed as the impairment for contact recreation uses: Bighorn River at Basin, Wyo.; Bitter Creek near Garland, Wyo.; Big Goose Creek above Park Creek near Sheridan, Wyo.; Little Goose Creek near Sheridan, Wyo.; Goose Creek below Sheridan, Wyo.; Belle Fourche River below Moorcroft, Wyo.; Belle Fourche River below Hulett, Wyo.; Crow Creek near Archer, Wyo., and Blacks Fork near Lyman, Wyo. Wheatland Creek below Wheatland, Wyo., is listed on the 303(d) list as well, but has ammonia identified as the primary impairment. A less restrictive criterion applies to this reach of Wheatland Creek because of its close proximity to a sewage-treatment-plant outfall.

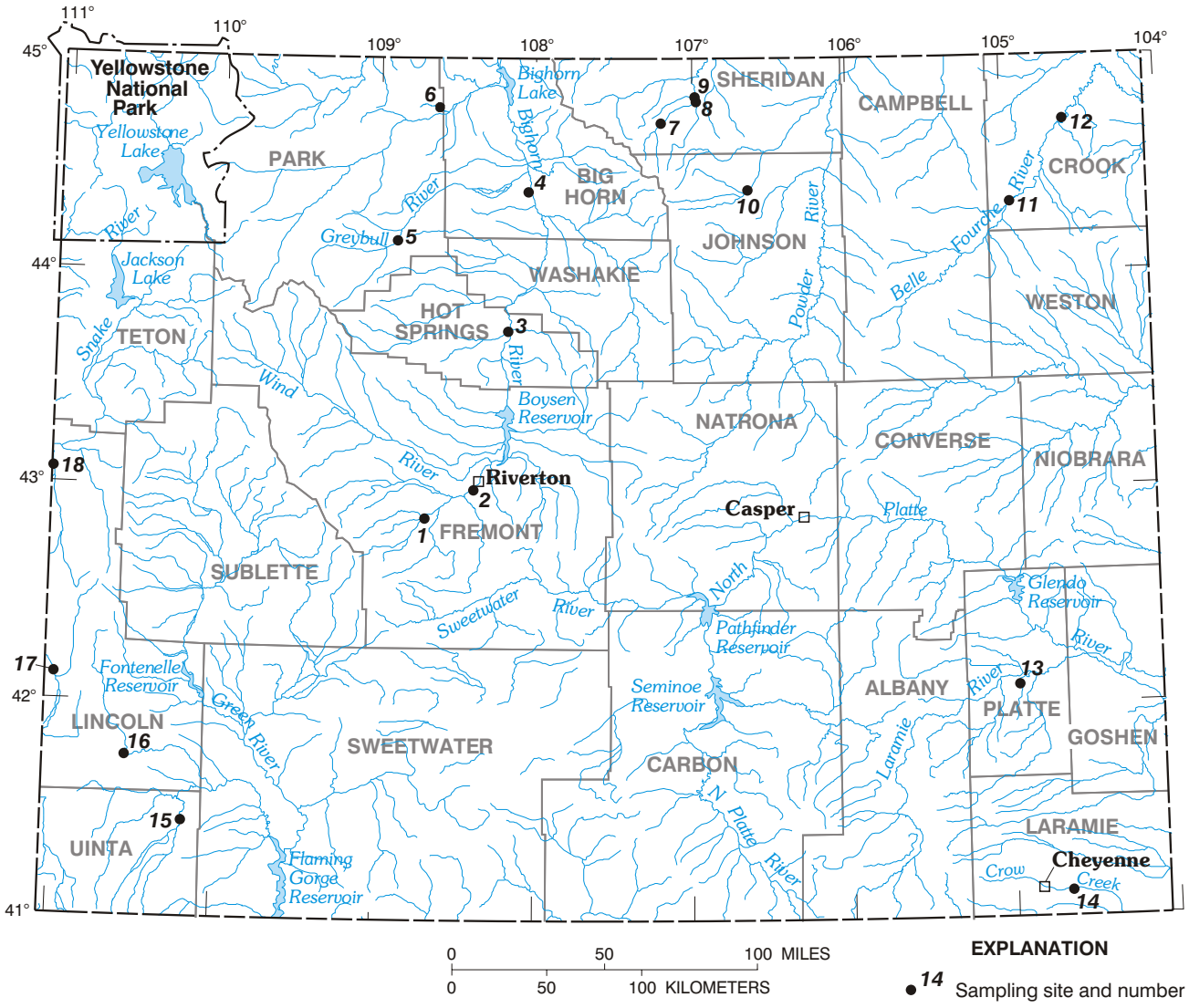

Figure 1. Location of sampling sites in Wyoming.

Table 2. Summary statistics for fecal coliform concentrations for sampling sites on Wyoming streams, 1990-1999

[Fecal coliform concentrations in colonies per 100 milliliters; * indicates site is included on the 303(d) list for 2000 for fecal coliform impairment; percent exceedence is the percent of samples at that site exceeding 400 colonies per 100 milliliters.]

Site no. (fig. 1)	USGS station no.	Period of record (no. of samples)	Fecal coliform concentrations			Percent exceedence
			Minimum	Median	Maximum	
1	06232600	1990-1999 (28)	<1	32	400	0
2	06235500	1990-1999 (40)	1	65	2,600	15
3	06264700	1990-1999 (41)	6	87	3,200	7
4	06274300*	1990-1999 (41)	1	120	8,900	20
5	06276500	1996-1999 (16)	2	21	390	0
6	06284500*	1993-1999 (29)	2	140	1,100	21
7	06302000*	1999 (2)	22	--	1,000	--
8	06304500*	1990-1999 (40)	1	62	860	15
9	06305500*	1990-1999 (40)	1	320	8,500	35
10	06320210	1993-1999 (28)	2	44	500	14
11	06426500*	1990-1999 (37)	<1	200	14,000	30
12	06428050*	1993-1999 (28)	3	51	17,000	21
13	06669050	1990-1999 (40)	8	170	45,000	35
14	06756060*	1991-1999 (36)	9	140	6,800	17
15	09222000*	1996-1999 (16)	3	88	9,000	19
16	09224050	1993-1999 (28)	<1	28	220	0
17	10038000	1993-1998 (28)	<1	21	340	0
18	13027500	1990-1999 (20)	<1	15	500	5

FECAL COLIFORM RESULTS

Summary statistics of fecal coliform concentrations are presented for the 18 sites currently being monitored for fecal coliform (table 2). The median was selected as a measure of the central tendency of the data to minimize the effects of outliers. The period of record summarized for this report is from 1990 to 1999. For some sites, only a partial period of record was available, and sampling frequency may have been variable between years. A median concentration was not calculated for Big Goose Creek (site 7) because only two samples have been collected by the USGS from the current sampling location established in May 1999. Prior to May 1999, samples on Big Goose Creek were collected about 4 miles upstream from the present sampling site. Because inflows from tributaries in between the sites may contribute fecal coliform, the data for the two sites were not combined. For all sites, fecal coliform concentrations from analyses with non-ideal colony counts are included in the statistical summary. Non-ideal colony counts occur when bacteria growth outside the ideal range of 20-60 colonies occurs on a single plate. Time-series scatter plots of the data are shown for eight of the nine sites identified on the 303(d) list (fig. 2). Big Goose Creek (site 7) is not included because of the small sample size (n=2) from the current sampling location.

Fecal coliform concentrations did not exceed the water-quality criterion of 400 cols/100 mL in 83 percent of all samples collected. For all sites, minimum and median fecal coliform concentrations were less than 400 cols/100 mL. At least one sample at 14 of the 18 sites, however, did exceed 400 cols/100 mL during 1990-99. The four sites that had no samples exceeding this criterion are on the Popo Agie River (site 1), the Greybull River (site 5), the Hams Fork (site 16), and the Bear River (site 17).

Fecal coliform concentrations at Goose Creek below Sheridan, Wyo., (site 9) exceeded the water-quality criterion in 35 percent of the samples. The highest median concentration for all the sites (320 cols/100 mL) was at Goose Creek. Fecal coliform exceeded the water-quality criterion in 35 percent of the samples from Wheatland Creek (site 13), and the highest maximum fecal coliform concentration from all streams (45,000 cols/100 mL) occurred in a sample from that site. High fecal coliform concentrations of 14,000 and 17,000 cols/100 mL were found in samples from sites on the Belle Fourche River below Moorcroft, Wyo. (site 11), and below Hulett, Wyo. (site 12), respectively. All four of these sampling sites occur below mixed urban and agricultural areas.

The Bighorn River, Goose Creek, and the Belle Fourche River have upstream and downstream sites that can be compared for spatial changes in the basin. The median concentrations of fecal coliform varied on the Bighorn River from 87 cols/100 mL at the upstream site at Lucerne (site 3) to 120 cols/100 mL at the downstream site at Basin (site 4). The maximum concentration at Lucerne (3,200 cols/100 mL) was much lower than the maximum

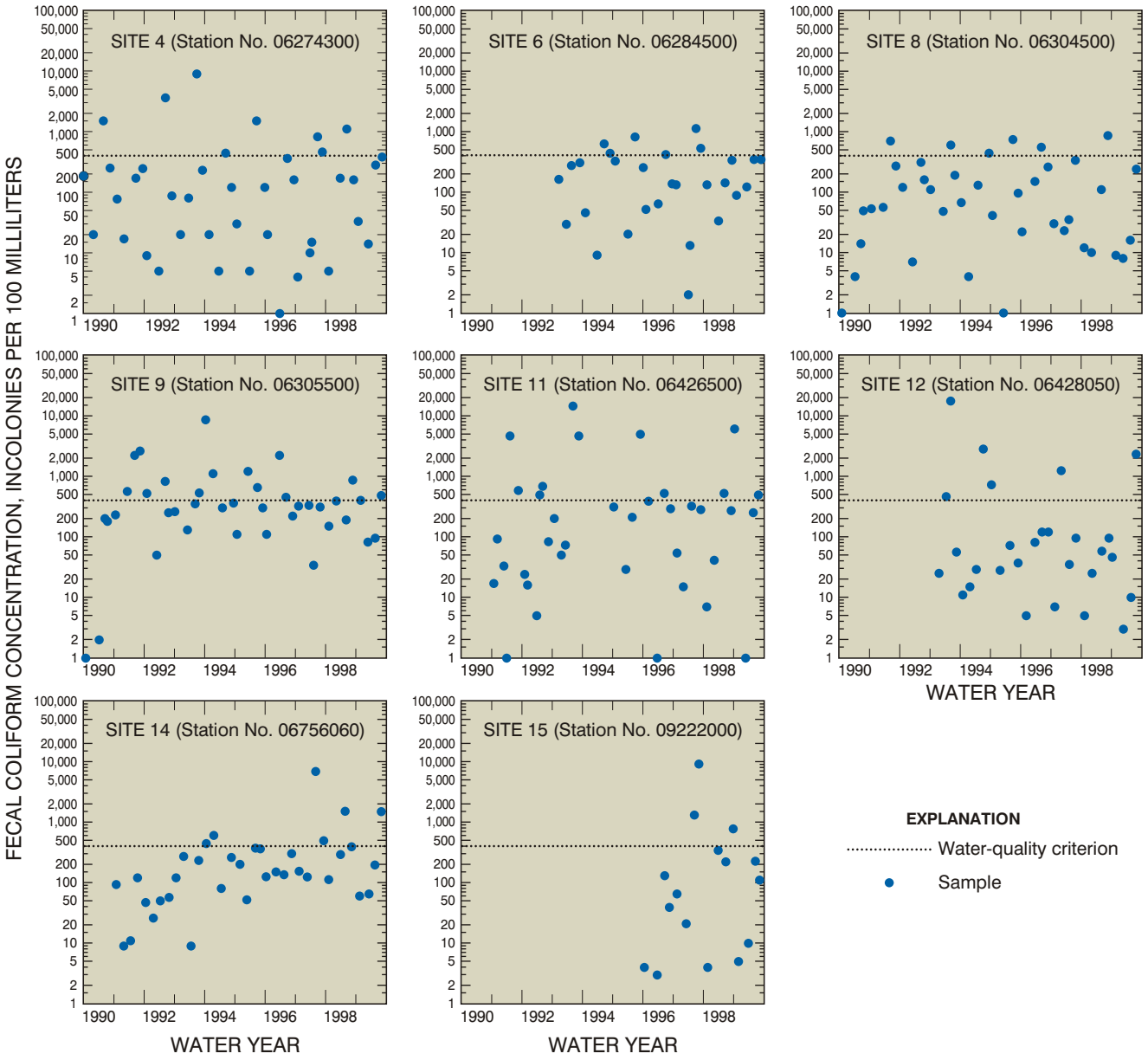

Figure 2. Fecal coliform concentrations for selected Wyoming streams, 1990-99.

concentration at Basin (8,900 cols/100 mL). Most of the land use in Bighorn River Basin is agricultural and rangeland, with small, dispersed urban areas (Zelt and others, 1999). In the Goose Creek watershed, the elevated median fecal coliform concentration (320 cols/100 mL) in samples from Goose Creek (site 9) may result from its location downstream of the Sheridan, Wyo., urban area. The median concentration was lower (62 cols/100 mL) in samples from Little Goose Creek (site 8) which flows through part of the urban area as well. Concentrations of fecal coliform in Big Goose Creek (site 7) indicate bacteria were present upstream from the urban area as well. Mixed land use occurs upstream from the Big Goose Creek site, including agricultural, rangeland, and rural domestic. On the Belle Fourche River, the median fecal coliform concentration was lower at the downstream site (site 12, 51 cols/100 mL) than at the upstream site (site 11, 200 cols/100 mL). In contrast, the maximum concentration was greater at the downstream site (17,000 cols/100 mL) than at the upstream site (14,000 cols/100 mL).

Boxplots are presented to show the temporal variations in fecal coliform concentrations and stream discharge at eight of the nine stations identified on the 303(d) list (fig. 3). Individual sample points are shown instead of boxes where the number of samples is less than nine. Some general patterns are discernible in the fecal coliform data from different sites. At all sites except Goose Creek (site 9), the maximum fecal coliform concentration occurred during April-June or July-September. The high concentrations during April-June on the Bighorn River (site 4), Bitter Creek (site 6), the Belle Fourche River

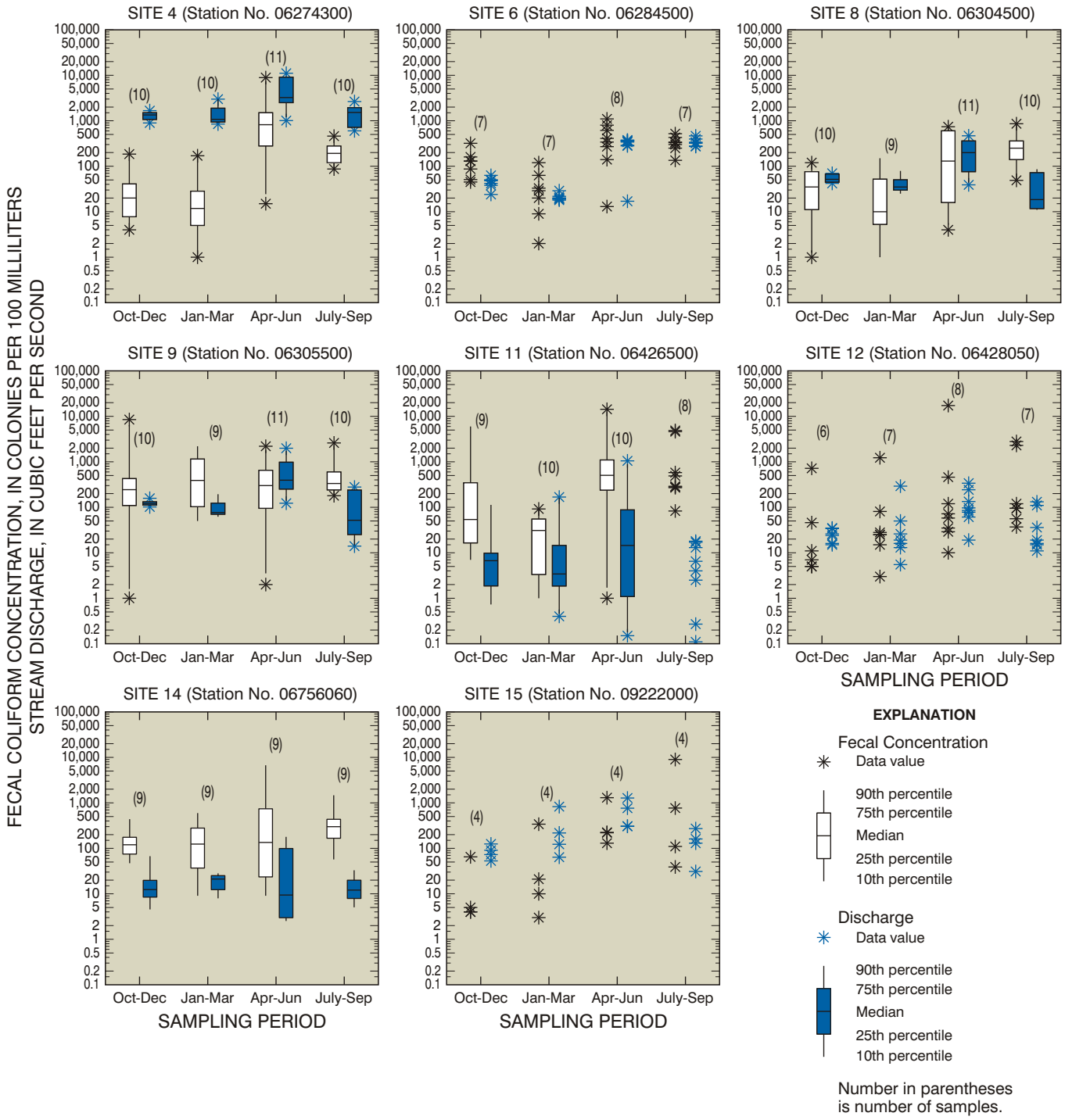

Figure 3. Temporal variations in fecal coliform concentrations and discharge for selected Wyoming streams.

(sites 11 and 12), and Crow Creek (site 14) coincide with the period of increased discharge. Fecal coliform concentrations generally show positive correlations with discharge because surface runoff from pastures, feedlots, and urban areas can contribute sediment and associated fecal coliform to streams (Smith and others, 1993, Wilhelm and Maluk, 1998). Increased discharge can also resuspend fine bottom sediments. Bacteria can survive in the protective environment of bottom sediment, particularly those with at least 25 percent clay (S. Embrey, 1991). Survival rates of bacteria in sediment may be longer than 30 days, compared to die-off rates of several days in the water column (Sherer and others, 1992). In addition to transport processes and variable survival rates, land-use activity, such as cattle grazing and outdoor recreational activities, generally increase during spring and summer months as well. The elevated concentrations and sources coincide with the time period when public-health risk is also higher because contact recreation potentially is occurring during warmer months. However, most of the health risk studies

have focused on swimming-associated illness. While full contact swimming does occur in some Wyoming streams, recreational contact is generally more passive in the form of canoeing, rafting, and fishing.

The highest fecal coliform concentration in samples collected from Goose Creek below Sheridan, Wyo. (site 9), occurred during October-December. However, this concentration is outside the range that is typical for that time period. The highest median concentration at Goose Creek occurred during January-March. Although fecal coliform concentrations were generally lower during the summer months on Goose Creek, the concentrations in some summer samples were higher than 400 cols/100 mL. These fecal coliform data indicate the need for monitoring streams for fecal coliform throughout the year to account for varying hydrologic conditions and levels and types of land and water use.

Environmental conditions can affect the survival rate of bacteria once they leave the digestive tract of warm-blooded animals. Spearman's rank correlation procedure was used to determine the relation between various water-quality field measurements during sample collection. The procedure provides a measure of the intensity of association between two variables. The correlation coefficient, rho, is computed using ranks of the data rather than actual data values (Helsel and Hirsh, 1995). Rho values range between 1 and +1; a negative value indicates an inverse relation between the data ranks. Correlation coefficients between fecal coliform concentrations and selected water-quality field measurements for eight sites are shown in table 3. Spearman correlation coefficients were considered statistically significant where p-values were less than 0.05. Discharge and water temperature were positively correlated with fecal coliform concentrations, whereas specific

conductance, pH, and dissolved oxygen generally were negatively correlated with fecal coliform. The correlation with discharge was statistically significant for three sites: the Bighorn River (site 4), Bitter Creek (site 6) and Blacks Fork (site 15). Specific conductance, which generally is inversely correlated with discharge, also had significant negative correlations with fecal coliform at the Bighorn River (site 4) and Bitter Creek (site 6) sites. A positive correlation between fecal coliform and water temperature was statistically significant at all sites, except Goose Creek (site 9). A negative correlation between fecal coliform and dissolved oxygen was statistically significant at all sites, except Goose Creek (site 9). The correlations with dissolved oxygen generally were stronger than the correlations with temperature for these sites.

ADDITIONAL MONITORING

Analyses for fecal coliform indicator bacteria are an easy, inexpensive method for determining the potential presence of other pathogens. However, more detailed information would be beneficial on the nature of the fecal contamination in selected Wyoming streams. Specific types of fecal coliform bacteria, like *Escherichia coli* (*E. coli*), are more closely linked with swimming-associated gastrointestinal illness than the more general fecal coliform analyzed in this study (Dufour, 1984). As a result of freshwater beach studies, the U.S. Environmental Protection Agency recommended the use of *E. coli* or enterococci as better indicators for State water-quality criteria (U.S. Environmental Protection Agency, 1986). Methods for

Table 3. Spearman rank correlation coefficients between fecal coliform and water-quality field measurements for selected Wyoming streams

[Italicized numbers indicate a significant relation where p-values were less than 0.05]

Site no. (fig. 1)	USGS station no.	Discharge	Specific conductance	pH	Water temperature	Dissolved oxygen
4	06274300	*0.495*	*-0.545*	*-0.498*	*0.713*	*-0.776*
6	06284500	*0.775*	*-0.843*	*-0.556*	*0.549*	*-0.634*
8	06304500	0.266	-0.079	-0.237	*0.605*	*-0.735*
9	06305500	0.021	0.012	-0.066	0.019	-0.214
11	06426500	0.309	-0.123	-0.166	*0.551*	*-0.581*
12	06428050	0.331	-0.350	-0.249	*0.420*	*-0.692*
14	06756060	0.287	*-0.397*	0.034	*0.425*	*-0.342*
15	09222000	*0.696*	-0.494	-0.403	*0.572*	*-0.684*

direct analysis for pathogens generally are expensive and sampling procedures can be complicated; however, these methods are evolving. Techniques for differentiating sources of fecal contamination also are evolving, including multiple antibiotic resistance and ribotype profiles (S. Parveen, University of Florida, written commun., 2000). Additional monitoring using other indicators or direct analysis of pathogens may help to better define the occurrence and sources of pathogenic contamination in Wyoming's streams.

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