Title

Evaluation of Water Quality Objectives for Santa Ana Basin Waterbodies

Authors

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Abstract

Orange, Riverside, and San Bernardino Counties, representing stormwater dischargers throughout the Santa Ana Basin, through a task force managed by the Santa Ana Watershed Project Authority, are assisting the Santa Ana Regional Water Quality Control Board review recreational beneficial uses and associated water quality objectives for inland surface waterbodies. This study required compilation of 30 years of bacteria data and development of queries to determine the relative frequency of exceedences of water quality objectives. Results were joined to a layer of bacteria stations and multi-attribute symbology was developed. Stratification of the data record at each bacteria station tested several factors hypothesized to be responsible for exceedences, including wet weather and seasonality. The ArcGIS Spatial Analyst extension was used to allocate rainfall stations for each bacteria monitoring station facilitating the stratification. Exceedences of objectives based on bacteria samples collected during dry weather were compared between seasons. In this paper, results of this analysis will be presented and discussed.

Introduction

The Stormwater Quality Standards Study was proposed to integrate basin-wide watershed planning and water quality program management efforts with the Santa Ana Regional Water Quality Control Board (Regional Board) Triennial Review Priority List and Work Plan. The California Regional Boards are required by federal law to review water quality standards, which include beneficial uses, water quality objectives, and an anti-degradation policy, on a 3-year cycle (triennial review). These standards are adopted in the region's Water Quality Control Plan (Basin Plan). The Regional Board has ranked updating the bacteriological water quality objectives associated with protecting recreational beneficial uses as one of their high priorities. Another priority is to review and where appropriate, revise beneficial use designations for a number of water bodies. The beneficial use designations were originally assigned to ocean beaches and major freshwater lakes and major streams in 1975. Minor streams, including many improved stormwater channels, were never formally designated. The presumption of body contact recreation (REC-1) for surface waters not specifically identified and designated in the Basin Plan is based on federal law and regulation, which establish that presumption.

Stakeholders in the Santa Ana Watershed expressed strong interest in assisting the Santa Ana Regional Board in providing additional data and science to assist in the evaluation of the appropriateness of the REC-1 beneficial use designation and associated water quality objectives to virtually all of the inland water bodies and storm drain channels. To coordinate this assistance effort, the Stormwater Quality Standards Study Task Force (Task Force) was formed. The Task Force and Regional Board had similar data collection needs in order to understand the fate, transport, and exposures to pollutants associated with impaired water bodies. Thirty years of bacteria data from monitoring of Santa Ana basin waterbodies was compiled as part of the Stormwater Standards Study. Geographical Information Systems (GIS) and other tools were utilized to show spatial relationships between these data and surrounding features.

Methods

Following the collection and quality assurance checking of the long term bacteria data record, a complete point layer of sampling locations was developed. MS Access was used to develop queries of the dataset to assess compliance by comparing actual data with the established REC-1 use water quality objectives for one key indicator, fecal coliform, and potential future objectives for another indicator, Escherichia coli (E. coli) (Table 1).

Fields in the point attribute table of the bacteria monitoring location layer were created to show the results of the database queries. Results from queries of the database were joined to the attribute table using a reference location identifier. These fields were used to symbolize sampling locations in the GIS model. The points on these maps were symbolized by two attributes, 1) fraction of non-compliant calendar months and 2) number of non-compliant calendar months when sufficient data was present to determine compliance. These attributes are depicted as varying intervals of color and size of points, respectively. Several different queries are used to assess the relationship between compliance with REC-1 bacteria standards and flow condition, season, and time period.

Table 1
REC-1 Water Quality Objectives for Bacterial Constituents

Water Quality Constituent	Single Sample[1]	Geometric Mean of Five or More Samples[1]
Fecal Coliform	400 MPN/100mL	200 MPN/100mL
E. coli[2]	236 MPN/100mL	126 MPN/100mL

[1] Criteria based on data collected within a given calendar month
[2] E. coli objectives are only proposed and not yet regulated by the US EPA or Regional Board

Stratification of the data record at each bacteria station tested several factors hypothesized to be responsible for exceedences, including wet weather conditions and seasonality. This allowed the Task Force to highlight factors that may be responsible for a disproportionate occurrence of exceedences of water quality objectives for bacteria.

To extract wet weather samples from the long term bacteria database, rainfall data was collected from several meteorological stations across the Santa Ana basin. The Santa Ana basin is approximately 3,000 mi^2 and therefore meteorological stations used in this stratification were selected based on regional climatic patterns to account for spatial variability. The Spatial Analyst extension was used to allocate rainfall stations to each bacteria monitoring station. These rainfall stations were then used to identify wet weather days at each of the bacteria monitoring stations, where daily rainfall exceeded 0.1 inches at the meteorological station. Queries were developed for the remainder of the bacteria record to show frequencies of exceedences of water quality objectives for bacteria during dry weather conditions.

Exceedences of objectives based on bacteria samples collected during dry weather days were compared between seasons. The rainy season was defined as December 1^{st} through March 31^{st} and the non-rainy season, April 1^{st} though November 31^{st}. Wet weather data was excluded from the seasonal analysis to assess differences in bacteria water quality in dry weather flow between the rainy and non-rainy seasons. No queries were developed to compare wet weather samples collected at different times of year, due to the limited number of samples.

Results

Potential exceedences of REC-1 bacteria water quality objectives were observed for most Basin Plan reaches with sample results, including larger streams such as the Santa Ana River, medium sized inland surface streams such as Chino Creek, small urban channels such as Salt Creek near Lake Elsinore, and mountain streams such as Knickerbocker Creek in Big Bear Lake (Figure 1). Symbology was developed for each bacteria monitoring location where color represents the frequency of exceedences of REC-1 use objectives and size shows the number of calendar months where the criteria was evaluated. There were significantly fewer bacteria monitoring locations that had more than five samples collected within a single calendar month, as shown by the fewer points symbolized when evaluating compliance with the geometric mean objectives for fecal coliform and E. coli.

In general, robust historical datasets show that most reaches of the Santa Ana River have exceeded the evaluated bacteria objectives. Urban flood control channels, specifically in the Newport Bay drainage area, also show a long term pattern of bacteria objective exceedences. Streams within undeveloped or mountainous regions show less frequent exceedences, however less historical data is available from these waterbodies.

Wet Weather

Results of the stratification of the long term bacteria database showed that exceedences of bacteria objectives were common during wet weather flow conditions. Figure 2 shows the spatial distribution of exceedence frequency of bacteria objectives when evaluating the single sample criteria for fecal coliform and E. coli collected on wet weather days. There was only one monitoring location where more than five wet weather samples were collected during a single calendar month, therefore results are not included in map format. Many of the bacteria counts in wet weather samples were orders of magnitude above the REC-1 use objectives. However, this dataset was small (Fecal coliform, n = 122; E. coli, n = 64) and high frequency of exceedences of objectives were also observed in many Basin Plan reaches during dry weather flow conditions.

Dry Weather

Dry weather bacteria samples made up the majority of the database. These data were stratified one step further into rainy and non-rainy seasons, whereby the rainy season was implied to occur between December 1st and March 31st and the non-rainy season between April 1st and November 31st. The differences in bacteria objective exceedences frequencies were not highly significant. Observation of map (a) in Figures 3 and 4 may show a trend toward more exceedences of the geometric mean criteria for fecal coliform during the non-rainy season.

Discussion

Utilizing the symbol size to show the number of calendar months when criteria were evaluated prevents misinterpretation of results. Bacteria count dynamics in waterbodies are highly variable and may never be fully understood. Sharp increases in bacteria resulting from atypical conditions could be responsible for individual exceedences of monthly water quality objectives. Such may be the case in Icehouse Canyon, Cucamonga Canyon, and at the Seven Oaks Dam, where small frequencies of exceedences were observed. These sites exceed objectives due to single samples collected during the fall of 2002, although criteria were evaluated for 10-15 months between 2001 and 2003 at these sites. Results from these locations aided the Task Force in determining whether the REC-1 use objectives for fecal coliform and proposed objectives for E. coli were below those that could be considered background levels.

Stratification of the bacteria record did not reveal any significant relationship between season or flow condition and the likelihood of exceedences of REC-1 bacteria water quality objectives for inland surface waterbodies of the Santa Ana Basin. However, bacteria samples collected during wet weather events showed fecal coliform and E. coli counts that were orders of magnitude higher than the median of all samples in many reaches. Analysis of actual bacteria counts rather than exceedences of static water quality objective would be more likely to reveal the presence of any relationships between bacteria count and flow condition.

Dry weather samples showed slightly higher frequency of exceedences of bacteria water quality objectives in the non-rainy season. This difference is observed between Figures 3 and 4 and confirmed by reviewing the results database, specifically for exceedences of fecal coliform count when applying the geometric mean criteria. This could be attributed to higher contributions of baseflow including groundwater in the winter months, which would dilute bacteria in urban dry weather flow. Natural groundwater would have lower bacteria counts due to interaction with microorganisms in the soil.

Conclusions

Bacteria conditions in inland surface waterbodies of the Santa Ana basin are a concern for potential recreational users. The current water quality objectives using fecal coliform as the primary regulatory indicator for these waters is challenging local stormwater and flood control agencies, because most waterbodies traveling through urbanized areas exceed objectives in at least one calendar month during all seasons and flow conditions. Employing multiple attribute symbologies facilitated the evaluation of a historical record of Santa Ana Basin surface waterbody bacteria in relation to REC-1 use water quality objectives.

The Task Force sought to identify those waters where REC-1 bacteria water quality objectives were critical to protect the public and to develop a strategy to determine waterbodies where REC-1 uses are not attainable and might therefore be candidates for redesignation. This process involves more site specific investigation into factors that impact recreational use of inland surface waterbodies of the Santa Ana Basin. During the next phase of the Stormwater Standards Study, the Task Force will further investigate recreational use in select waterbodies where the attainability of recreational use is in question. Once the waterbodies that need to be protected are more clearly defined, a more detailed investigation of bacteria and appropriate objectives, in surface waters, will be needed.

Further analysis of the historical bacteria dataset might provide more discernable trends between bacteria counts and other variables, which were not identified by evaluating only exceedences of specific water quality objectives. Additionally, the use of bacteria source tracking or drainage area land use patterns could help to relate watershed and/or in stream characteristics to problematic bacteria levels.

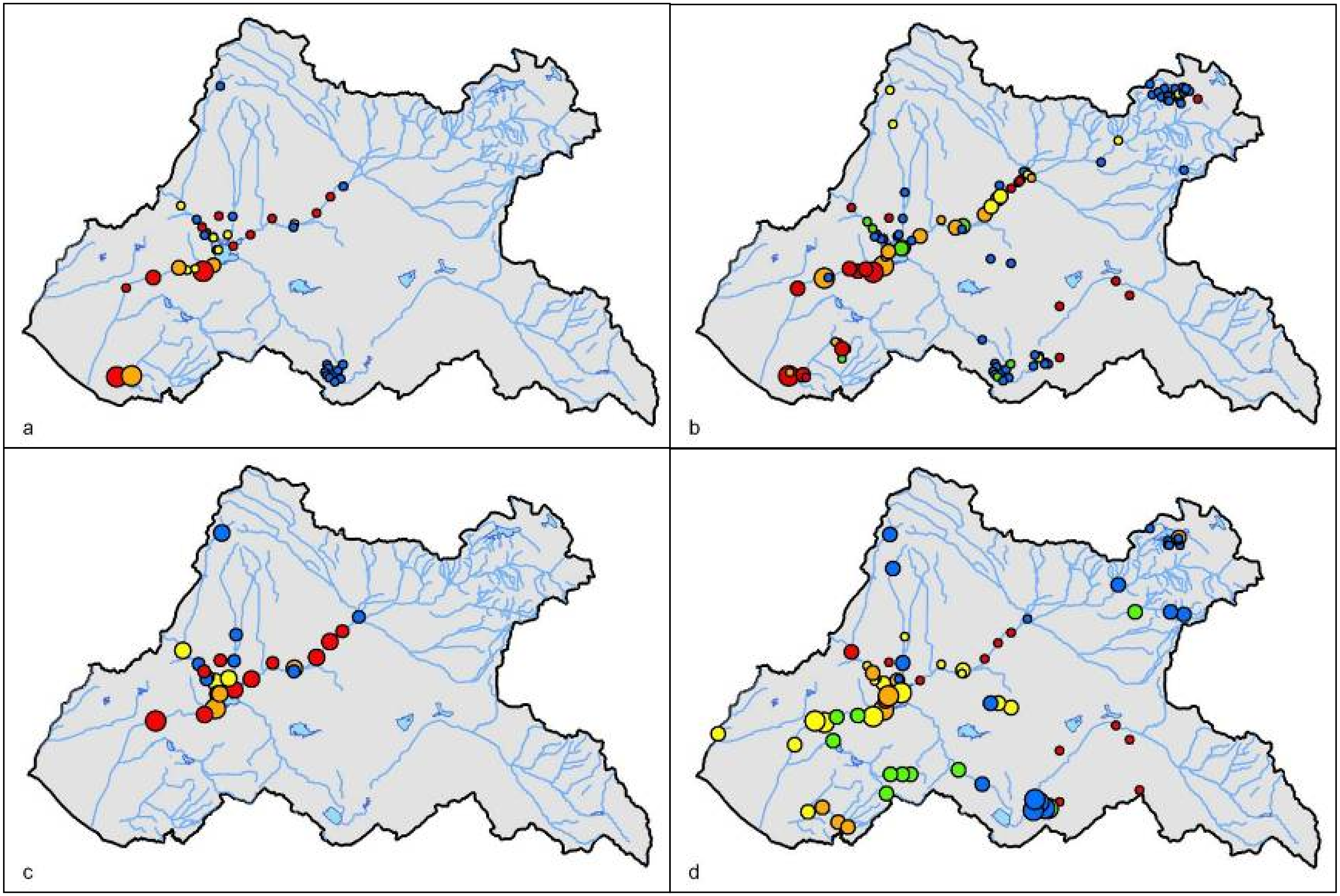

Figure 1 - Frequency of Exceedences of REC-1 bacteria water quality objects in Santa Ana Basin waterbodies.
Results from the fecal coliform analysis using the geometric mean and single sample criteria are shown in maps (a) and (b), respectively. Results from the E coli analysis using the geometric mean and single sample criteria are shown in maps (c) and (d), respectively. The symbol colors represent the fraction of sampled calendar months exceeding criteria (Blue = 0.0, Green = 0.01 - 0.25; Yellow = 0.26 to 0.5; Orange = 0.51 to 0.75; Red = 0.76 to 1.0. The symbol size represents the number of calendar months when the criteria was evaluated. Three point sizes represent 1-2, 3-5, and greater than 5 calendar months with geometric means for five or more samples in maps (a) and (c). The single sample evaluation shown in maps (b) and (d) are broken into three symbol size intervals; 1-20, 21-100, and greater than 100 sampled calendar months.

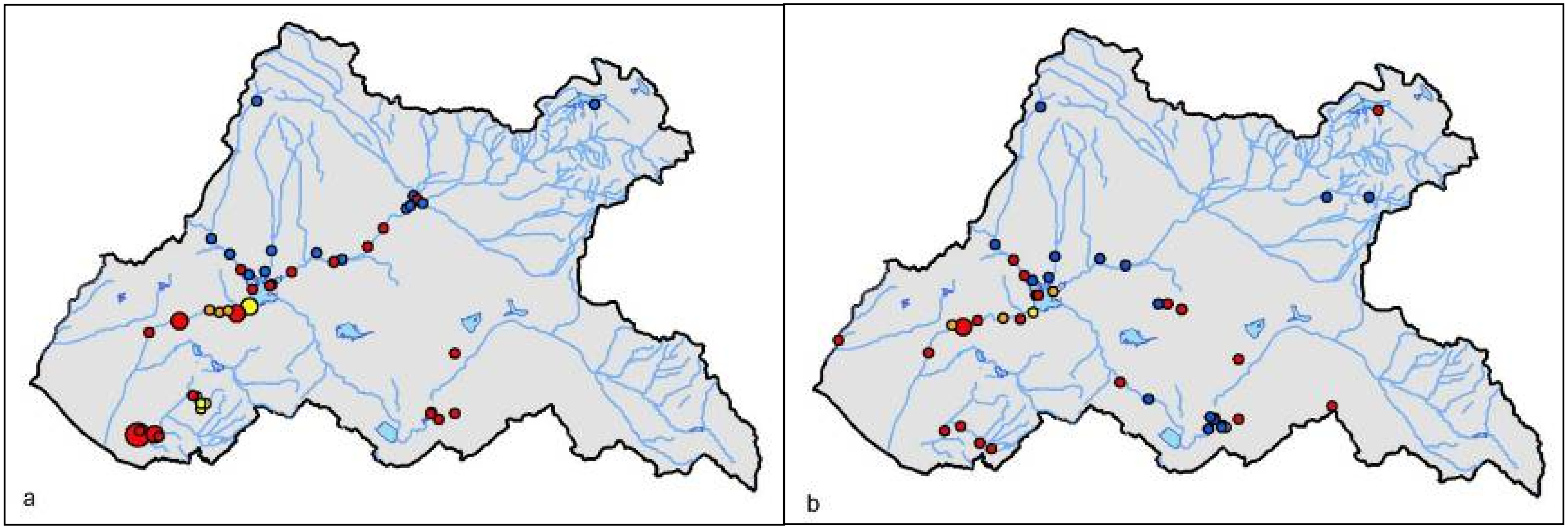

Figure 2
Frequency of exceedences of REC-1 bacteria water quality objects in Santa Ana Basin waterbodies during wet weather conditions. Results from the fecal coliform and E. coli analyses using the single sample criteria are shown in maps (a) and (b), respectively. The symbol colors represent the fraction of sampled calendar months exceeding criteria (Blue = 0.0; Yellow = 0.01 to 0.5; Orange = 0.51 to 0.75; Red = 0.76 to 1.0. The symbol size represents the number of calendar months when the criteria was evaluated. The single sample evaluation shown in maps (a) and (b) are broken into three symbol size intervals; 1-5, 6-20, and greater than 20 sampled calendar months.

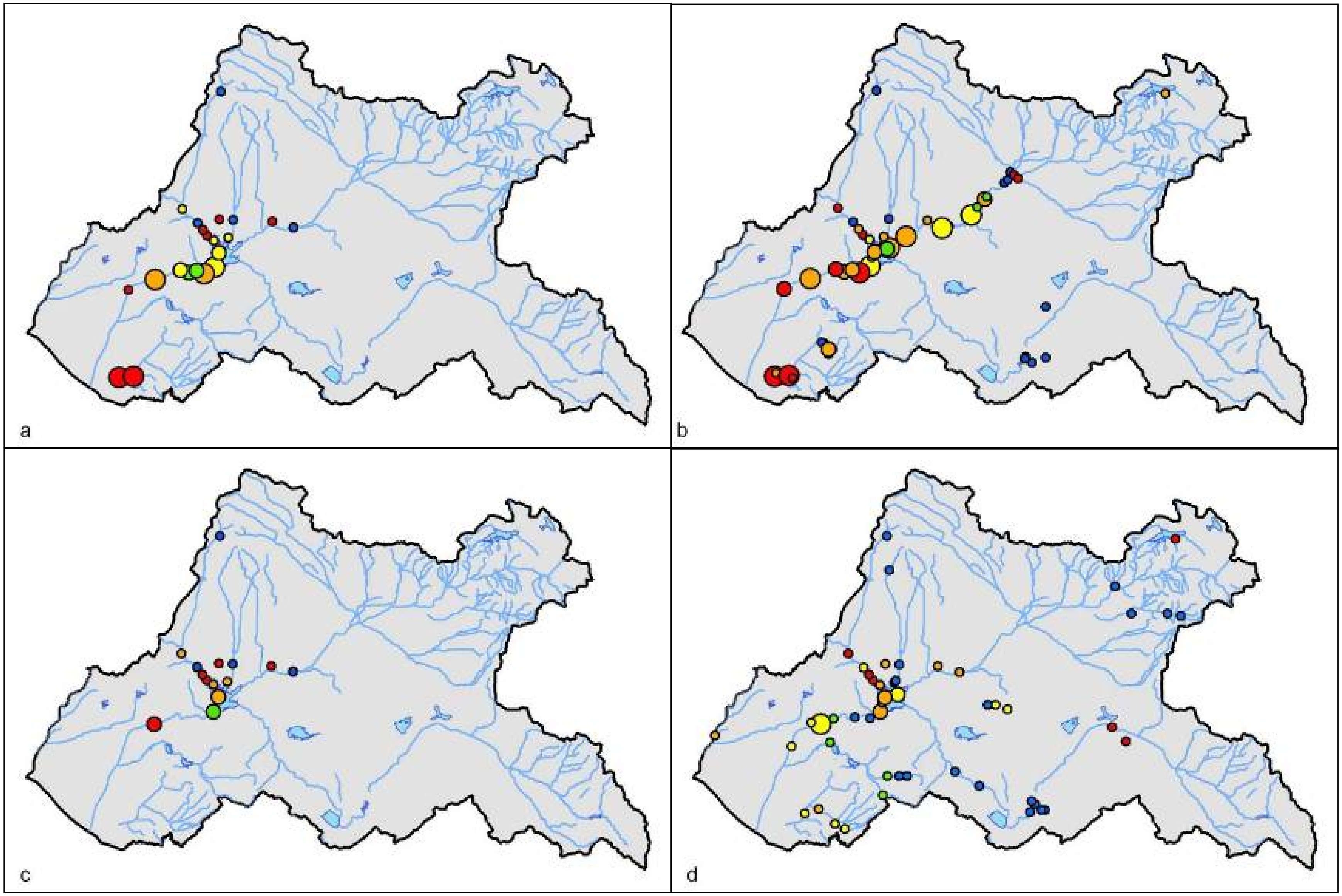

Figure 3 - Frequency of Exceedences of REC-1 bacteria water quality objects in Santa Ana Basin waterbodies during dry weather flow conditions occurring in the rainy season.
Results from the fecal coliform analysis using the geometric mean and single sample criteria are shown in maps (a) and (b), respectively. Results from the E coli analysis using the geometric mean and single sample criteria are shown in maps (c) and (d), respectively. The symbol colors represent the fraction of sampled calendar months exceeding criteria (Blue = 0.0, Green = 0.01 - 0.25; Yellow = 0.26 to 0.5; Orange = 0.51 to 0.75; Red = 0.76 to 1.0. The symbol size represents the number of calendar months when the criteria was evaluated. Three point sizes represent 1-2, 3-5, and greater than 5 calendar months with geometric means for five or more samples in maps (a) and (c). The single sample evaluation shown in maps (b) and (d) are broken into three symbol size intervals; 1-10, 11-25, and greater than 26 sampled calendar months.

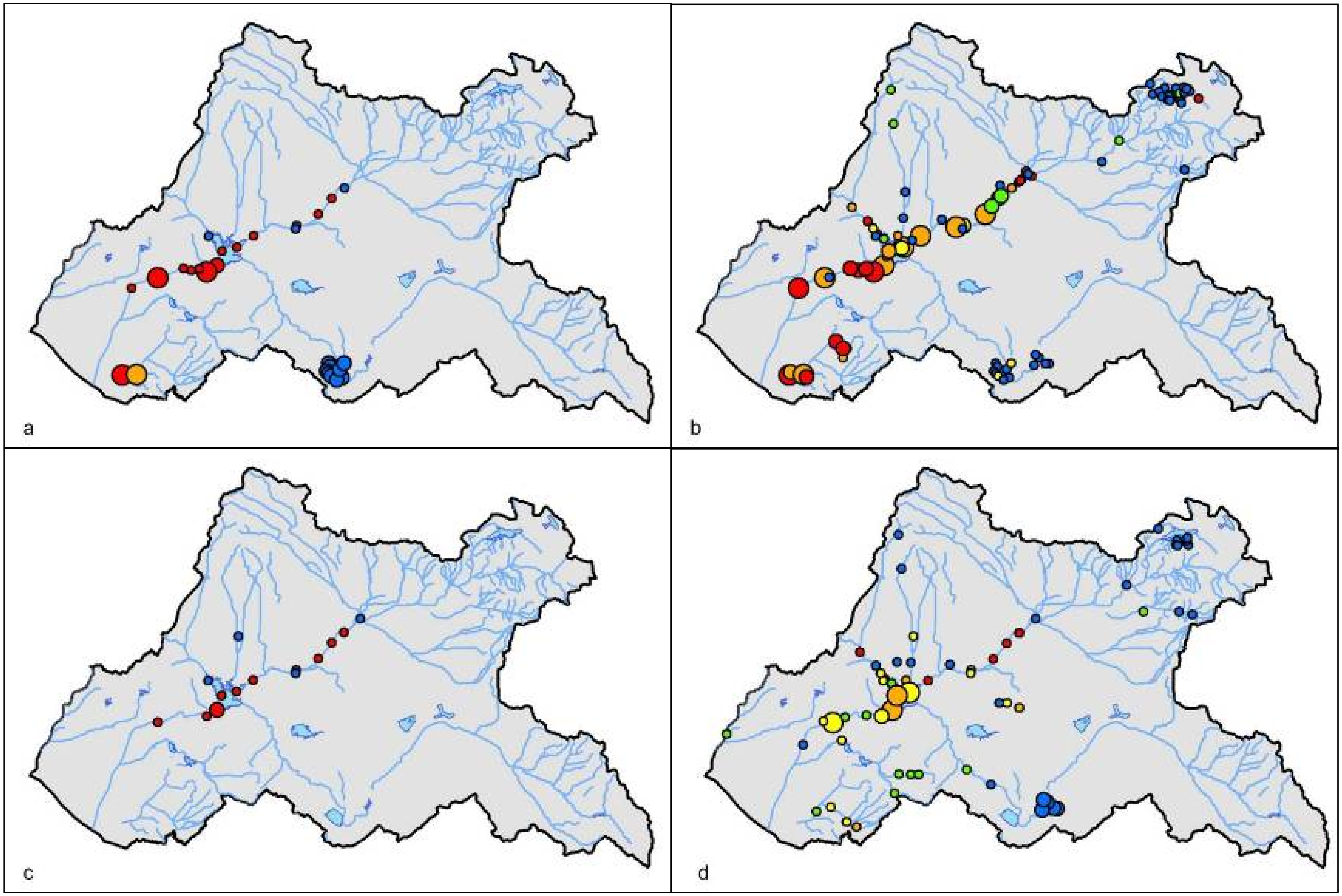

Figure 4 - Frequency of Exceedences of REC-1 bacteria water quality objects in Santa Ana Basin waterbodies during dry weather flow conditions occurring in the non-rainy season.

Results from the fecal coliform analysis using the geometric mean and single sample criteria are shown in maps (a) and (b), respectively. Results from the E coli analysis using the geometric mean and single sample criteria are shown in maps (c) and (d), respectively. The symbol colors represent the fraction of sampled calendar months exceeding criteria (Blue = 0.0, Green = 0.01 - 0.25; Yellow = 0.26 to 0.5; Orange = 0.51 to 0.75; Red = 0.76 to 1.0. The symbol size represents the number of calendar months when the criteria was evaluated. Three point sizes represent 1-2, 3-5, and greater than 5 calendar months with geometric means for five or more samples in maps (a) and (c). The single sample evaluation shown in maps (b) and (d) are broken into three symbol size intervals; 1-10, 11-25, and greater than 26 sampled calendar months.

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