Texas Bacterial Source Tracking Program

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Where did the Bacteria (*E. coli*) Come From?

- **Potential sources**
  - **Humans**
  - **Domesticated animals**
  - **Wildlife**
    - **~140 mammals**
    - **~650 birds**
- **Methods for determining sources**
  - **Source survey**
  - **Modeling**
  - **Bacterial source tracking (BST)**

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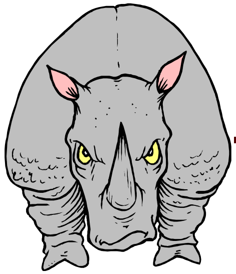
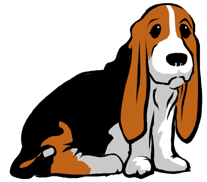
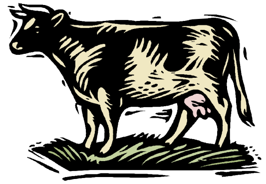


PREMISE BEHIND BST



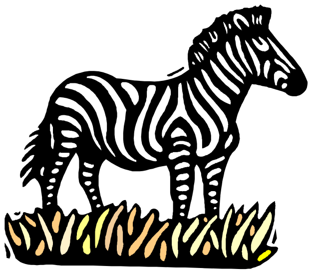
Different guts → Different adaptations

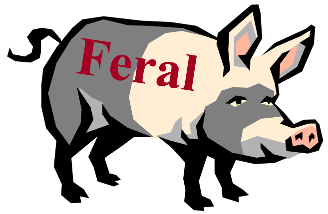
→ Different *E. coli* strains →

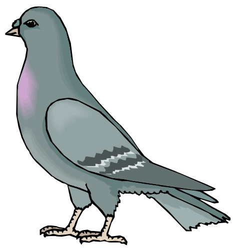


Genetic Differences

Phenotypic Differences







Classifications of BST Methods

	Library-dependent Methods	Library-independent Methods
Genotypic	Ribotyping Bacterial community fingerprinting Rep-PCR[2] PFGE[2] Mitochondrial DNA	F+ coliphages (FRNA & FDNA phage) Direct pathogen detection (PCR, RT-PCR) *Bacteroides* genotyping Enterotoxin biomarkers
Phenotypic	Antibiotic resistance analysis (ARA) Carbon source profiling (CUP)	*Bifidobacterium* Phage infecting B. fragilis F+ coliphage serotyping

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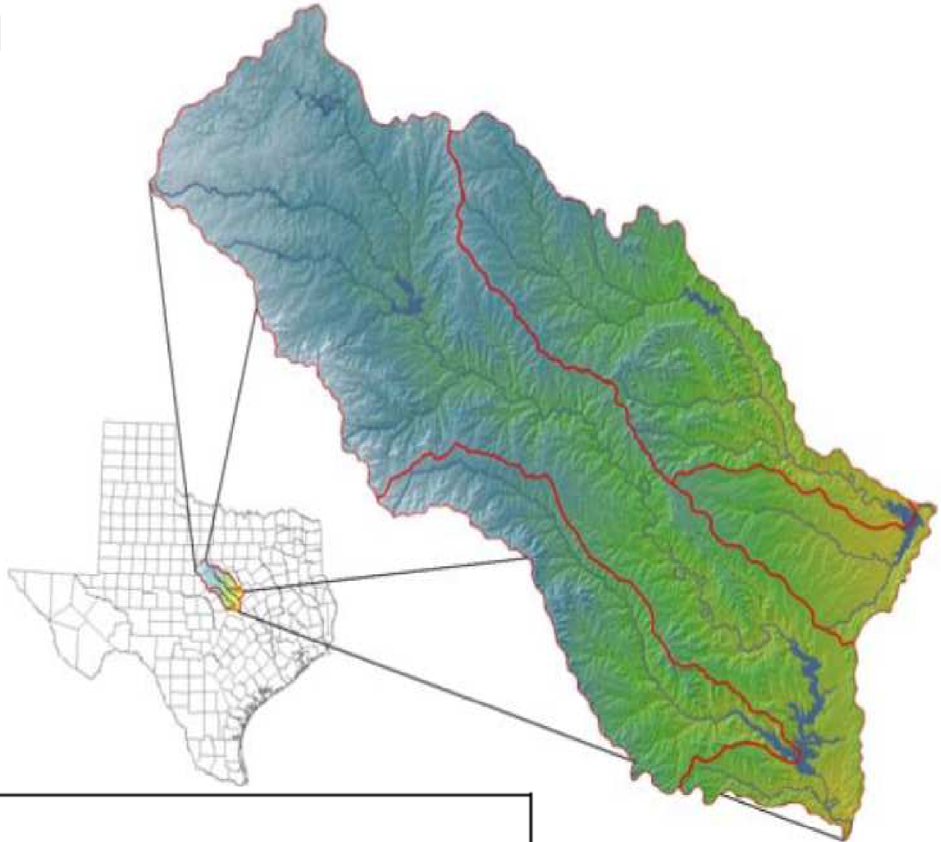
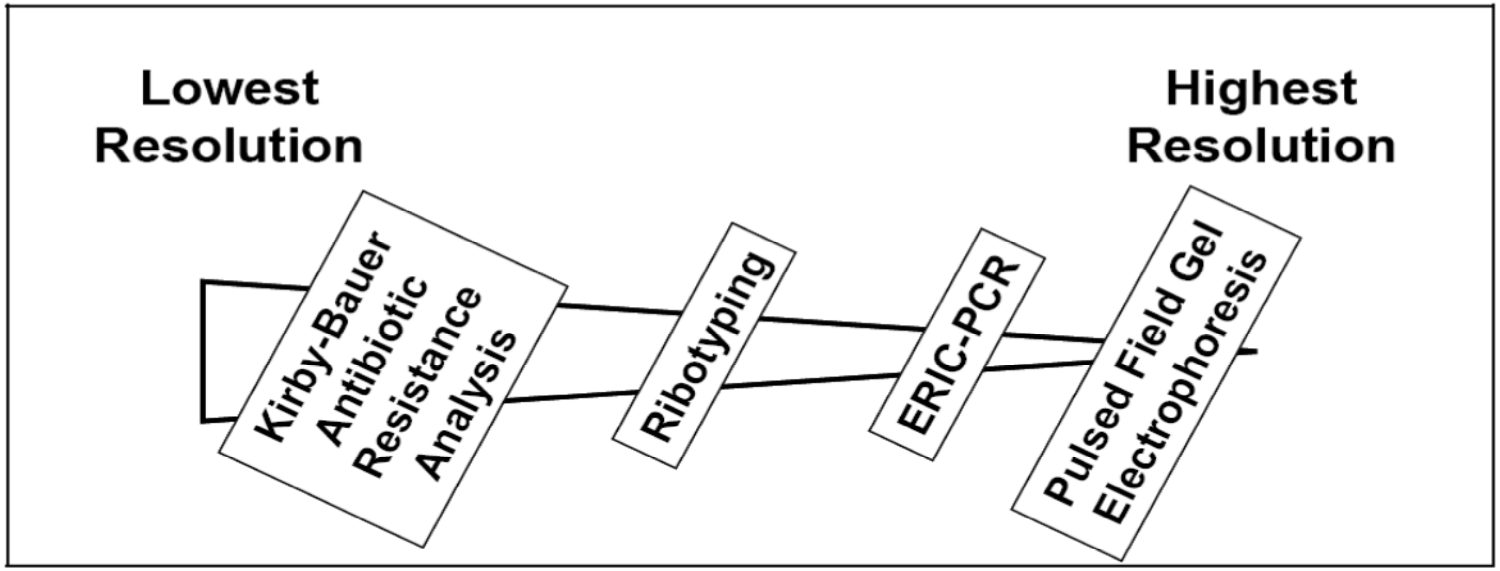
History of BST Use in Texas

- Lake Waco/Belton Project initiated Sep. 2002
- Funded by TSSWCB
- Evaluated utility & methods
- Completed Feb. 2006



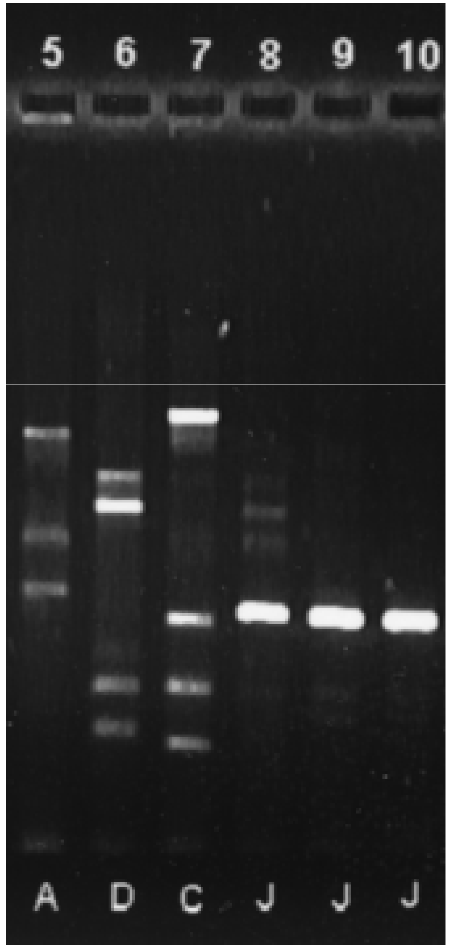


History of BST Use in Texas

- Lake Waco/Belton Project Findings
  - 4-method composite performed better than individual methods
  - Recommended 2-method composites
    - ERIC-ARA = lower cost but more sample & data processing
    - ERIC-RP = higher cost but automated
- TMDL Task Force Report – 2007
  - Confirmed ERIC-RP as recommended method

Establishment of Texas BST Program (2007)

- Two DNA fingerprinting methods selected:
  - Enterobacterial repetitive intergenic consensus sequence-polymerase chain reaction (ERIC-PCR)
  - RiboPrinting® (RP)
- Required BST Library Development



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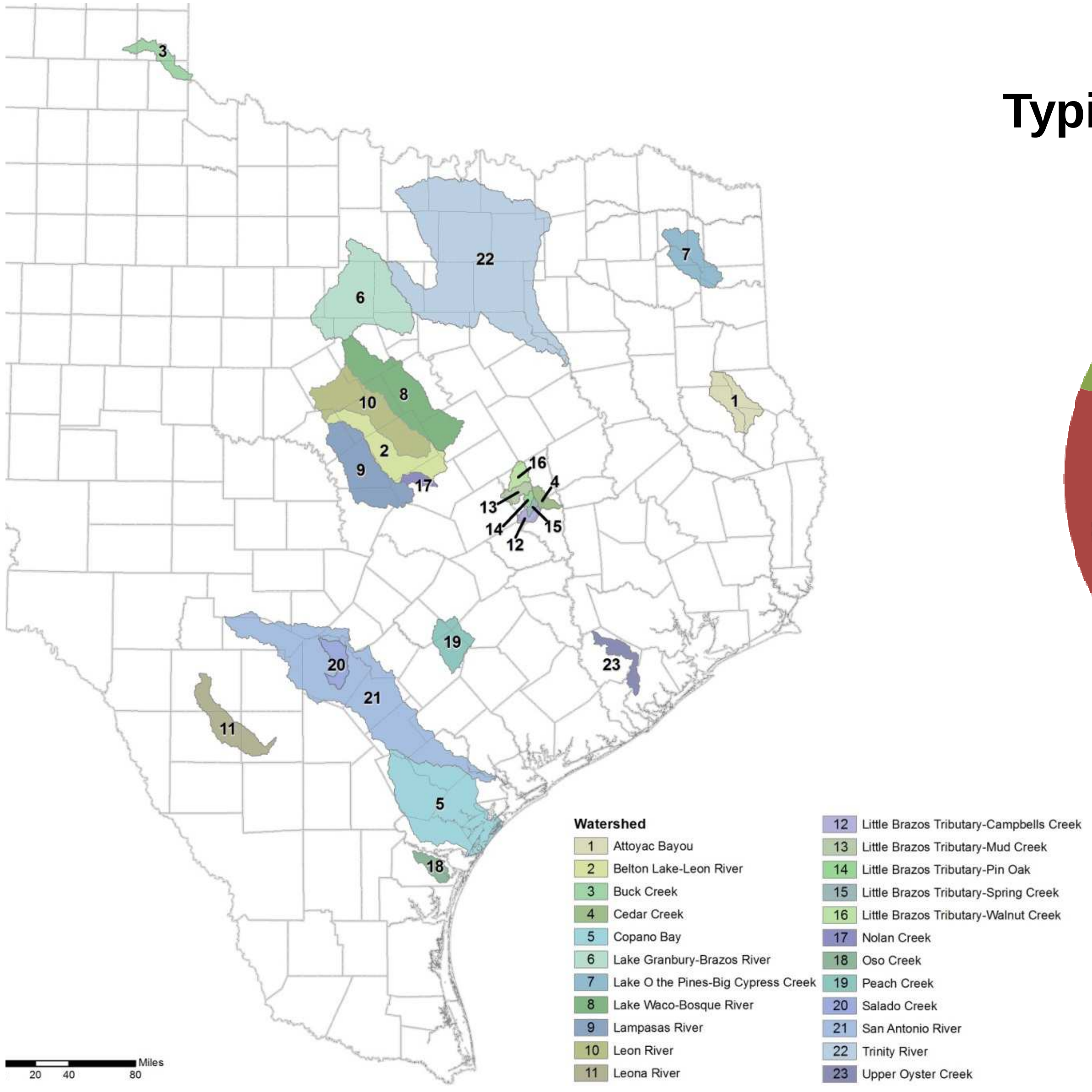
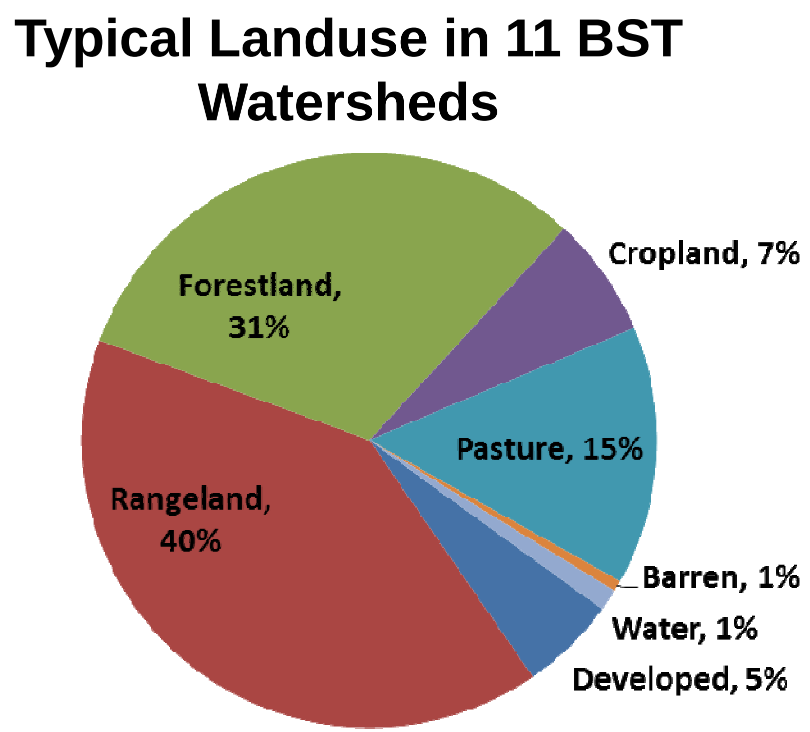
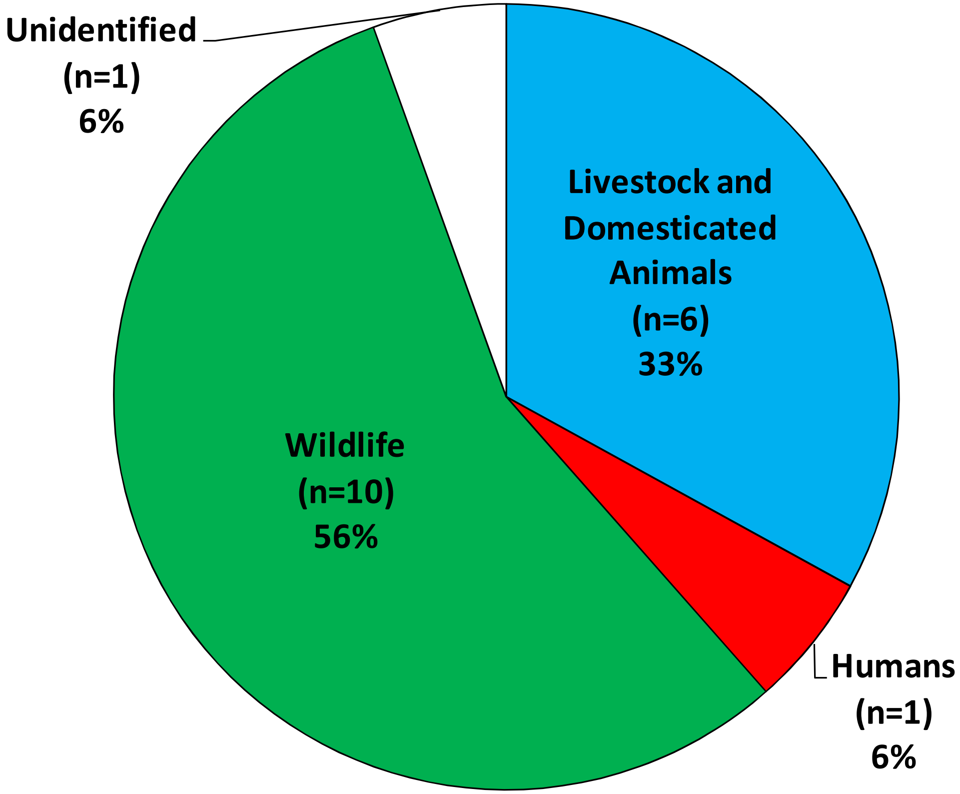
Texas BST Studies To Date



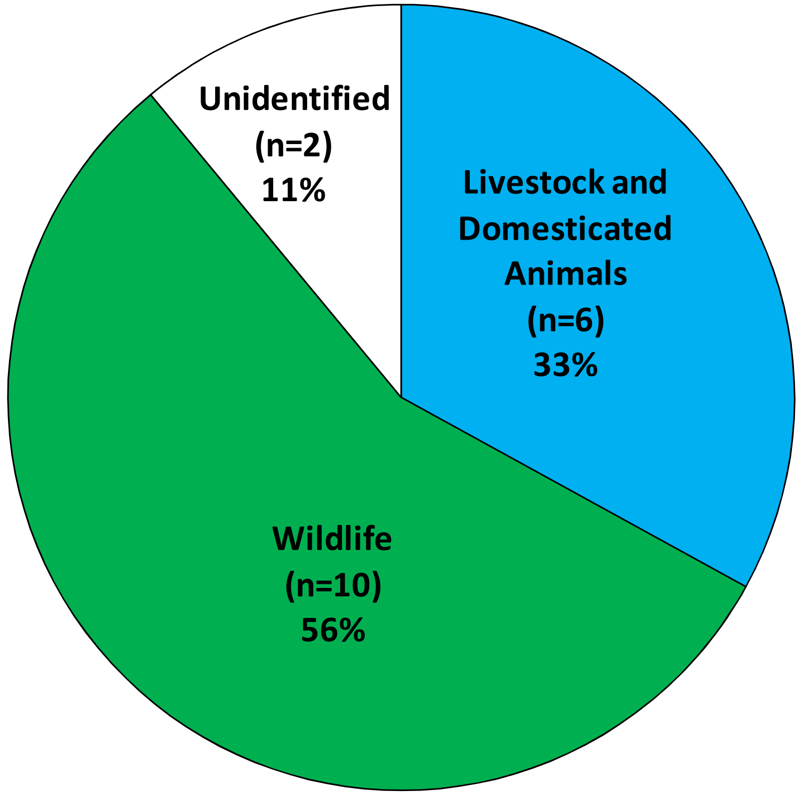


E. coli BST Results - Attoyac
Base Flow vs Storm Flow (3-Way Split)

Base Flow



Storm Flow



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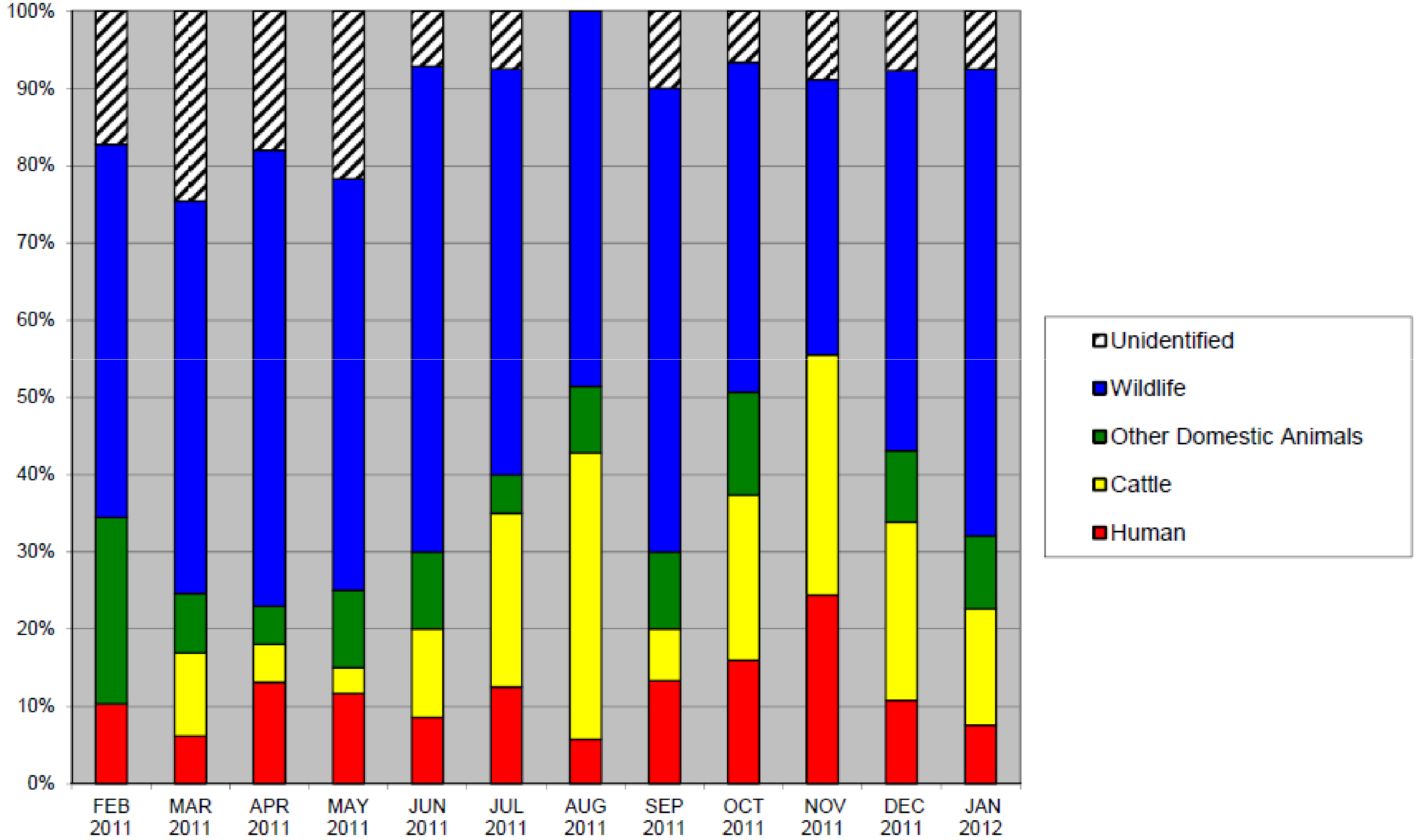
E. coli BST Results - Lampasas
(Monthly 4-way Split All Sites Combined)



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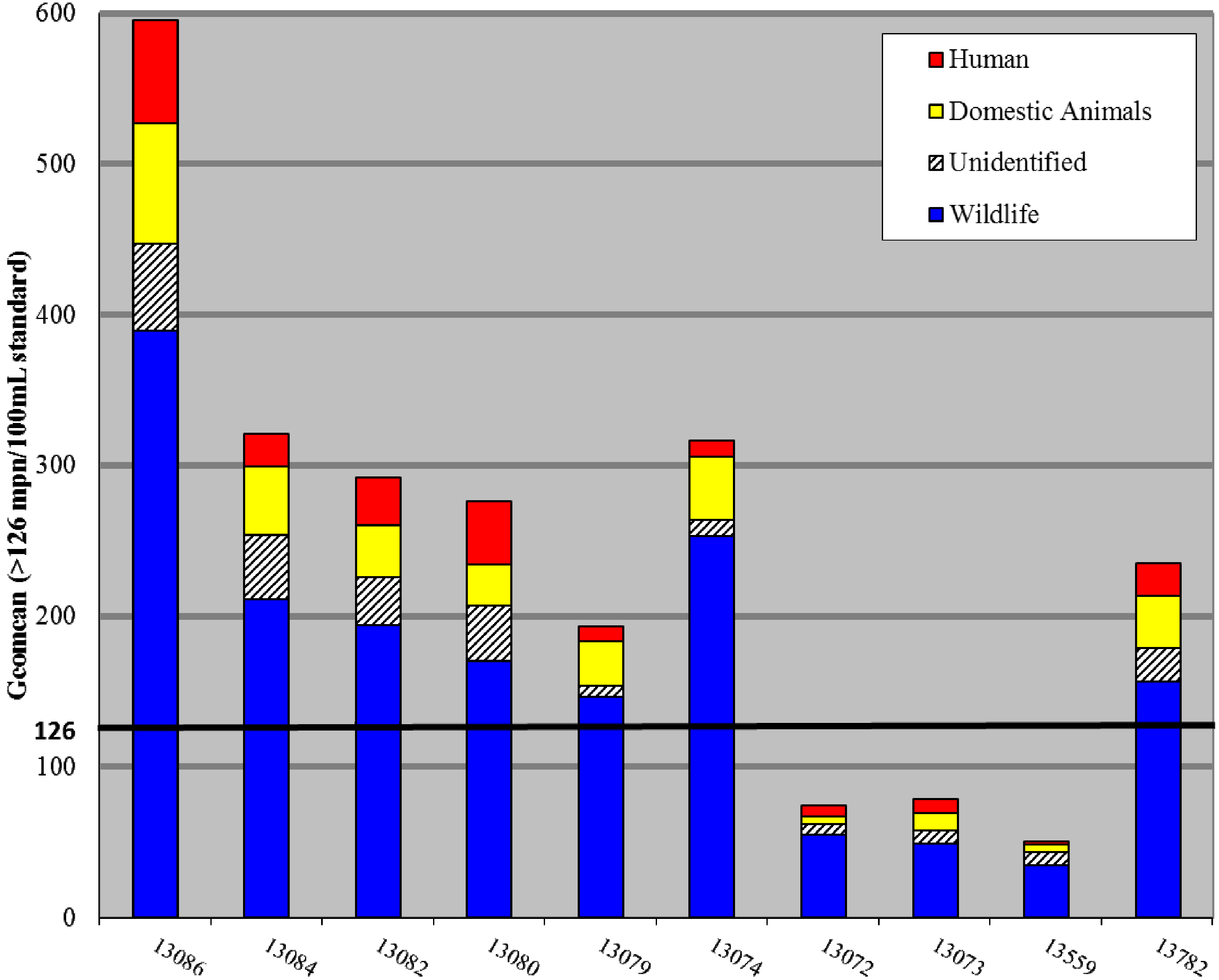
Arroyo Colorado
3-way split BST results for each site scaled to *E. coli* annual geomeans



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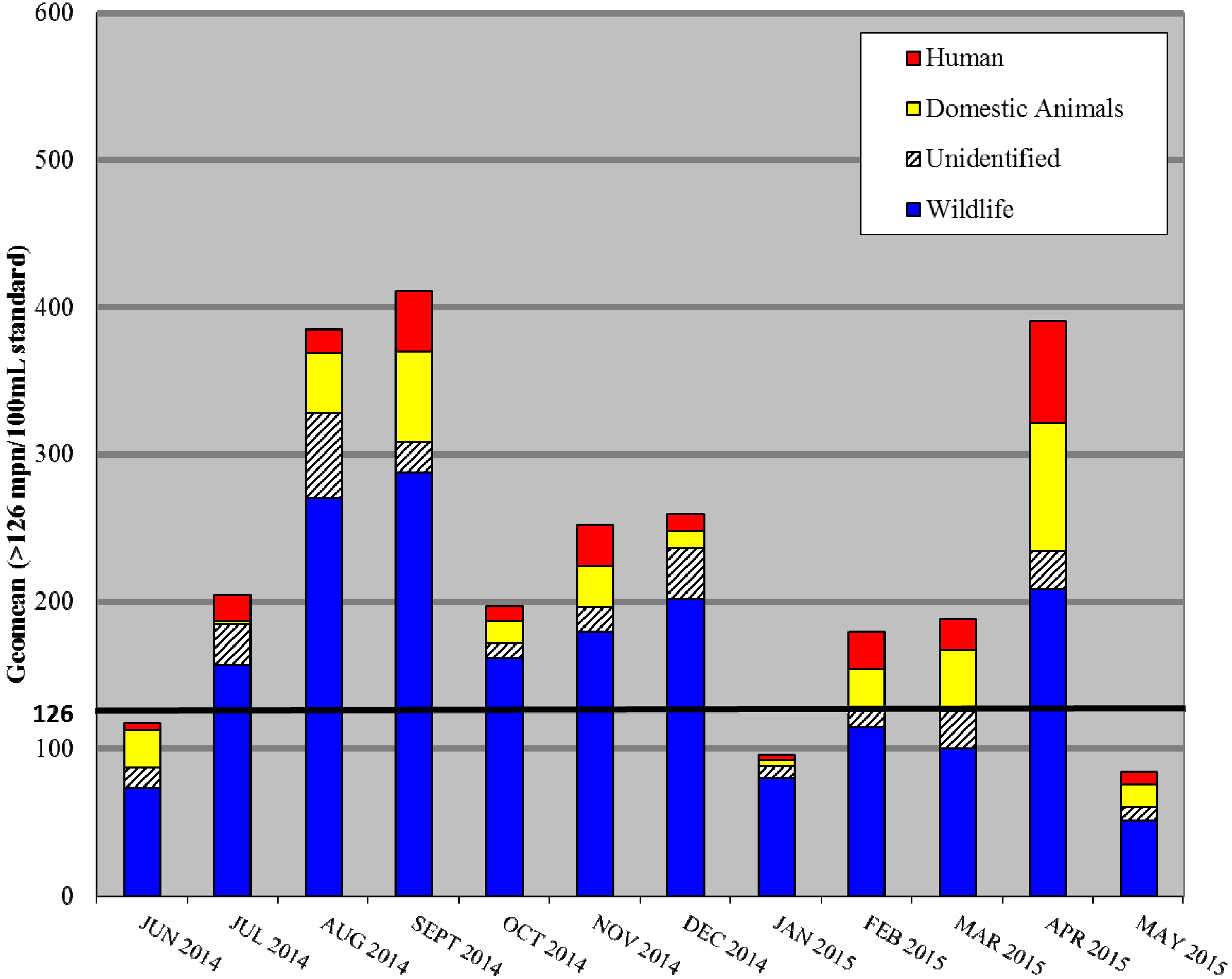
Arroyo Colorado:
3-way split BST results by month for all sites combined, scaled to *E. coli* geomeans



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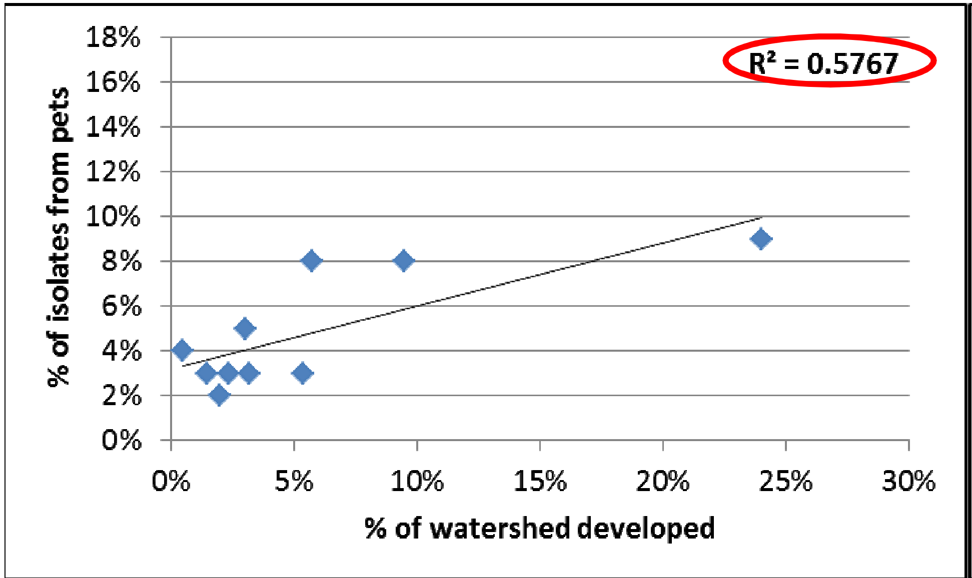
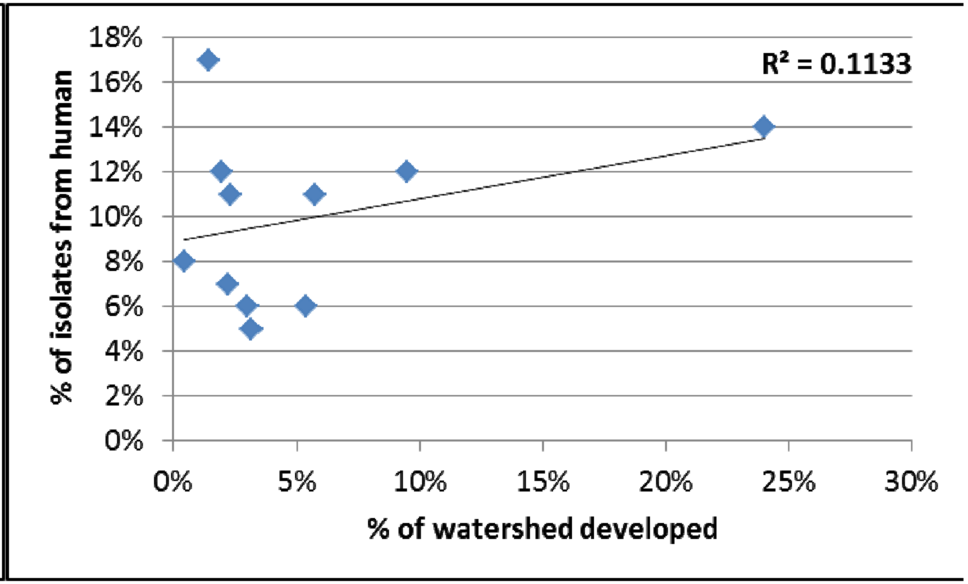
Relation of Landuse to BST Results

Developed vs Pet & Human Contributions

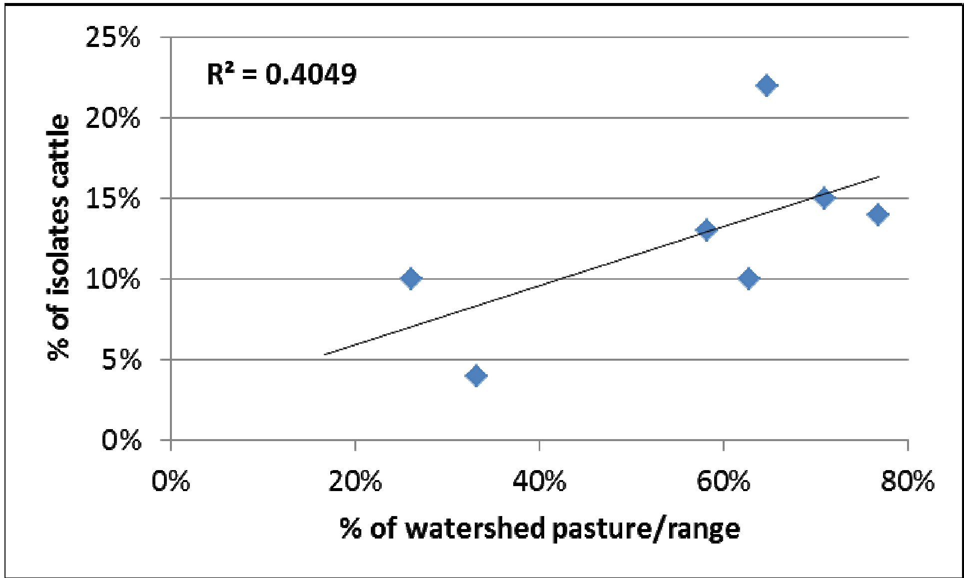


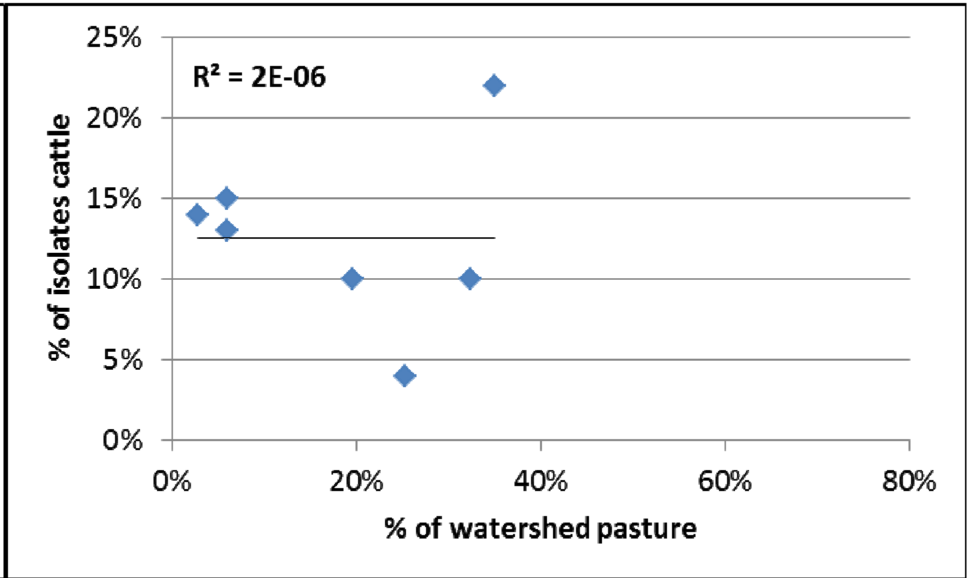


- **Significant correlation between % of watershed developed and % of isolates from pets**
- No correlation between % of watershed developed and % of isolates from human

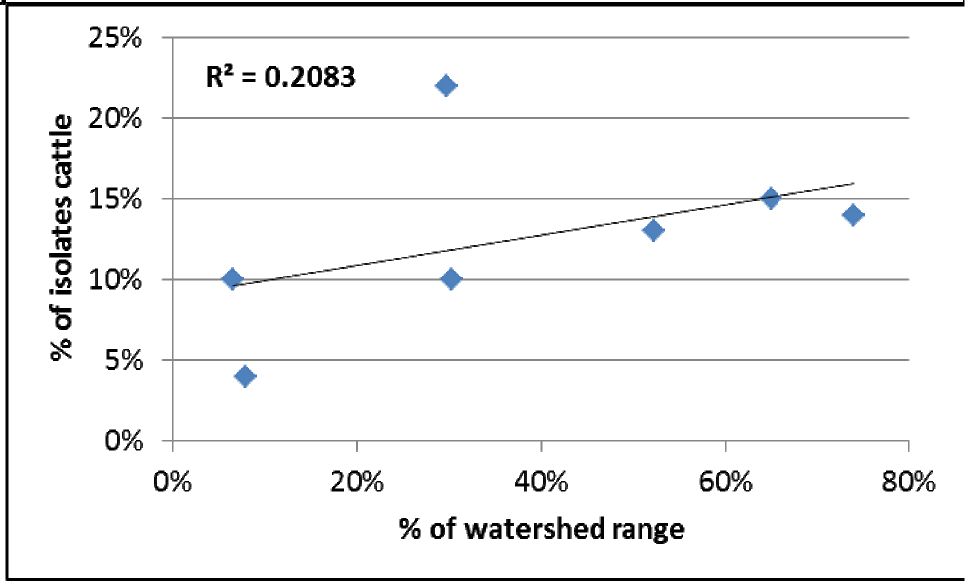
Relation of Landuse to BST Results

Cattle



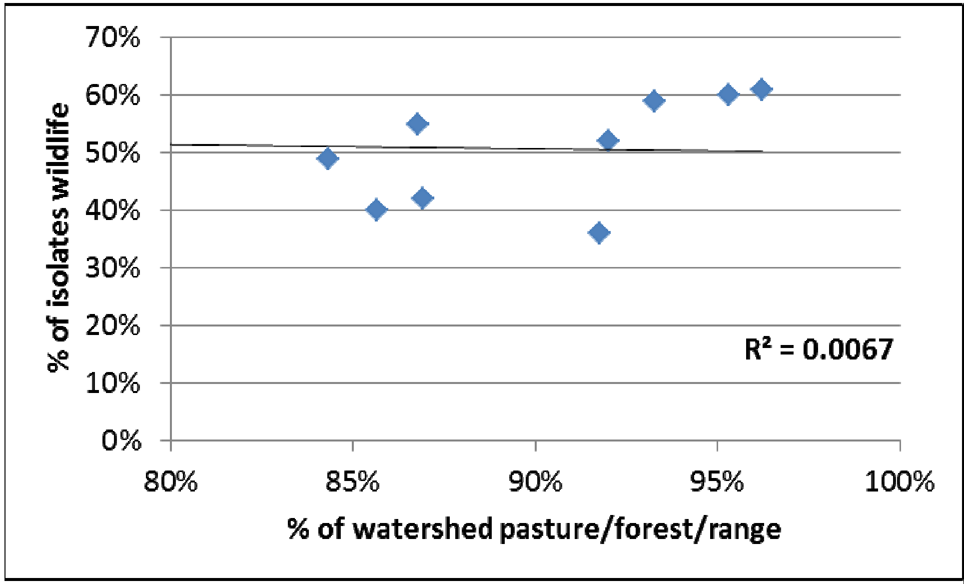


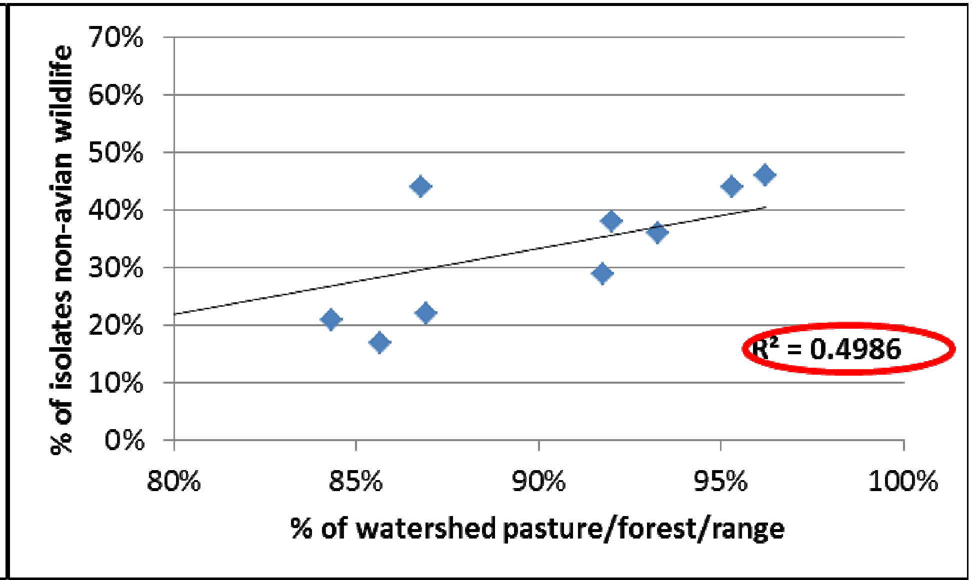
- No correlation between watershed landuse and % of isolates from cattle



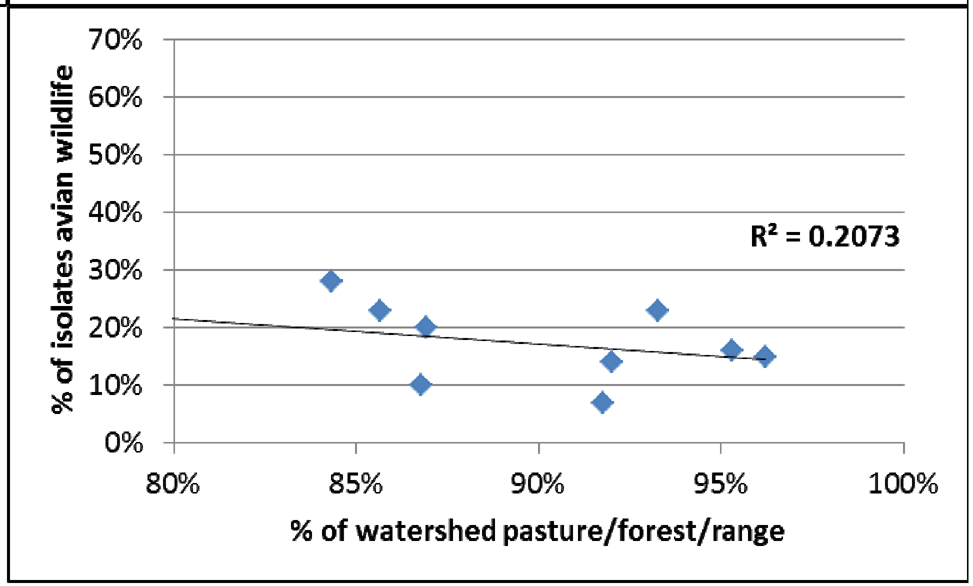
Relation of Landuse to BST Results

Wildlife



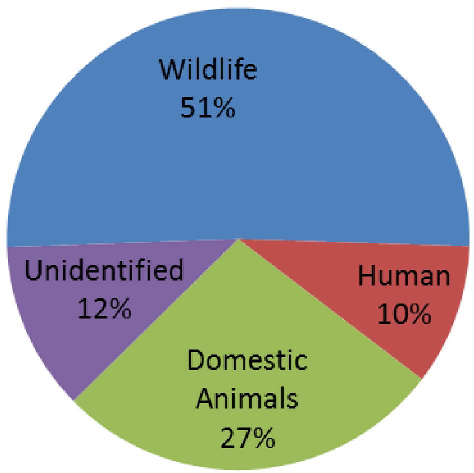


- Only one significant correlation observed:
  - Btwn % of watershed as pasture/range/forest & % of isolates as non-avian wildlife



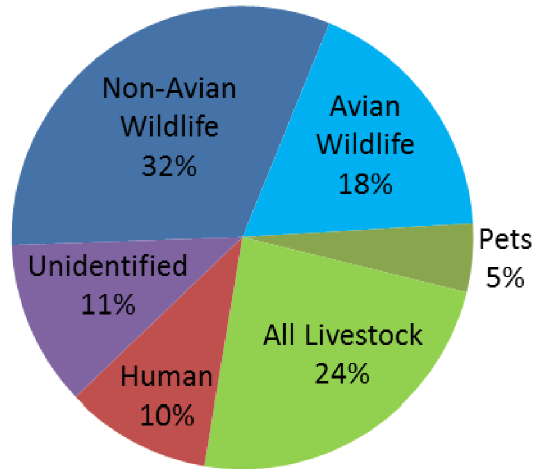
3-Way Split

(averages based on findings in 11 watersheds)



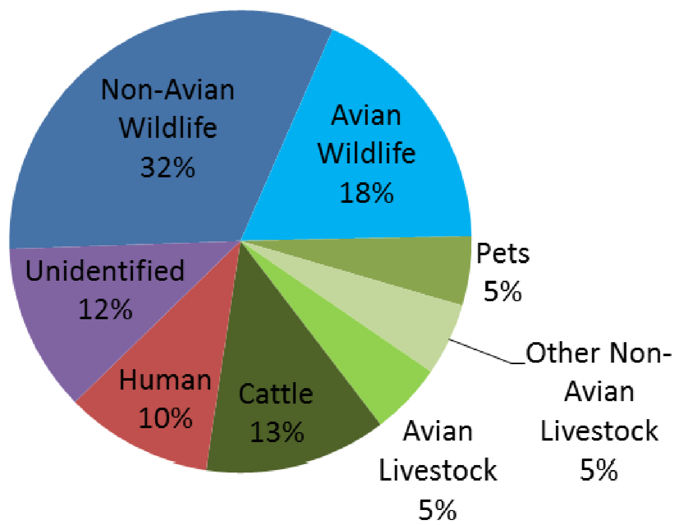
5-Way Split

(averages based on findings in 10 watersheds)



7-Way Split

(averages based on findings in 7 watersheds)



Mean Background Levels in Runoff

Site	Fecal Coliform (#/100 mL)	*E. coli* (cfu/100 mL)	Reference
Ungrazed pasture	10,000		Robbins et al. 1972
Ungrazed pasture	6,600		Doran et al. 1981
Control plots		6,800	Guzman et al. 2010
Pasture destocked >2 mos.		1,000-10,000	Collins et al. 2005
Ungrazed pasture		6,200-11,000	Wagner et al. 2012
Pasture destocked >2 wks.		2,200-6,000	Wagner et al. 2012

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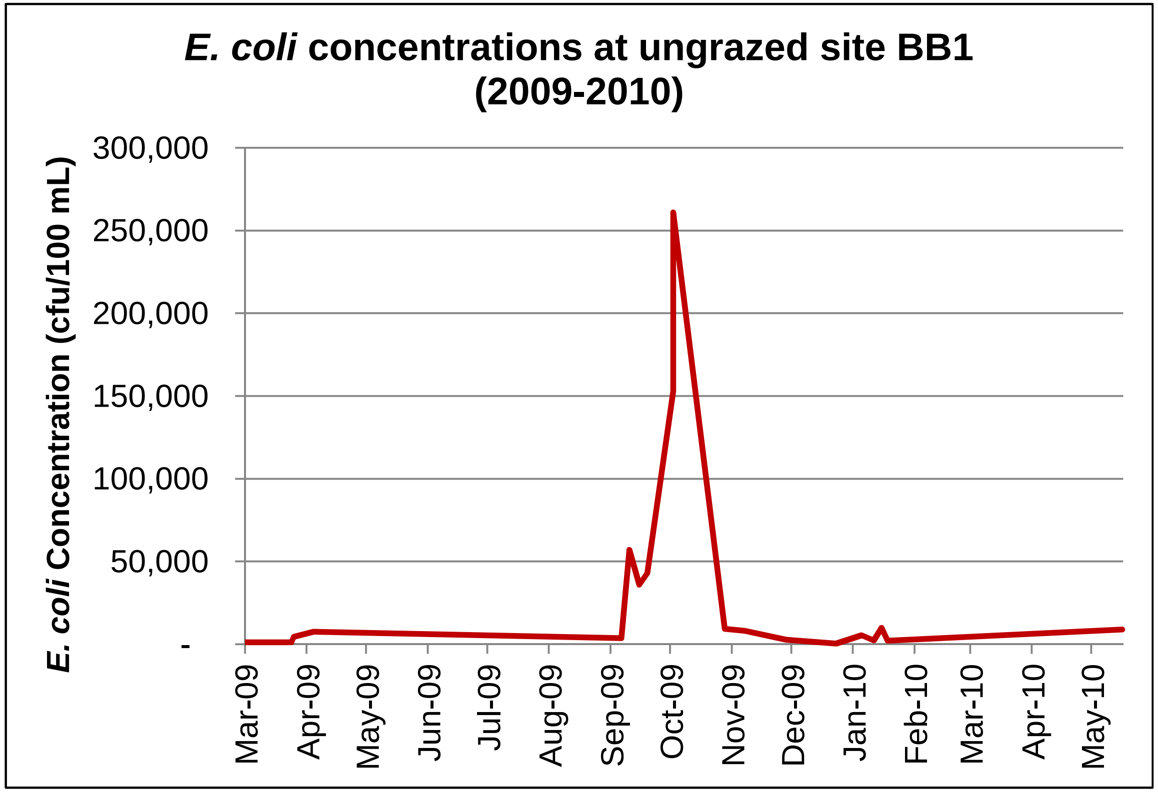
Impacts of Migratory Wildlife



Date	BB1	BB2	BB3
3/13/09			140
3/25/09	1,200		
3/26/09		1,000	7,200
3/27/09			2,000
4/17/09	1,155	980	450
4/18/09	4,400	2,225	2,100
4/28/09	7,600	12,200	24,000
10/4/09	57,000	5,114	3,065
10/9/09	36,000	24,043	15,000
10/13/09	42,851	23,826	5,591
10/22/09			172,500
10/26/09	261,000	181,000	45,000

>80% of *E. coli* loading from wildlife at 3 sites in 2009

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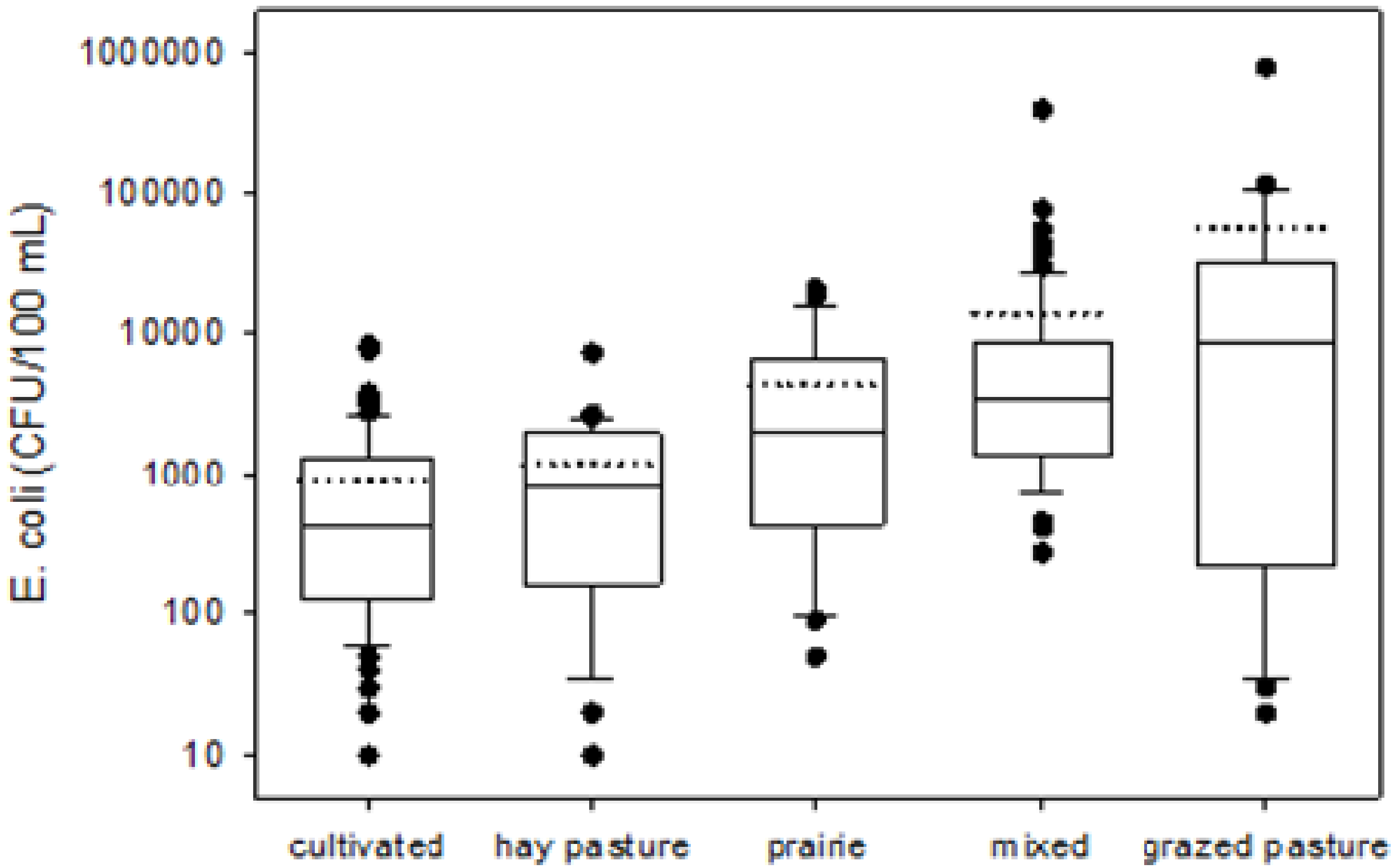
E. coli in edge-of-field runoff (Harmel)



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Summary of BST Findings

- BST performing well & useful tool for identifying significant bacteria sources
- No correlations btwn landuse & isolate source
  – LULC ≠ good predictor of bacterial sources
- Wildlife = source of 50% of isolates in predominately rural watersheds
  – Edge of field monitoring confirms significance of background sources & impacts

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WHAT CAN WE DO ABOUT BACTERIA FROM WILDLIFE?

Wildlife (and Exotics) Management

Upper Llano

Goal: Increase number of "active" TPWD Wildlife Management Plans in watershed by 2/year to a total of 66 wildlife management plans in 10 years – i.e. increase acreage under wildlife management plan from 85,410 to 125,000

Description: This strategy focuses on the overpopulation of deer (native and exotic) throughout the watershed by promoting an increase in the acreage under Wildlife Management Plans and Wildlife Management Associations. Landowners can receive technical guidance from TPWD on matters pertaining to wildlife habitat management and deer population management. Landowners, with assistance from TPWD, can establish wildlife management associations or co-ops to create wildlife management plans for large contiguous areas. Landowners can also seek to acquire Managed Land Deer Permits from TPWD to allow hunting seasons to be extended. This management strategy requires ongoing commitment and collaboration by landowners in each county. Landowners and deer processing facilities can collaborate to evaluate possible incentives for culling the deer population. .

Implementation Strategies

Participation	Recommended Strategies	Period	Capital Costs
Landowners, land managers, lessees especially in subbasins with riparian areas; TPWD	Evaluate formation of Wildlife Management Association(s)	2016–2025	N/A
	Enroll and continue participation implementation of Wildlife Management Plans	2016–2025	N/A
	Work with TPWD biologists to develop and implement Wildlife Management Programs or Landowner Incentive Programs	2016–2025	N/A
	Voluntarily locate supplemental feeding locations away from riparian areas.	2016-2025	N/A
	Voluntarily participate with professional harvesting services to remove exotics	2016-2025	N/A
LRFS, AgriLife Extension and TPWD	Educate citizens, hunters and landowners on wildlife management and benefits of developing and implementing Wildlife Management Plans, participating in Landowner Incentive Program, and forming Wildlife Management Association(s)	2016-2025	$2,000/each $7,500/each traveling event
LRFS, Local Chambers of Commerce and TPWD	Coordinate and facilitate pairing of hunters seeking exotic hunts with landowners, highlighting the potential economic benefits of year-round hunting.	2016-2018	N/A

Estimated Load Reduction

There are no specific loading data for exotics. For comparison, decreasing deer population densities in the riparian zone from one deer per 2 acres to one deer per 10 acres results in nitrogen decreasing 36kg/yr or 16%; phosphorus decreasing 41 kg/yr or 12%; and sediment decreasing 65 tons/yr or 12%.

Feral Hog Control

Attoyac Bayou

Goal: To manage the feral hog population through available means in efforts to reduce the total number of hogs in the watershed by 10% (1,015 hogs) and maintain that level of reduction annually.			
Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs as practical and educating landowners on BMPs for hog removal.			
Implementation Strategies			
Participation	**Recommended Strategies**	**Period**	**Capital Costs**
Landowners, land managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog utilization	2015–2018	$200 per feeder exclusion
	Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers	2015–2025	N/A
	Voluntarily shoot all hogs on site; ensure that lessees shoot all hogs on site	2015–2025	N/A
AgriLife Extension	Deliver Feral Hog Education workshop	2015, 2018, 2025	$7,500 ea.
County/AgriLife Extension	Promote use of Extension's online tracking tool to report hog harvest data	2015–2025	$10,000
Estimated Load Reduction			
Reducing the feral hog population will reduce bacteria loading to the landscape and direct deposition to the creek. This effort will primarily reduce direct deposition as these animals spend the majority of their time in the riparian corridor. As estimated and used in the SELECT model, each feral hog can contribute as much as 1.16 E+09 cfu of *E. coli* to the watershed daily. Using this number plus a reasonable attenuation factor that assumes 25% of the fecal bacteria deposited by feral hogs reaches the water body, reducing the population by 10% yields a maximum annual load reduction of 1.07 E+14 cfu of *E. coli*. See Appendix D for calculations.			

Pets & Urban Wildlife

Management Measure	Responsible Party	Unit Cost	Number Implemented Year			Total Cost
			1-3	4-6	7-10	
Urban Stormwater Management Measures						
Pet Waste Collection Stations	City of Kyle	$620/station installation $85 annual/station	10	4	4	$22,040[1]
Pet Waste Collection Stations	City of Lockhart	$620/station installation $85 annual/station	10	4	4	$22,040
Pet Waste Collection Stations	City of Luling	$620/station installation $85 annual/station	6	2	2	$12,475
Pet Waste Collection Stations	City of Buda	$620/station installation $85 annual/station	10	4	4	$22,040
Comprehensive Urban Stormwater Assessment	City of Kyle	$30,000/survey	1	---	---	$30,000[1]
Retrofit Stormwater Detention Basins	City of Kyle	$35,000 engineering $50,000/basin	2	---	---	$135,000[1]
Initiate Street Sweeping Program	City of Kyle	$110,000/sweeper	---	---	---	$110,000[2]
Comprehensive Urban Stormwater Assessment	City of Lockhart	$25,000/survey	1	---	---	$25,000
Manage Urban Waterfowl Populations	City of Lockhart	---	---	---	---	N/A
Comprehensive Urban Stormwater Assessment	City of Luling	$20,000/survey	1	---	---	$20,000
Rehabilitate Stormwater Retention Pond	City of Luling	$500,000/pond	1		---	$500,000
Initiate Street Sweeping Program	City of Buda	$150,000/sweeper	1	---	---	$150,000[2]

Impact of Other Common Management Measures???

- Urban stormwater management :
  - Stormwater BMP implementation

- Ag management:
  - Develop and implement WQMPs & Conservation Plans

ADDITIONAL CONSIDERATIONS REGARDING MODELING & BST

Modeling & BST Cost Comparison

- Surveyed costs of 9 modeling and 7 BST projects

- Modeling
  - Range $40K – $282K
  - Median = $95K
  - Mean = $122K

- BST
  - Range $61K - $475K
  - Median = $84K
  - Mean = $163K

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How is variability/uncertainty explained in modeling numbers?

Animal	Estimated per capita contribution of fecal coliform (cfu/day) *Metcalf & Eddy (1991)*	Fecal coliform (count/animal/ day) *EPA (2000)*	Manure characteristics per 1000 lb live animal mass (cfu/day) *ASAE (2003)*
Beef Cattle	5.4E+09	1.04E+11	1.3E+11
Horses	N/A	4.20E+08	4.2E+08
Goats	N/A	N/A	N/A
Sheep	1.8E+10	1.20E+10	2.0E+11
Hogs	8.9E+09	1.08E+10	8.0E+10
Poultry- chicken & turkey	2.4E+08	1.36E+08 9.30E+07	3.4E+10
Human	2.0E+09	N/A	N/A
Deer	N/A	5.00E+08	N/A
Feral Hogs	N/A	1.08E+10	N/A

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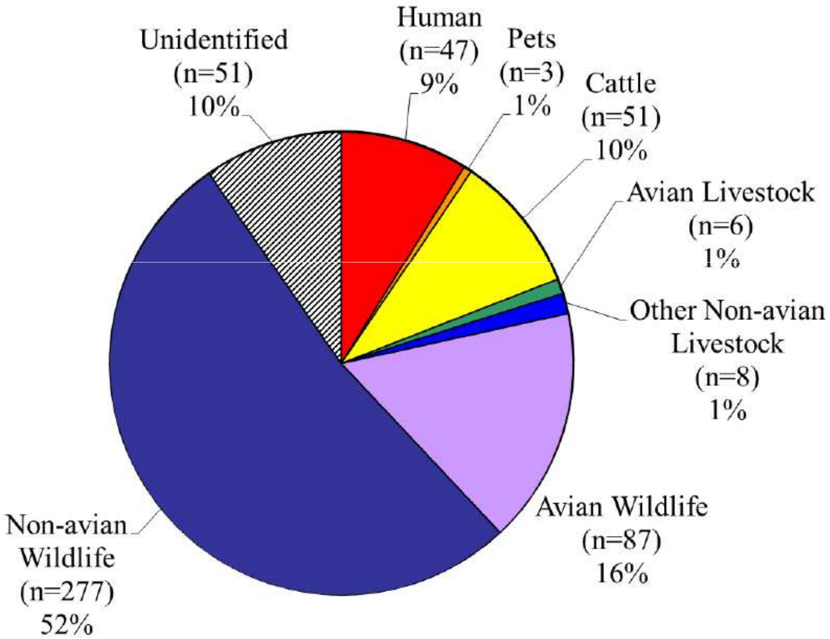
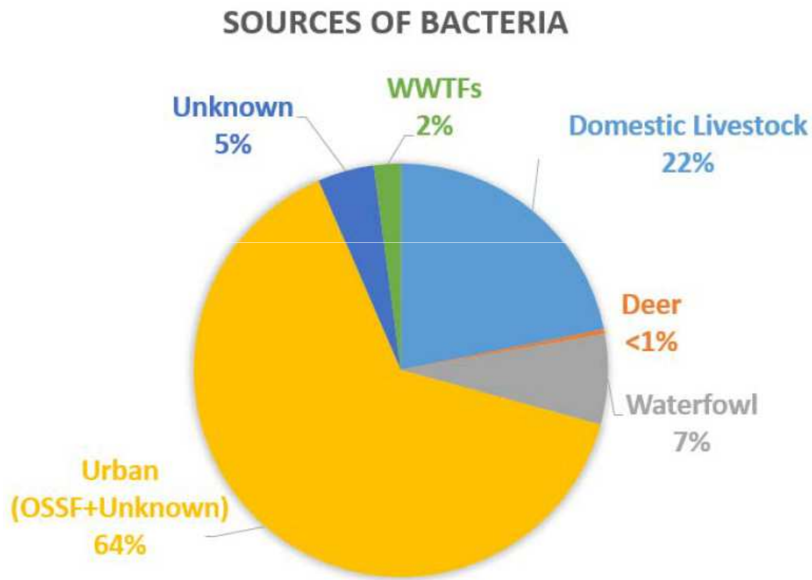
Arroyo Colorado Bacteria Sources

BST Results



Initial SWAT Model Results



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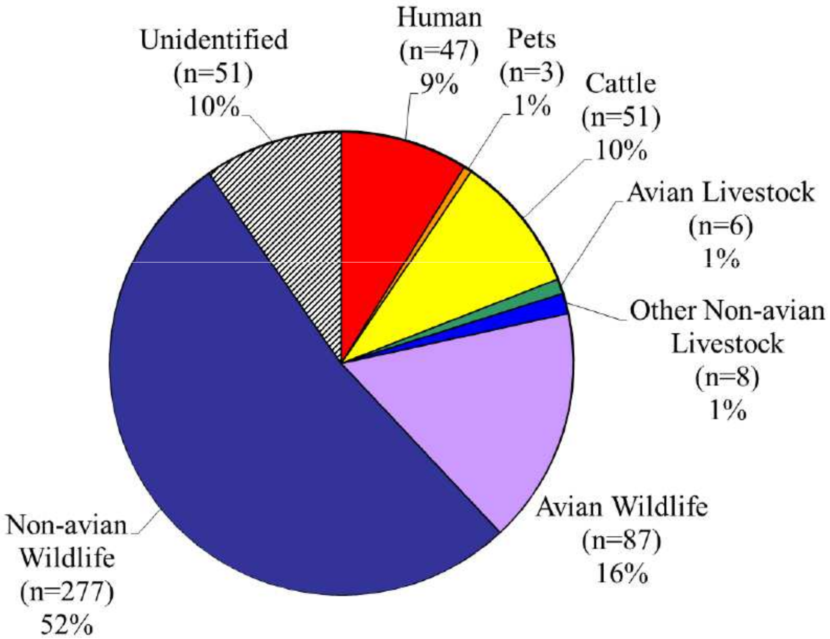
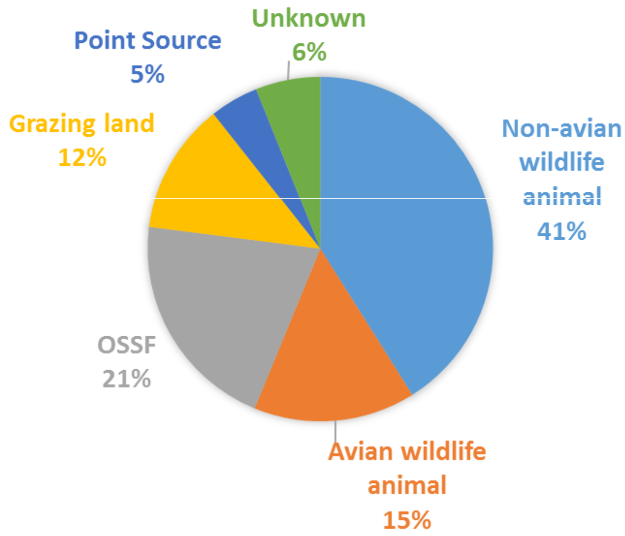
Calibrated/validated SWAT with BST

BST Results



Final SWAT Model Results



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FUTURE USES OF BST

Establish Site-specific Water Quality Standards Using BST & Quantitative Microbial Risk Assessment

Quantitative Microbial Risk Assessment

- EPA 2012 recreational water quality criteria provided tools for developing site-specific criteria:
  - epidemiological studies
  - quantitative microbial risk assessment
  - use of alternative indicators or methods

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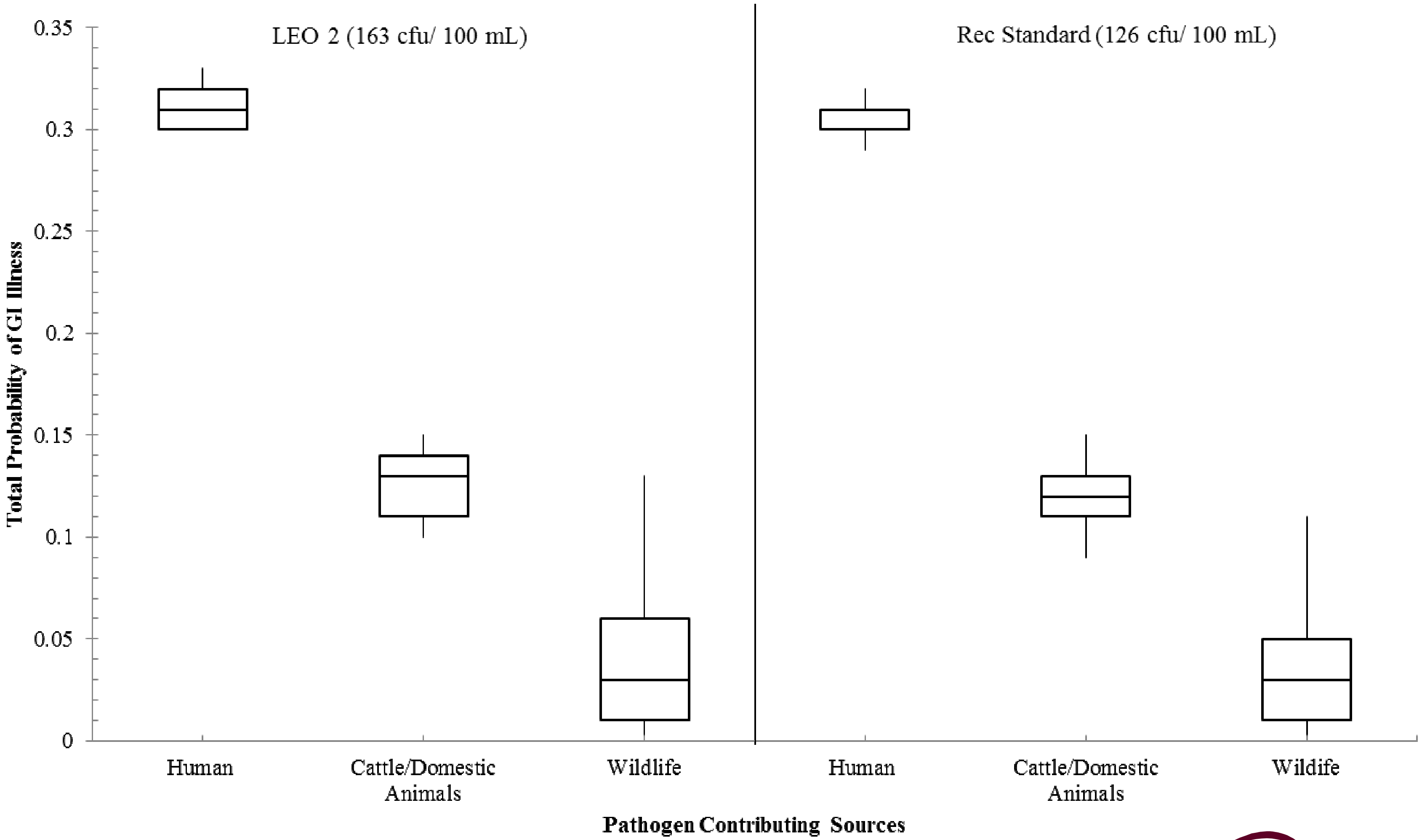
Each Source Contributing 100% of the Bacteria Concentration



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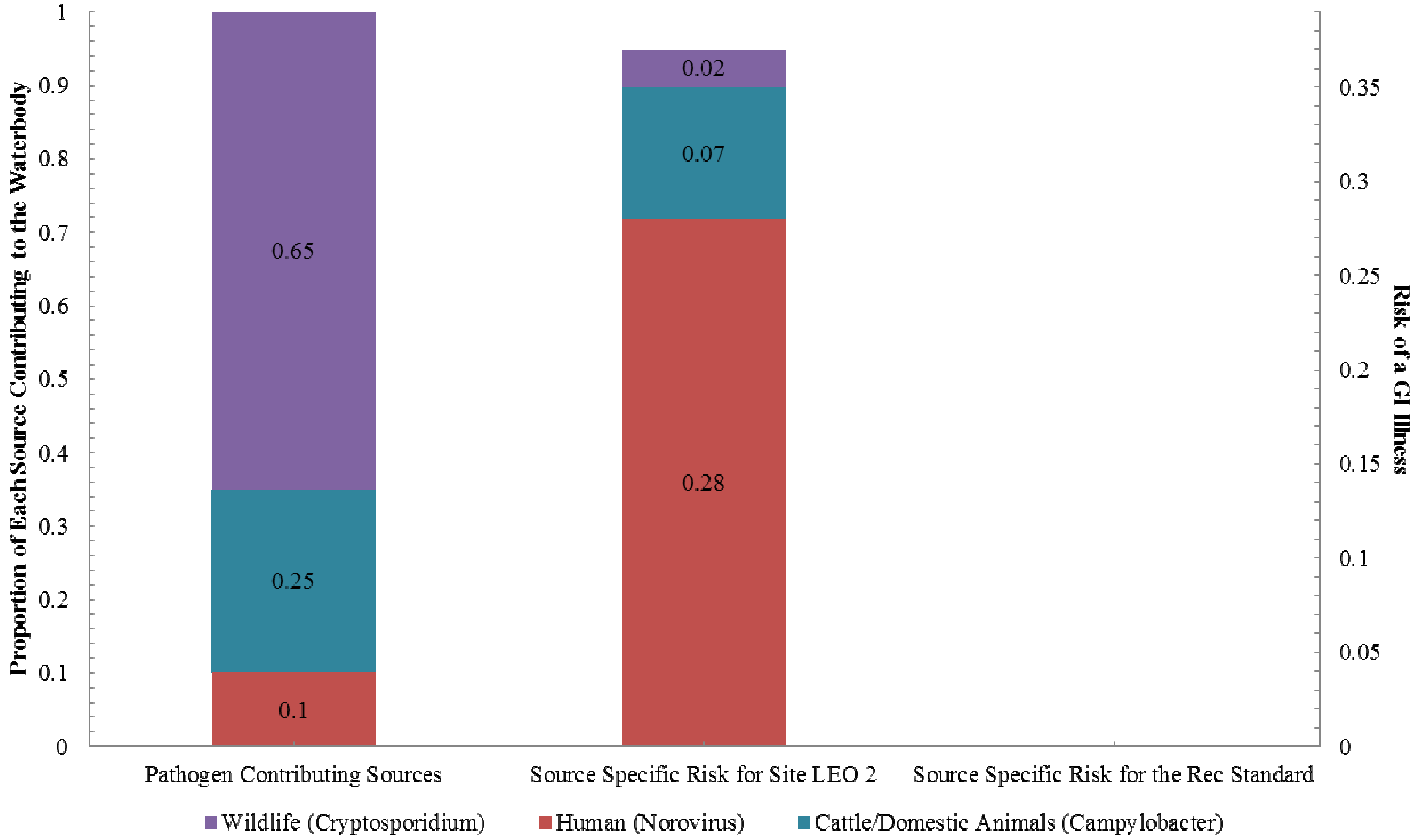
Risk of GI Illness: BST Percentages



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QMRA Findings & Implications

- Human and non-human fecal sources have different potential risks for a GI illness
  - Proportion of a single source contributing to the overall *E.coli* concentration <u>not</u> an indicator of overall human health risk
- Risk driven by human source
- Management toward reducing human sources
  - Compliance & maintenance of WWTPs, sanitary sewer systems, wastewater collection systems & infrastructure

Questions?

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