Trends in Reported Foodborne Illness in the United States: 1996-2013

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INTRODUCTION

- Current statistical methods for analyzing FoodNet data make pair-wise comparisons between most recent surveillance year and one or more baseline periods.
- Advantage: avoids specifying model form for trend
- Disadvantage: can’t distinguish trends from year to year variability
- Objective: Analyze trends in reported U.S. foodborne illness with/without specifying model form for trend

DATA

- FoodNet (Foodborne Diseases Active Surveillance Network) data: 1996-2013
  - Reported illness counts by site (State_EntYr) and year
  - Population size by site and year (increased over time)
  - FoodNet composition stable since 2004

- *Campylobacter*
- *Listeria*
- *Salmonella*
- *Shigella*
- STEC O157
- *Vibrio*
- *Yersinia*

METHODS

- Poisson Log-Linear Model with Site (1996-2013)
  - $\text{Log}(E[y_{ij}]) = \log(\text{population}_{ij}) + \beta_0 + \beta_1(\text{year}_i) + \beta_j(\text{site}_j) + \varepsilon_{ij}$
  - $y_{ij} = \text{count}_{ij}$; $E[y_i] = \mu_i$ (point on predicted curve)
  - Poisson (count) model is heteroscedastic
    - Generalized Poisson dispersion: $\text{Var}[y_i] = \phi\mu_i$
    - Negative Binomial dispersion: $\text{Var}[y_i] = \mu_i + \delta\mu_i^2$
  - Differs from CDC method in that time is treated as a continuous covariate, considers generalized Poisson as well as negative binomial dispersion
- A conventional approach, but assumes log-linear trend

METHODS

- Penalized B-spline Regression
  - Semi-parametric method – no assumed trend model form
  - B-spline basis functions provide local control, local fit is insensitive to points far removed
  - Penalized form of B-spline regression is insensitive to number, placement of join-points (“knots”)
- Wide range of applications

METHODS

- Generalized Additive Model for Poisson Regression
- $\text{Log}(E[y_i]) = \log(\text{population}_i)+\beta_0+f(\text{year}_i)+\varepsilon_i$
- Smooth $f(\text{year}_i) = \sum B_k(\text{year}_i)\beta_k$
  - $B_k(x)$ = B-spline basis function
- Year (nx1 vector) $\rightarrow$ **X** (nxk matrix)
  - Fit the model with basis functions as covariates

METHODS

- At any given point, q+1 B-splines are non-zero (local control)
  - q = B-spline degree (e.g., q=3 for cubic)
  - B-splines sum to 1
- Basis dimension (k) = q + n'
  - n' = no. intervals along domain
  - e.g., 2 internal knots divides domain into n' = 3 intervals
- Eilers and Marx (1996) provides recursive algorithm for B-spline basis functions for uniformly spaced knots
- In practice, need to impose identifiability constraint → k-1 orthogonal columns (QR decomposition)
- Smoothness controlled by penalty term, fit insensitive to basis dimension

METHODS

- P-IRLS to obtain GLM likelihood maximization, s.t. smooth
- Given λ, min: $\left\|\sqrt{W}(z - X\beta)\right\|^2 + \lambda\beta^T S\beta$
  - λ = curvature penalty parameter
  - $w_i \propto [V(\mu_i)g'(\mu_i)^2]^{-1}$
  - $z_i = g'(\mu_i)(y_i - \mu_i) + X_i\beta$
  - X = design matrix (constrained)
  - g = link function (log)
  - S (penalty matrix) = D^TD
    - penalize differences among neighboring β coefficients
  - For D = second order difference matrix ~ $\int[f''(x)]^2 dx$
    - measure of total curvature

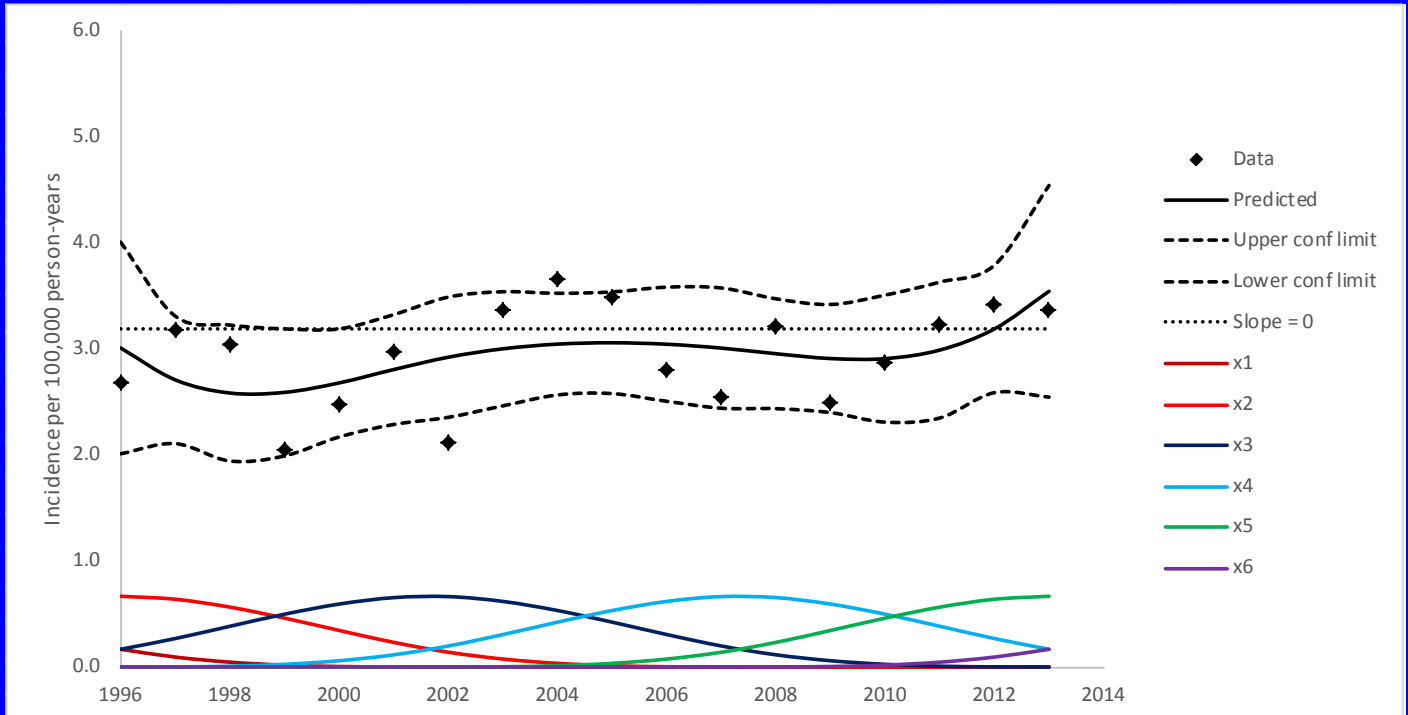
METHODS

- Select degree of smoothness (λ) based on model selection criterion (e.g., GCV, AIC)
- Effective degrees of freedom (edf) = tr(A)
  - where $\hat{\mu} = Ay$
- With λ = 0, tr(A) = k
- As λ→∞, GAM → Poisson Log-Linear Model (X →1 edf (Year))

METHODS

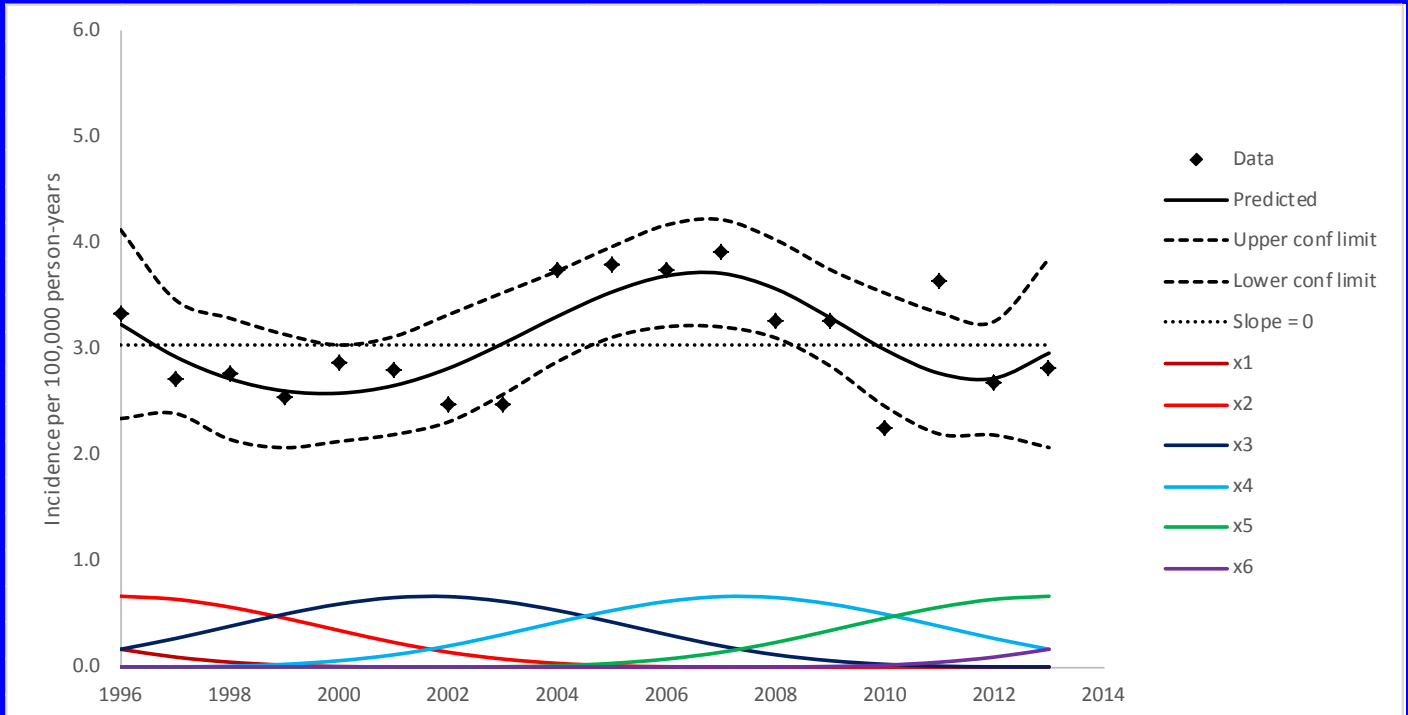
- X: cubic B-spline basis with 2 internal knots
  - k = q(3)+ n’(3) = 6 unconstrained basis functions
- S (penalty matrix): 2nd order difference matrix
- All Sites (1996-2013)
  - Composition of FoodNet sites stable since 2004
- Original 5 Sites (1996-2013)
  - Attempt to control for changes in FoodNet composition over time
- Ljung-Box test for serial correlation (AR(1))

METHODS
B-Spline Provides Flexibility



	PENALTY	0.00										
	AICC	0.995143										

METHODS
Penalized B-Spline Avoids Overfitting



	PENALTY	0.00										
	AICC	0.766499										

PRELIMINARY RESULTS

- Poisson Log-Linear Model

Poisson Log Linear Model

CAMPYLOBACTER	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	5.2702	3.7713	1.9528	0.1623	1.3240	4.1002	0.1043	0.7468
Year	-0.0073	0.0019	15.2107	0.0001	-0.0054	0.0020	6.8889	0.0087
CA_1996	1.4694	0.0579	644.8468	0.0000	1.4770	0.0627	555.1890	0.0000
CA_2000	1.1268	0.0701	258.5311	0.0000	1.1290	0.0668	285.8118	0.0000
CO_2001	0.5648	0.0674	70.2924	0.0000	0.5703	0.0674	71.6515	0.0000
CO_2002	1.0996	0.1021	116.0965	0.0000	1.1015	0.0739	221.9737	0.0000
CT_1996	0.5866	0.0670	76.6550	0.0000	0.5945	0.0638	86.8874	0.0000
CT_1997	0.9476	0.0719	173.7944	0.0000	0.9543	0.0650	215.5177	0.0000
CT_1998	0.6183	0.0798	60.0296	0.0000	0.6237	0.0668	87.1792	0.0000
GA_1996	-0.0885	0.0670	1.7447	0.1866	-0.0648	0.0641	1.0219	0.3121
GA_1997	-0.2269	0.0919	6.0899	0.0136	-0.2020	0.0684	8.7062	0.0032
GA_1999	-0.0152	0.0651	0.0546	0.8152	-0.0125	0.0653	0.0365	0.8485
MD_1998	0.0524	0.0701	0.5584	0.4549	0.0572	0.0653	0.7685	0.3807
MD_2001	-0.1294	0.0857	2.2819	0.1309	-0.1295	0.0700	3.4192	0.0644
MD_2002	0.0414	0.0939	0.1942	0.6595	0.0401	0.0725	0.3058	0.5803
MN_1996	0.8194	0.0571	205.5809	0.0000	0.8272	0.0626	174.8439	0.0000
NM_2004	0.7641	0.0705	117.4649	0.0000	0.7639	0.0716	113.7315	0.0000
NY_1998	0.6488	0.0740	76.8452	0.0000	0.6537	0.0659	98.3130	0.0000
NY_1999	0.4326	0.0822	27.7239	0.0000	0.4377	0.0678	41.6936	0.0000
NY_2002	0.1121	0.0932	1.4470	0.2290	0.1155	0.0724	2.5486	0.1104
NY_2003	0.7309	0.0963	57.5967	0.0000	0.7327	0.0741	97.7662	0.0000
NY_2004	0.6802	0.1294	27.6526	0.0000	0.6812	0.0818	69.2886	0.0000
OR_1996	0.8676	0.0585	220.2090	0.0000	0.8727	0.0626	194.3326	0.0000
TN_2000	-0.2411	0.0746	10.4626	0.0012	-0.2372	0.0675	12.3719	0.0004
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	2.7423	0.0000			0.0234	0.0023		
SSPR	324.4895				367.1452			

Poisson Log Linear Model

LISTERIA	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	31.8912	11.7758	7.3344	0.0068	30.6845	11.5738	7.0289	0.0080
Year	-0.0224	0.0059	14.5477	0.0001	-0.0218	0.0058	14.2617	0.0002
CA_1996	0.7329	0.1663	19.4344	0.0000	0.7411	0.1647	20.2577	0.0000
CA_2000	0.2308	0.2367	0.9508	0.3295	0.2349	0.2171	1.1700	0.2794
CO_2001	0.2513	0.1915	1.7225	0.1894	0.2559	0.1854	1.9048	0.1675
CO_2002	-0.1350	0.4529	0.0888	0.7657	-0.1325	0.3852	0.1182	0.7309
CT_1996	1.0383	0.1655	39.3409	0.0000	1.0441	0.1643	40.3740	0.0000
CT_1997	0.6363	0.2048	9.6535	0.0019	0.6420	0.1923	11.1473	0.0008
CT_1998	0.5177	0.2168	5.7050	0.0169	0.5222	0.2014	6.7204	0.0095
GA_1996	0.2290	0.1686	1.8456	0.1743	0.2333	0.1666	1.9594	0.1616
GA_1997	-0.1576	0.2370	0.4424	0.5060	-0.1537	0.2158	0.5072	0.4763
GA_1999	-0.2658	0.1808	2.1595	0.1417	-0.2639	0.1765	2.2340	0.1350
MD_1998	0.3572	0.1752	4.1573	0.0415	0.3583	0.1721	4.3349	0.0373
MD_2001	0.4628	0.1936	5.7173	0.0168	0.4642	0.1869	6.1660	0.0130
MD_2002	0.2546	0.2330	1.1941	0.2745	0.2565	0.2160	1.4107	0.2349
MN_1996	-0.4035	0.1744	5.3538	0.0207	-0.4024	0.1706	5.5605	0.0184
NM_2004	0.1277	0.2224	0.3299	0.5657	0.1307	0.2106	0.3854	0.5347
NY_1998	0.4262	0.2070	4.2384	0.0395	0.4263	0.1945	4.8038	0.0284
NY_1999	0.8784	0.1934	20.6396	0.0000	0.8841	0.1852	22.7803	0.0000
NY_2002	0.2756	0.2347	1.3786	0.2403	0.2770	0.2173	1.6249	0.2024
NY_2003	0.5925	0.2697	4.8268	0.0280	0.5983	0.2440	6.0108	0.0142
NY_2004	-0.0717	0.4813	0.0222	0.8816	-0.0699	0.4089	0.0292	0.8642
OR_1996	0.1809	0.1681	1.1592	0.2816	0.1860	0.1660	1.2549	0.2626
TN_2000	-0.3213	0.2018	2.5339	0.1114	-0.3185	0.1919	2.7537	0.0970
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	1.2178	0.0000			0.0576	0.0166		
SSPR	312.7524				343.3450			

Poisson Log Linear Model

SHIGELLA	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	70.2796	14.8840	22.2957	0.0000	92.9580	14.4239	41.5342	0.0000
Year	-0.0400	0.0074	29.1268	0.0000	-0.0513	0.0072	51.0144	0.0000
CA_1996	0.7497	0.2071	13.1059	0.0003	0.6995	0.2123	10.8562	0.0010
CA_2000	-0.2412	0.3472	0.4828	0.4872	-0.2859	0.2261	1.5987	0.2061
CO_2001	-0.1156	0.2629	0.1933	0.6602	-0.1501	0.2270	0.4376	0.5083
CO_2002	-0.1075	0.5604	0.0368	0.8479	-0.1055	0.2423	0.1896	0.6633
CT_1996	-0.9577	0.3310	8.3697	0.0038	-1.0313	0.2165	22.6990	0.0000
CT_1997	-0.5555	0.3728	2.2202	0.1362	-0.5737	0.2190	6.8636	0.0088
CT_1998	-1.5342	0.5896	6.7705	0.0093	-1.5275	0.2313	43.5984	0.0000
GA_1996	0.7893	0.1975	15.9691	0.0001	0.7718	0.2115	13.3164	0.0003
GA_1997	0.5018	0.2448	4.2020	0.0404	0.4750	0.2147	4.8963	0.0269
GA_1999	0.8001	0.1956	16.7389	0.0000	0.8156	0.2184	13.9476	0.0002
MD_1998	0.1473	0.2270	0.4208	0.5166	0.0908	0.2172	0.1747	0.6760
MD_2001	-0.2599	0.2962	0.7695	0.3804	-0.2795	0.2277	1.5060	0.2198
MD_2002	-1.1408	0.4994	5.2174	0.0224	-1.1658	0.2394	23.7056	0.0000
MN_1996	-0.0538	0.2067	0.0677	0.7947	-0.0945	0.2121	0.1986	0.6558
NM_2004	0.3747	0.2613	2.0560	0.1516	0.3853	0.2413	2.5500	0.1103
NY_1998	-0.0669	0.2965	0.0509	0.8215	-0.0206	0.2181	0.0090	0.9246
NY_1999	-1.1297	0.4786	5.5724	0.0182	-1.1165	0.2281	23.9606	0.0000
NY_2002	-1.5188	0.6027	6.3502	0.0117	-1.5461	0.2448	39.8839	0.0000
NY_2003	-2.0499	1.0981	3.4849	0.0619	-2.0442	0.2841	51.7593	0.0000
NY_2004	-1.7235	1.3391	1.6566	0.1981	-1.6948	0.3102	29.8559	0.0000
OR_1996	-0.6654	0.2445	7.4080	0.0065	-0.7284	0.2136	11.6238	0.0007
TN_2000	0.6466	0.2089	9.5844	0.0020	0.6808	0.2217	9.4262	0.0021
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	6.7682	0.0000			0.2969	0.0239		
SSPR	388.0268				442.6833			

Poisson Log Linear Model

STECO157	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	60.4425	8.1942	54.4097	0.0000	61.8459	9.7252	40.4410	0.0000
Year	-0.0358	0.0041	77.0799	0.0000	-0.0365	0.0048	56.8915	0.0000
CA_1996	0.0216	0.1306	0.0274	0.8686	0.0348	0.1388	0.0629	0.8020
CA_2000	-0.0439	0.1810	0.0589	0.8082	-0.0487	0.1593	0.0934	0.7600
CO_2001	0.2873	0.1330	4.6705	0.0307	0.2775	0.1461	3.6056	0.0576
CO_2002	0.7558	0.2168	12.1475	0.0005	0.7463	0.1753	18.1318	0.0000
CT_1996	-0.0116	0.1398	0.0068	0.9341	-0.0473	0.1426	0.1102	0.7399
CT_1997	-0.0037	0.1716	0.0005	0.9828	-0.0216	0.1531	0.0199	0.8879
CT_1998	0.3837	0.1566	6.0022	0.0143	0.3542	0.1494	5.6238	0.0177
GA_1996	-1.0131	0.1529	43.8881	0.0000	-1.0206	0.1457	49.0583	0.0000
GA_1997	-0.8448	0.2100	16.1853	0.0001	-0.8557	0.1667	26.3378	0.0000
GA_1999	-1.0657	0.1532	48.4024	0.0000	-1.0672	0.1489	51.3870	0.0000
MD_1998	-0.6242	0.1530	16.6468	0.0000	-0.6288	0.1478	18.1078	0.0000
MD_2001	-1.3010	0.2446	28.2914	0.0000	-1.3084	0.1843	50.3875	0.0000
MD_2002	-0.5041	0.2141	5.5460	0.0185	-0.5041	0.1742	8.3709	0.0038
MN_1996	1.0093	0.1057	91.2273	0.0000	0.9923	0.1328	55.8516	0.0000
NM_2004	-0.5208	0.1948	7.1502	0.0075	-0.5263	0.1720	9.3640	0.0022
NY_1998	0.3425	0.1472	5.4164	0.0199	0.3321	0.1461	5.1669	0.0230
NY_1999	0.5312	0.1471	13.0363	0.0003	0.4783	0.1479	10.4520	0.0012
NY_2002	-0.1659	0.1913	0.7521	0.3858	-0.1778	0.1663	1.1424	0.2851
NY_2003	0.2577	0.2150	1.4367	0.2307	0.2572	0.1767	2.1183	0.1455
NY_2004	0.2940	0.2875	1.0458	0.3065	0.2759	0.2073	1.7723	0.1831
OR_1996	0.7089	0.1105	41.1495	0.0000	0.7054	0.1336	27.8627	0.0000
TN_2000	-0.2787	0.1395	3.9923	0.0457	-0.2877	0.1463	3.8664	0.0493
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	1.8314	0.0000			0.0955	0.0123		
SSPR	339.9408				383.9270			

Poisson Log Linear Model

YERSINIA	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	71.1822	10.8817	42.7905	0.0000	54.3429	11.5051	22.3104	0.0000
Year	-0.0419	0.0054	59.6345	0.0000	-0.0335	0.0057	34.1159	0.0000
CA_1996	0.7576	0.1693	20.0160	0.0000	0.7601	0.1675	20.5870	0.0000
CA_2000	0.3920	0.2301	2.9012	0.0885	0.3845	0.2049	3.5222	0.0606
CO_2001	-0.1261	0.2163	0.3396	0.5600	-0.1259	0.1975	0.4064	0.5238
CO_2002	0.1699	0.4067	0.1745	0.6761	0.1641	0.3205	0.2620	0.6087
CT_1996	0.4827	0.1839	6.8846	0.0087	0.5019	0.1751	8.2133	0.0042
CT_1997	0.5620	0.2119	7.0362	0.0080	0.5841	0.1916	9.2929	0.0023
CT_1998	0.1967	0.2426	0.6576	0.4174	0.2141	0.2107	1.0329	0.3095
GA_1996	1.0606	0.1583	44.8977	0.0000	1.0648	0.1620	43.2090	0.0000
GA_1997	-0.3102	0.2529	1.5053	0.2199	-0.2984	0.2163	1.9025	0.1678
GA_1999	0.1568	0.1726	0.8257	0.3635	0.1757	0.1706	1.0617	0.3028
MD_1998	-0.0580	0.1940	0.0895	0.7648	-0.0496	0.1820	0.0743	0.7852
MD_2001	-0.3103	0.2470	1.5780	0.2090	-0.3116	0.2159	2.0817	0.1491
MD_2002	-1.1229	0.4067	7.6250	0.0058	-1.1276	0.3206	12.3728	0.0004
MN_1996	0.3298	0.1624	4.1228	0.0423	0.3507	0.1631	4.6218	0.0316
NM_2004	-1.0001	0.3461	8.3476	0.0039	-1.0183	0.2825	12.9912	0.0003
NY_1998	0.3008	0.2177	1.9091	0.1671	0.3180	0.1958	2.6387	0.1043
NY_1999	0.2455	0.2340	1.1015	0.2939	0.2596	0.2062	1.5849	0.2081
NY_2002	0.6712	0.2147	9.7711	0.0018	0.6726	0.1980	11.5405	0.0007
NY_2003	0.3831	0.3009	1.6210	0.2030	0.3797	0.2520	2.2698	0.1319
NY_2004	0.1228	0.4568	0.0723	0.7880	0.1108	0.3567	0.0966	0.7560
OR_1996	0.3923	0.1672	5.5057	0.0190	0.4315	0.1651	6.8312	0.0090
TN_2000	0.4560	0.1763	6.6902	0.0097	0.4559	0.1739	6.8775	0.0087
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	1.3696	0.0000			0.0832	0.0159		
SSPR	303.0346				318.5979			

Poisson Log Linear Model

VIBRIO	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	-135.0769	12.7410	112.3980	0.0000	-139.7475	12.6327	122.3765	0.0000
Year	0.0605	0.0063	91.0847	0.0000	0.0629	0.0063	99.8885	0.0000
CA_1996	1.9104	0.2077	84.6356	0.0000	1.9634	0.1930	103.5117	0.0000
CA_2000	1.5084	0.2421	38.8298	0.0000	1.5194	0.2169	49.0542	0.0000
CO_2001	0.4548	0.2551	3.1789	0.0746	0.4729	0.2265	4.3604	0.0368
CO_2002	0.8712	0.4117	4.4778	0.0343	0.8729	0.3355	6.7691	0.0093
CT_1996	1.1023	0.2323	22.5219	0.0000	1.0794	0.2079	26.9539	0.0000
CT_1997	1.8181	0.2308	62.0297	0.0000	1.7949	0.2075	74.8268	0.0000
CT_1998	1.3594	0.2528	28.9156	0.0000	1.3530	0.2225	36.9818	0.0000
GA_1996	0.7561	0.2215	11.6529	0.0006	0.8212	0.2021	16.5049	0.0000
GA_1997	0.6558	0.2706	5.8724	0.0154	0.6857	0.2349	8.5210	0.0035
GA_1999	0.8528	0.2157	15.6372	0.0001	0.8656	0.1991	18.8939	0.0000
MD_1998	1.6179	0.2106	59.0278	0.0000	1.6027	0.1950	67.5274	0.0000
MD_2001	0.7839	0.2518	9.6941	0.0018	0.7967	0.2242	12.6333	0.0004
MD_2002	1.8375	0.2263	65.9417	0.0000	1.8328	0.2086	77.1963	0.0000
MN_1996	0.1651	0.2270	0.5288	0.4671	0.1406	0.2046	0.4721	0.4920
NM_2004	-0.4443	0.3644	1.4869	0.2227	-0.4444	0.3039	2.1382	0.1437
NY_1998	0.1527	0.3259	0.2195	0.6394	0.1473	0.2723	0.2928	0.5884
NY_1999	0.7408	0.2855	6.7352	0.0095	0.7378	0.2450	9.0669	0.0026
NY_2002	0.2930	0.3257	0.8092	0.3684	0.2988	0.2747	1.1834	0.2767
NY_2003	-0.4513	0.5689	0.6292	0.4277	-0.4518	0.4502	1.0067	0.3157
NY_2004	0.3860	0.5318	0.5270	0.4679	0.3895	0.4238	0.8450	0.3580
OR_1996	0.9713	0.2152	20.3679	0.0000	0.9838	0.1973	24.8559	0.0000
TN_2000	0.2283	0.2503	0.8316	0.3618	0.2372	0.2224	1.1378	0.2861
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	1.3107	0.0000			0.0760	0.0188		
SSPR	299.1456				350.8983			

Poisson Log Linear Model

SALMONELLA	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	-20.6363	3.4426	35.9323	0.0000	-9.1893	3.5286	6.7819	0.0092
Year	0.0059	0.0017	11.7123	0.0006	0.0002	0.0018	0.0088	0.9252
CA_1996	0.1727	0.0477	13.1290	0.0003	0.1559	0.0516	9.1135	0.0025
CA_2000	-0.1217	0.0695	3.0656	0.0800	-0.1291	0.0573	5.0686	0.0244
CO_2001	-0.2012	0.0556	13.1079	0.0003	-0.1990	0.0556	12.7995	0.0003
CO_2002	-0.1040	0.1152	0.8145	0.3668	-0.1007	0.0693	2.1076	0.1466
CT_1996	-0.0770	0.0540	2.0348	0.1537	-0.0909	0.0527	2.9762	0.0845
CT_1997	0.1208	0.0628	3.7040	0.0543	0.1077	0.0545	3.8996	0.0483
CT_1998	-0.1339	0.0705	3.6037	0.0577	-0.1433	0.0565	6.4393	0.0112
GA_1996	-0.0248	0.0457	0.2931	0.5882	-0.0392	0.0514	0.5822	0.4455
GA_1997	0.1068	0.0571	3.4941	0.0616	0.0867	0.0535	2.6220	0.1054
GA_1999	0.8355	0.0401	434.8496	0.0000	0.8208	0.0520	249.4500	0.0000
MD_1998	0.1623	0.0473	11.7939	0.0006	0.1513	0.0524	8.3269	0.0039
MD_2001	-0.2150	0.0605	12.6415	0.0004	-0.2174	0.0564	14.8438	0.0001
MD_2002	0.2238	0.0606	13.6362	0.0002	0.2249	0.0573	15.4093	0.0001
MN_1996	-0.0702	0.0431	2.6497	0.1036	-0.0870	0.0510	2.9154	0.0877
NM_2004	0.1318	0.0567	5.4058	0.0201	0.1358	0.0589	5.3201	0.0211
NY_1998	-0.0548	0.0627	0.7645	0.3819	-0.0659	0.0550	1.4354	0.2309
NY_1999	-0.2100	0.0702	8.9564	0.0028	-0.2181	0.0569	14.7039	0.0001
NY_2002	-0.4300	0.0780	30.3702	0.0000	-0.4308	0.0605	50.6285	0.0000
NY_2003	-0.1997	0.0949	4.4255	0.0354	-0.1975	0.0652	9.1849	0.0024
NY_2004	-0.1953	0.1299	2.2592	0.1328	-0.1903	0.0751	6.4226	0.0113
OR_1996	-0.3257	0.0479	46.2627	0.0000	-0.3404	0.0517	43.3810	0.0000
TN_2000	0.0406	0.0480	0.7173	0.3970	0.0377	0.0537	0.4908	0.4836
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	2.5088	0.0000			0.0155	0.0016		
SSPR	316.7114				356.1833			

Poisson Log Linear Model

- Significant Negative Trend Term
  - *Campylobacter*, *Listeria*, *Shigella*, STEC O157, and *Yersinia*
- Significant Positive Trend Term
  - *Vibrio*
- Significant Site-Level Effects
  - All pathogens

Poisson Log Linear Model

- *Salmonella*
  - Significant Positive Trend Term for Generalized Poisson
  - No Significant Trend Term for Negative Binomial
- Generalized Poisson better fit than Negative Binomial
  - All pathogens (incl. *Salmonella*)
- Log linear model not a good overall fit

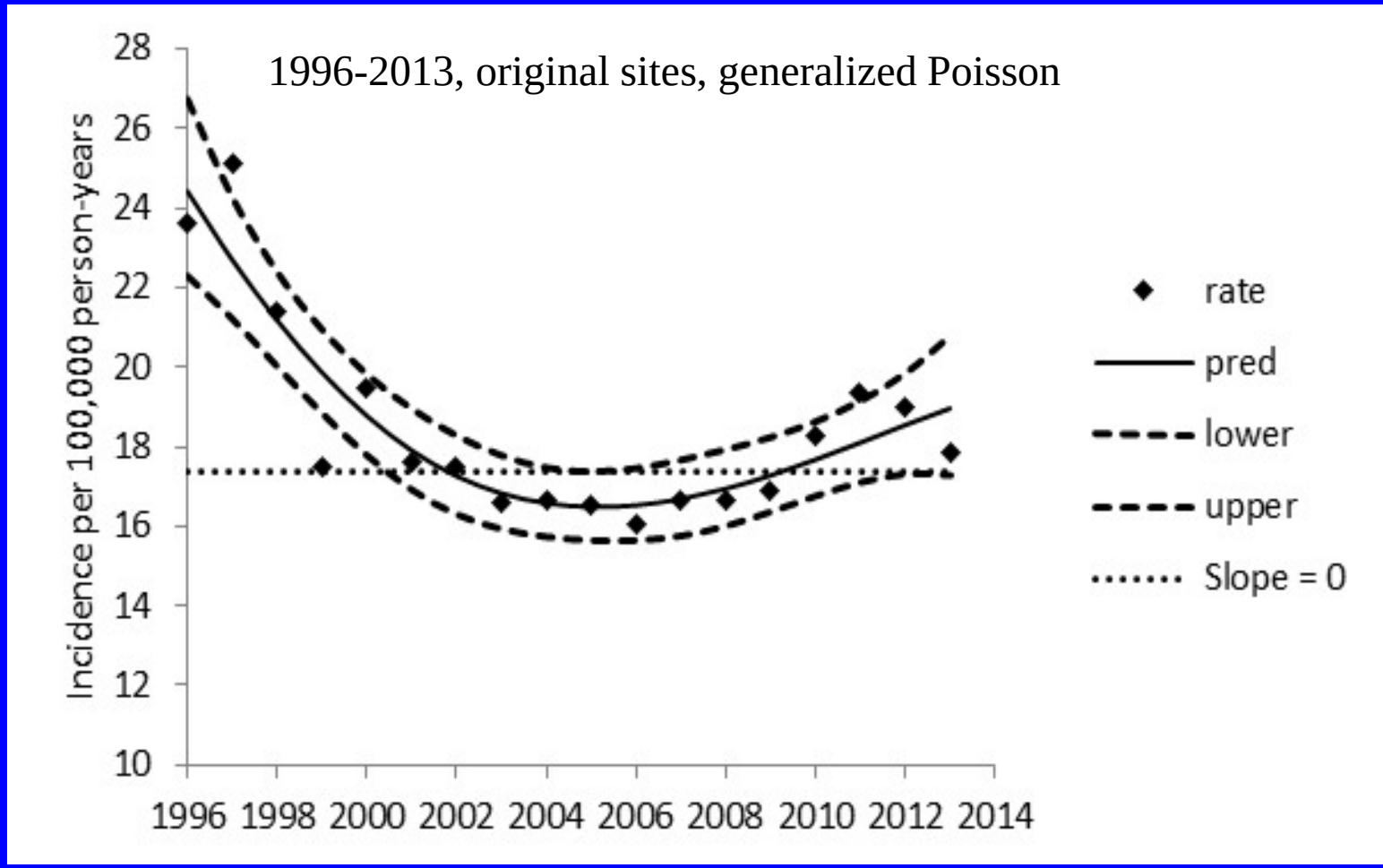
PRELIMINARY RESULTS

- Penalized B-Spline Regression

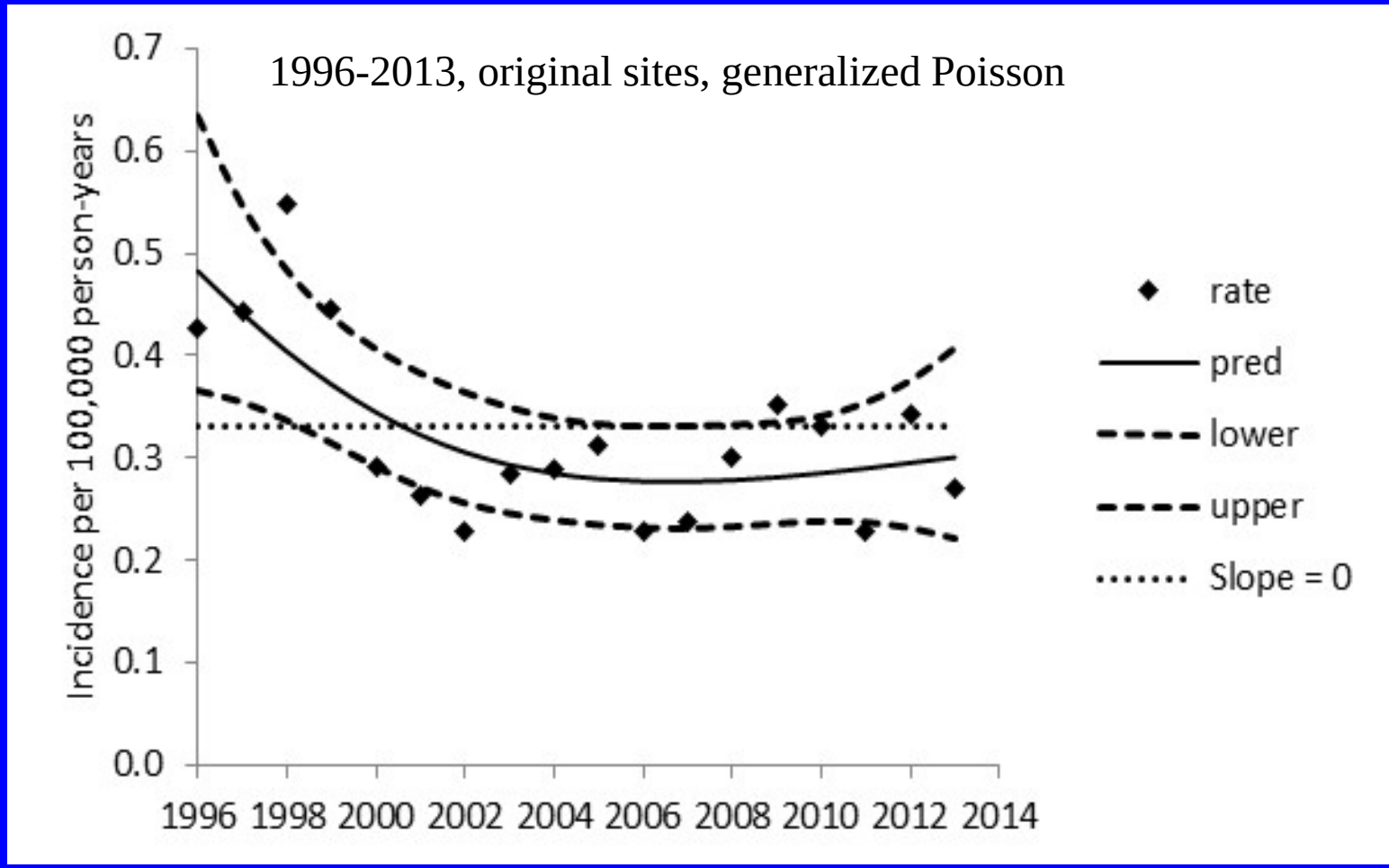
Penalized B-Spline Regression

- *Campylobacter*, *Listeria*, STEC O157, *Yersinia*
- Early declines followed by a period of no significant trend
- Results consistent for All Sites, Original Sites, Generalized Poisson, Negative Binomial

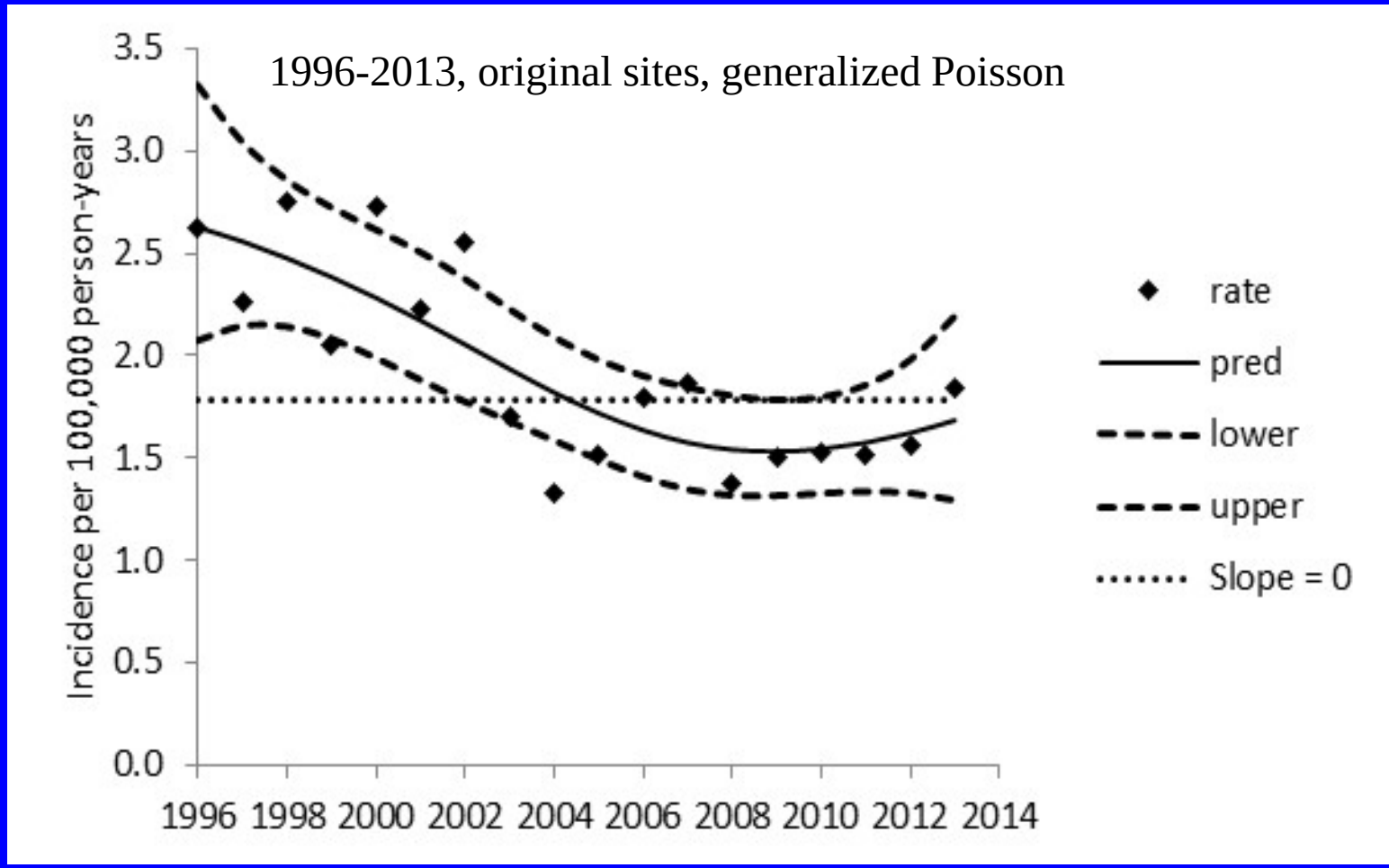
Campylobacter



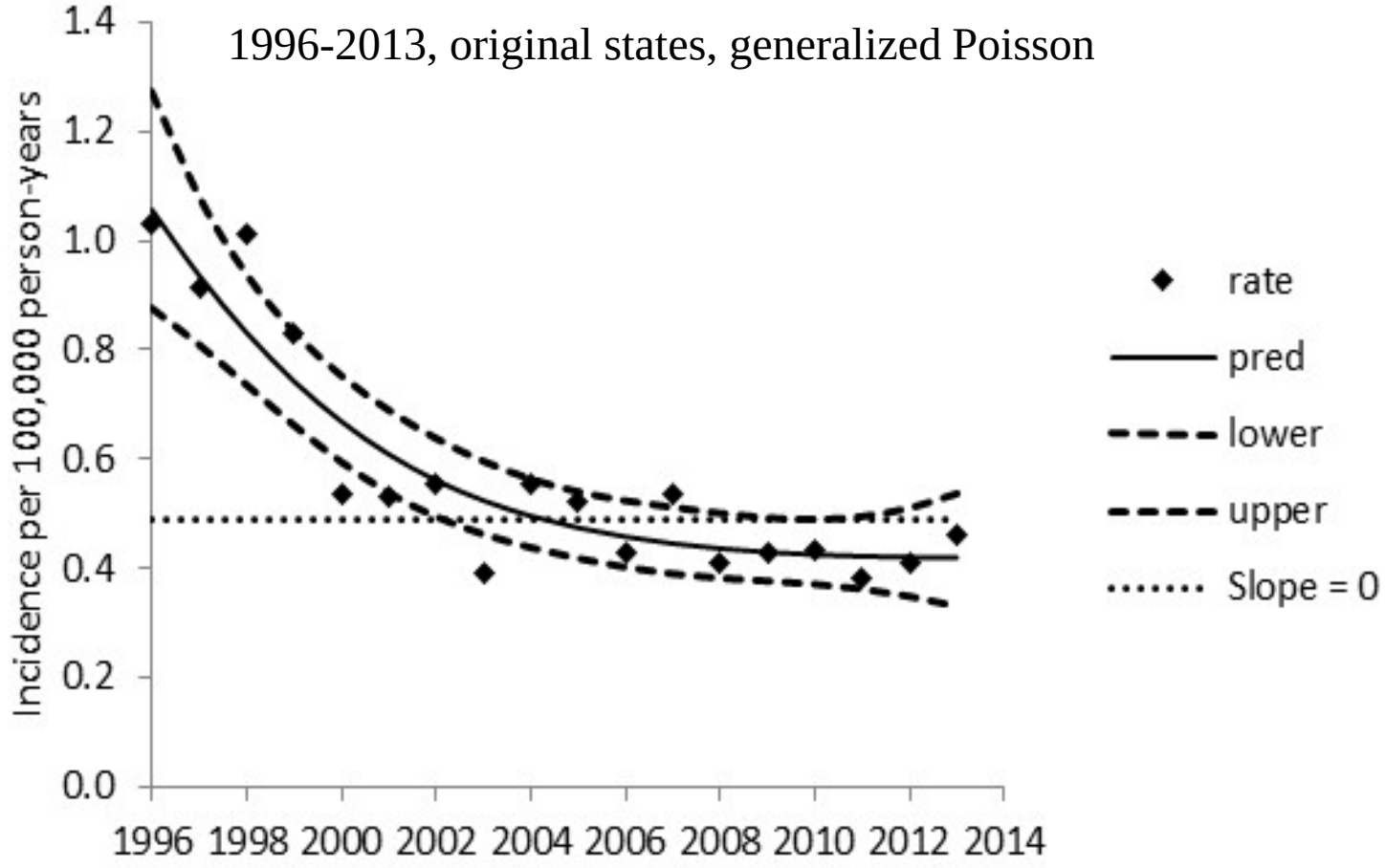
Listeria


1996-2013, original sites, generalized Poisson
Incidence per 100,000 person-years
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
rate
pred
lower
upper
Slope = 0

STEC O157


1996-2013, original sites, generalized Poisson
Incidence per 100,000 person-years
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
rate
pred
lower
upper
Slope = 0

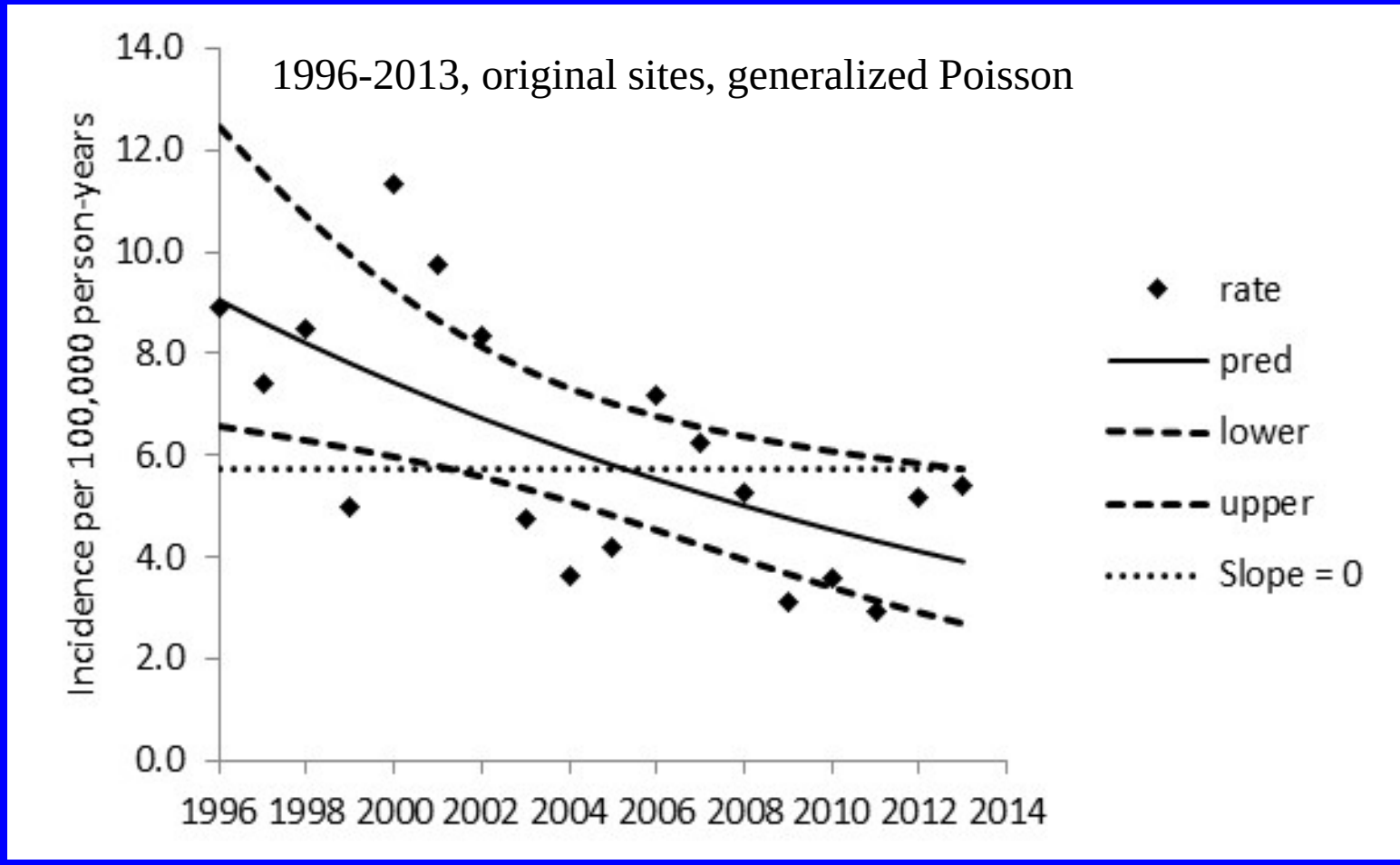
Yersinia


1996-2013, original states, generalized Poisson
Incidence per 100,000 person-years
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
rate
pred
lower
upper
Slope = 0

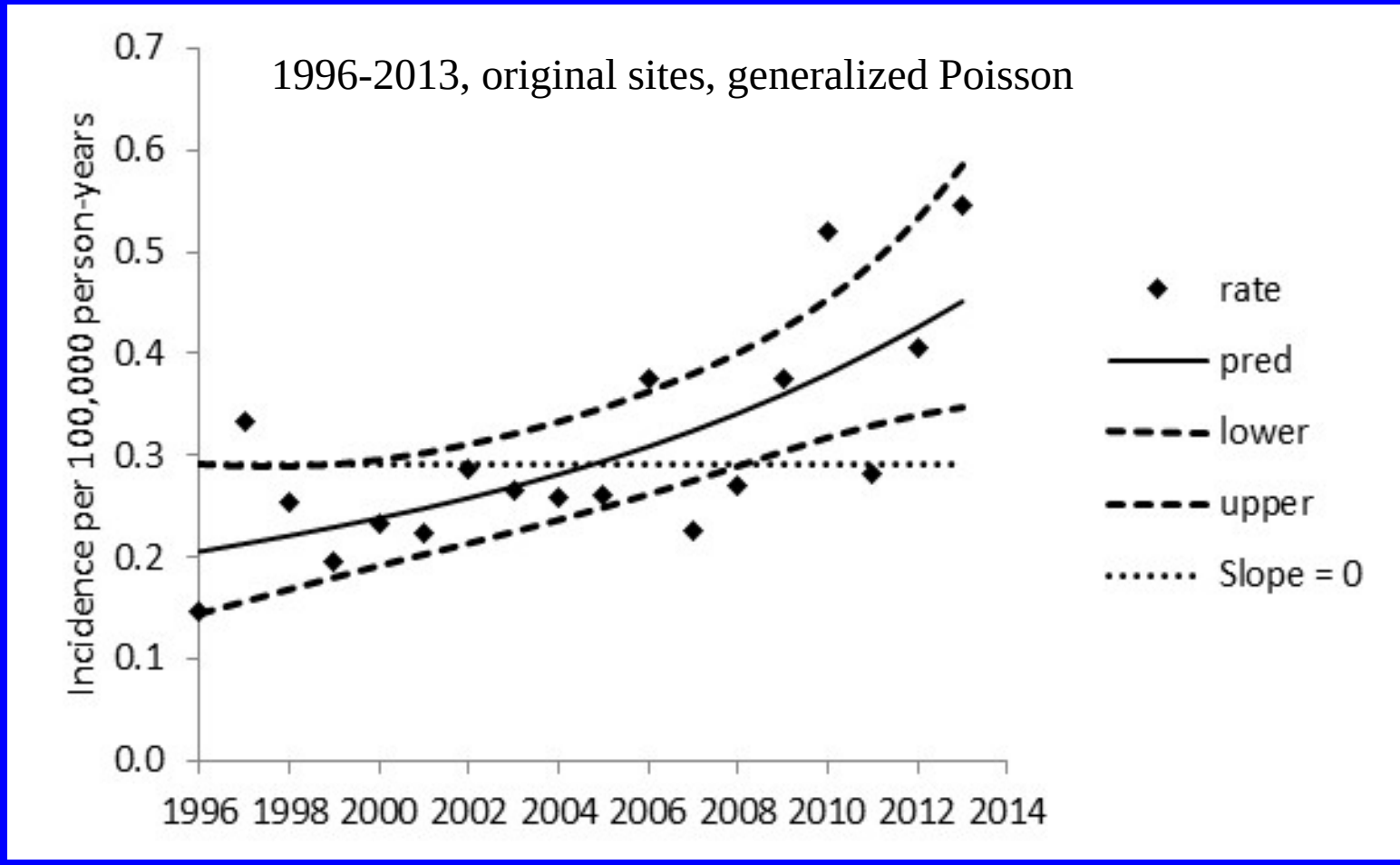
Penalized B-Spline Regression

- *Shigella* and *Vibrio*
- Continuous trends without an apparent plateau
- *Shigella* decreasing
- *Vibrio* increasing
- Results consistent for All Sites, Original Sites, Generalized Poisson, Negative Binomial

Shigella


1996-2013, original sites, generalized Poisson
Incidence per 100,000 person-years
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
rate
pred
lower
upper
Slope = 0

Vibrio

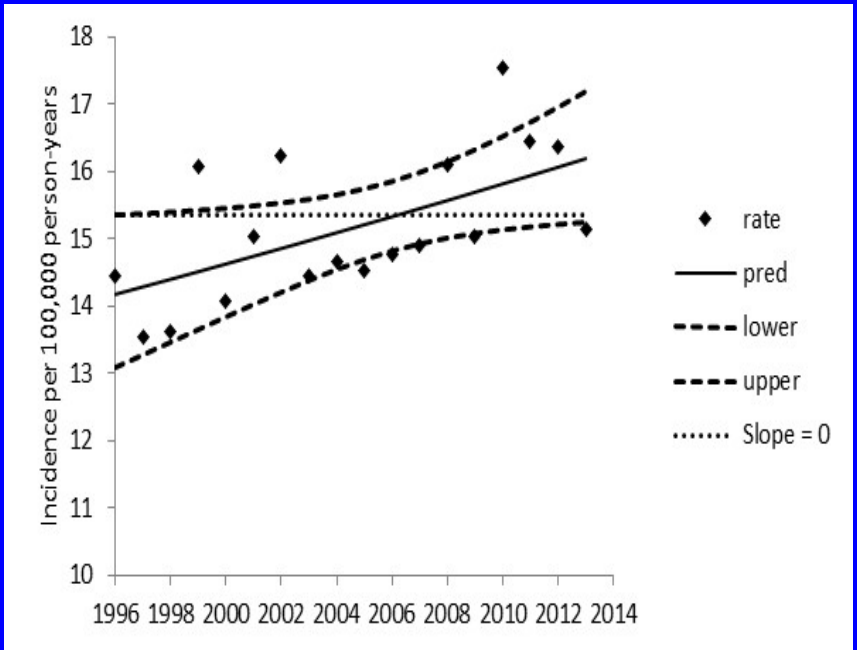

1996-2013, original sites, generalized Poisson
Incidence per 100,000 person-years
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
rate
pred
lower
upper
Slope = 0

Penalized B-Spline Regression

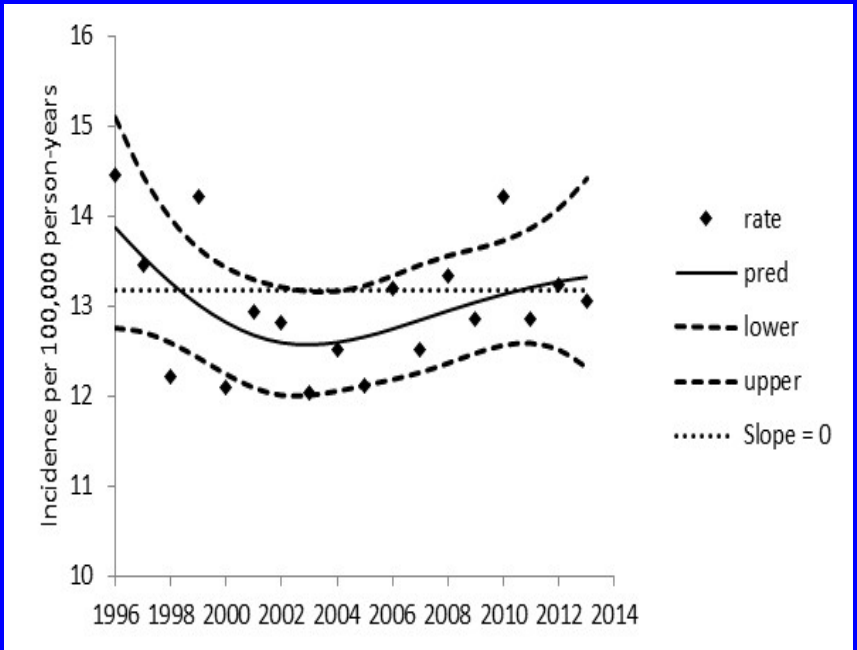
- *Salmonella*
- Inconclusive whether there is no trend or an increasing trend
  - Significant Trend in All Sites, 1996-2013
    - Inf. Smooth → Log-linear model
    - Negative auto-correlation (SE(LP) over stated) - GAMM
  - No Trend in Original 5 Sites, 1996-2013

Salmonella

All Sites, 1996-2013



Original Sites, 1996-2013



Salmonella

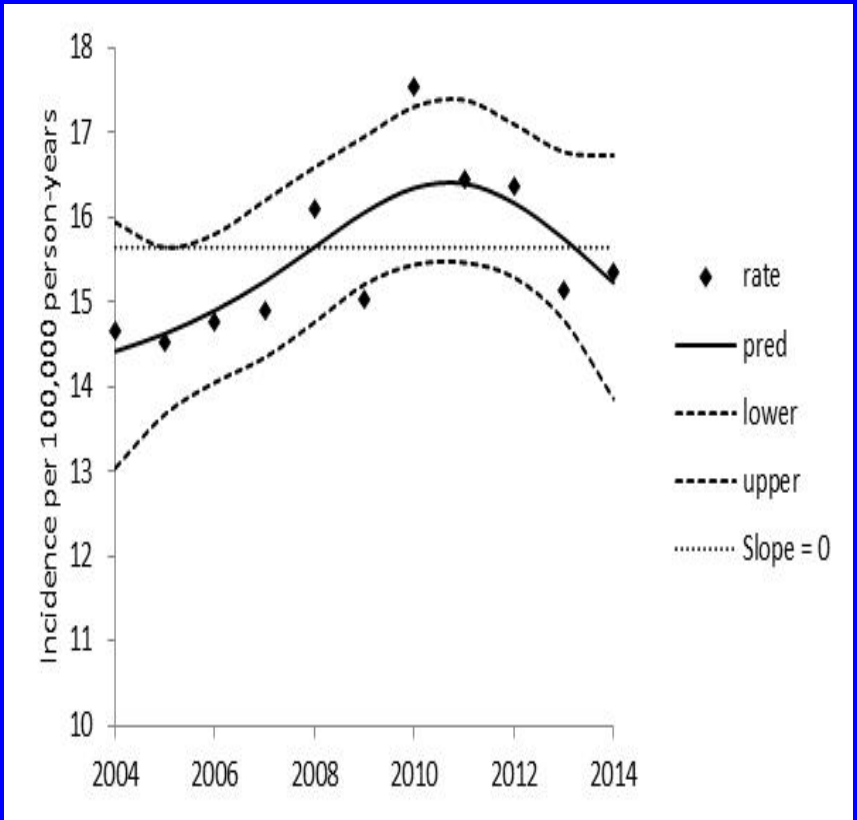
- Restrict the analysis to data since 2004 (FoodNet composition is stable)

Poisson Log Linear Model Salmonella 2004-13

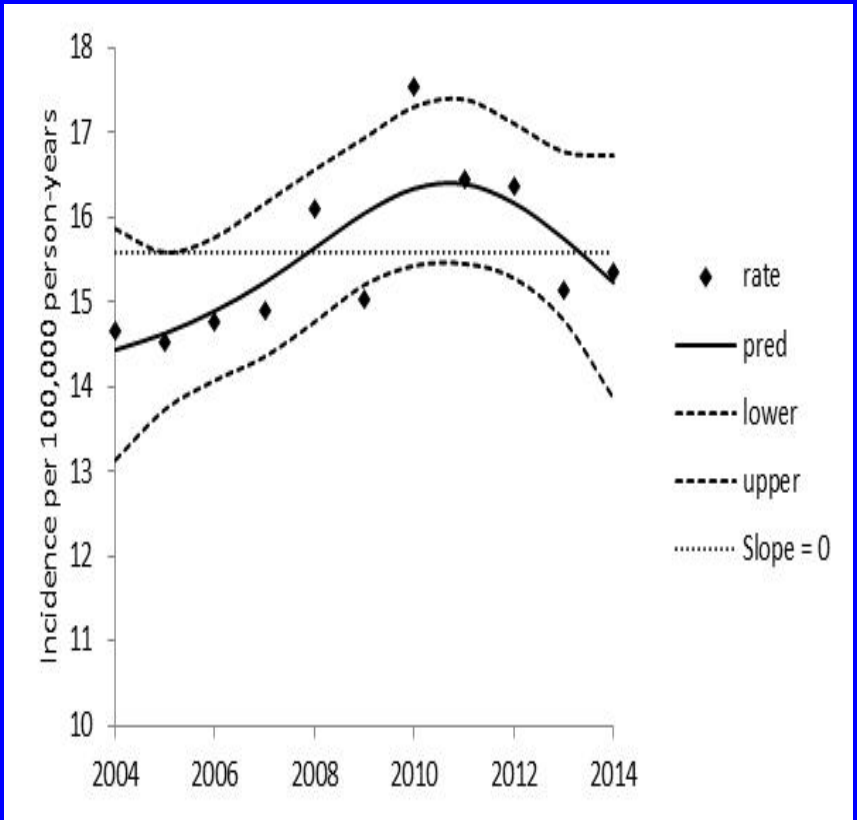
SALMONELLA 2004-13	Generalized Poisson				Negative Binomial			
Parameter	Est	SE	ChiSq	p	Est	SE	ChiSq	p
Intercept	-33.7745	5.8629	33.1853	0.0000	-18.8233	6.0539	9.6677	0.0019
Year	0.0124	0.0029	18.0847	0.0000	0.0050	0.0030	2.7168	0.0993
CA_1996	0.1392	0.0496	7.8812	0.0050	0.1419	0.0532	7.1116	0.0077
CA_2000	-0.0916	0.0695	1.7378	0.1874	-0.0883	0.0575	2.3628	0.1243
CO_2001	-0.2408	0.0547	19.3724	0.0000	-0.2319	0.0542	18.2878	0.0000
CO_2002	-0.1050	0.1111	0.8930	0.3447	-0.0968	0.0693	1.9552	0.1620
CT_1996	-0.1820	0.0594	9.3717	0.0022	-0.1791	0.0552	10.5310	0.0012
CT_1997	0.1075	0.0676	2.5275	0.1119	0.1120	0.0570	3.8546	0.0496
CT_1998	-0.1694	0.0759	4.9751	0.0257	-0.1659	0.0591	7.8848	0.0050
GA_1996	-0.0512	0.0463	1.2218	0.2690	-0.0478	0.0527	0.8246	0.3638
GA_1997	0.1288	0.0581	4.9172	0.0266	0.1302	0.0549	5.6158	0.0178
GA_1999	0.8754	0.0381	527.7696	0.0000	0.8751	0.0513	290.7412	0.0000
MD_1998	0.1236	0.0479	6.6546	0.0099	0.1256	0.0529	5.6364	0.0176
MD_2001	-0.2490	0.0599	17.2543	0.0000	-0.2461	0.0553	19.8120	0.0000
MD_2002	0.1953	0.0584	11.1779	0.0008	0.1992	0.0550	13.1283	0.0003
MN_1996	-0.0841	0.0430	3.8175	0.0507	-0.0819	0.0521	2.4736	0.1158
NM_2004	0.1219	0.0516	5.5746	0.0182	0.1236	0.0536	5.3109	0.0212
NY_1998	-0.1743	0.0692	6.3411	0.0118	-0.1710	0.0574	8.8691	0.0029
NY_1999	-0.2673	0.0747	12.8201	0.0003	-0.2649	0.0587	20.3443	0.0000
NY_2002	-0.4437	0.0758	34.2684	0.0000	-0.4413	0.0590	55.8896	0.0000
NY_2003	-0.1778	0.0878	4.0961	0.0430	-0.1750	0.0622	7.9029	0.0049
NY_2004	-0.2046	0.1168	3.0710	0.0797	-0.2023	0.0710	8.1124	0.0044
OR_1996	-0.3510	0.0495	50.3779	0.0000	-0.3465	0.0532	42.3902	0.0000
TN_2000	-0.0054	0.0474	0.0130	0.9091	-0.0004	0.0528	0.0001	0.9934
TN_2003	0.0000	0.0000			0.0000	0.0000		
Scale/Dispersion	2.2475	0.0000			0.0117	0.0016		
SSPR	208.2813				241.9529			

Penalized B-Spline Regression Salmonella 2004-14*

Generalized Poisson



Negative Binomial



*MMWR 2015 - preliminary 2014

SUMMARY
Trends for Bacterial Pathogens

- Early decline followed by year-to-year variability about lower level
  - *Campylobacter*, *Listeria*, STEC O157, *Yersinia*
- Continuous decline
  - *Shigella*
- Continuous increase
  - *Vibrio*
- Inconclusive whether increase or no trend
  - *Salmonella*

Further Investigation: Trends in Salmonella Serotypes

- Long term trends (1996-2013)
- Seasonal variation (month-to-month)
- $\text{Log}(E[y_{ij}]) = \log(\text{population}_{ij})+\beta_0+f_1(\text{year}_i)+f_2(\text{month}_j)+\varepsilon_{ij}$

Limitations

- Results are preliminary, work in progress
- Reported illness is a proxy, not true incidence
- Not all FoodNet reported illness is foodborne
- Assumes data missing at random
- Descriptive model, not infer causes
- Uncertainty about generalizing from FoodNet population to national level not quantified

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  - Stacy Crim, CDC
  - Mike Hoekstra, CDC
  - Mike Williams, FSIS

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- The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention.