Department of Pesticide Regulation

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MEMORANDUM

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DATE: January 23, 2017

SUBJECT: AN INVESTIGATION IN THIOBENCARB CONTAMINATION IN SACRAMENTO VALLEY DURING 2003–2016

1. Thiobencarb Contamination in Surface Water in the Sacramento Valley

Thiobencarb is an herbicide registered specifically for use on rice fields in California. It has mainly been applied in five counties in the Sacramento Valley (Butte, Colusa, Glenn, Sutter, and Yolo) and has been routinely detected in surface waterbodies downstream of use areas. The California Rice Commission (CRC) has long term monitoring data (2003–2016) on the thiobencarb signal at four sites, which covered about 96% of the rice fields in the Sacramento Valley. These sites are: Sacramento River Riverview Marina (SR1), which is a receiving water site and three agricultural drain sites Butte Slough (BS1), Colusa Basin Drain South End (CBD1), and Colusa Basin Drain North End (CBD5) (CH2MHill, 2016). The locations of these sites are illustrated in Figure 1. The receiving water site SR1 did not exceed the thiobencarb water quality objective of 1.0 ppb. The drain BS1 had only one exceedance over the performance goal of 1.5 ppb in May 2008. The other two drains CBD1 and CBD5 had detections above 0.5 ppb and exceedance over the performance goal of 1.5 ppb over the years (Figure 2 and 3). Based on the drainage maps in Appendix A (Map1 and Map 2), site CBD5 receives drainage water from Glenn and Colusa counties while site CBD1 receives drainage water from Glenn, Colusa and Yolo counties. This report evaluates the exceedances at these two sites and investigates the statistical linkage between exceedance frequencies and two factors that may affect the exceedances: (1) thiobencarb use in the corresponding drainage area, and (2) the effect of drought as indicated by water flow in the Colusa Drain near Hwy 20 (site CDR in Figure 1).

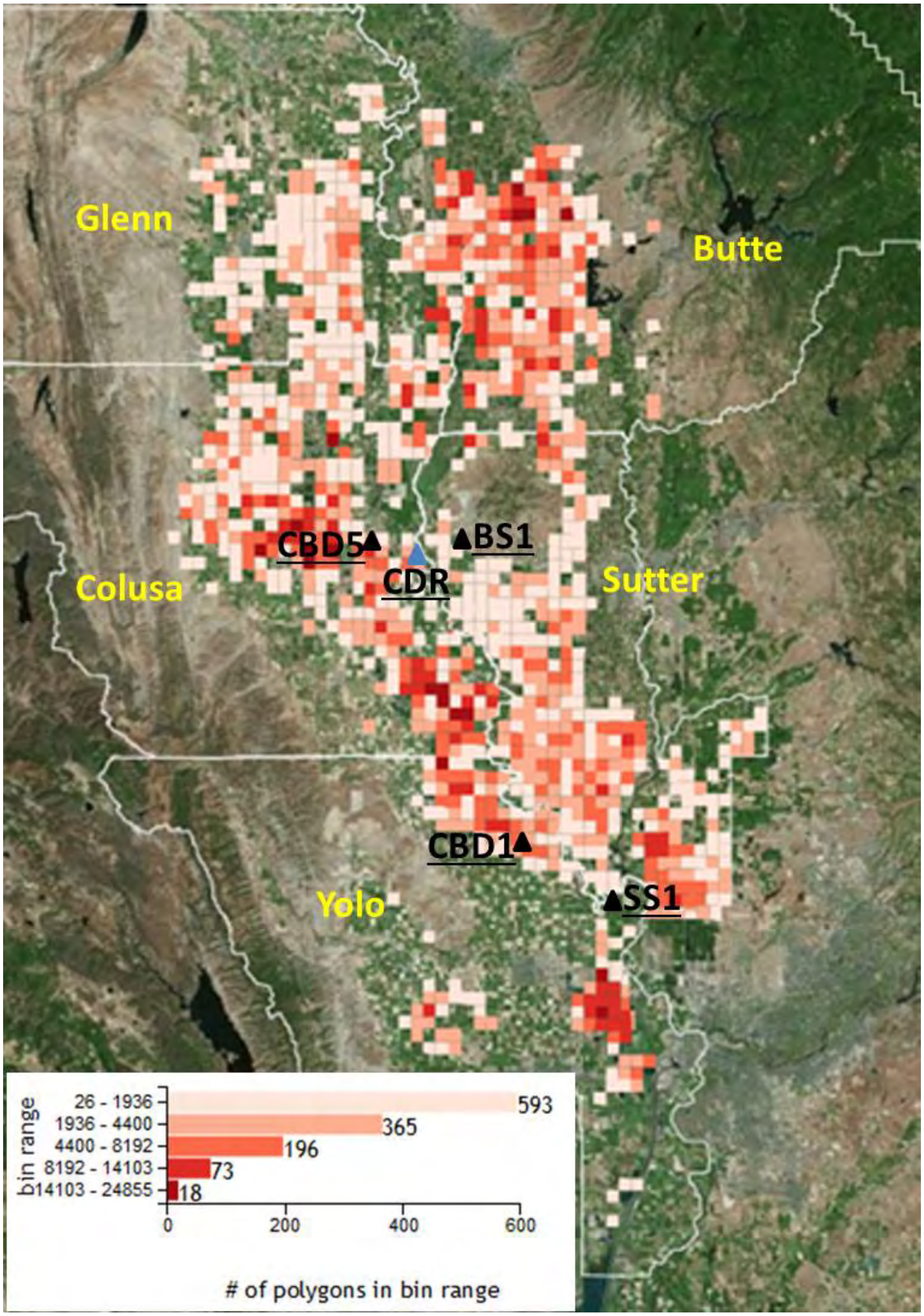


Figure 1 Thiobencarb use in the Sacramento Valley (pounds thiobencarb applied per square mile over the period of 2003–2014 as reported in PUR). Butte Slough (BS1), Colusa Basin Drain South End (CBD1), Colusa Basin Drain North End (CBD5), and Sacramento River Riverview Marina (SR1) are locations where thiobencarb concentration in surface water has been monitored. CDR is the flowrate monitoring station on the Colusa Drain near Hwy 20.

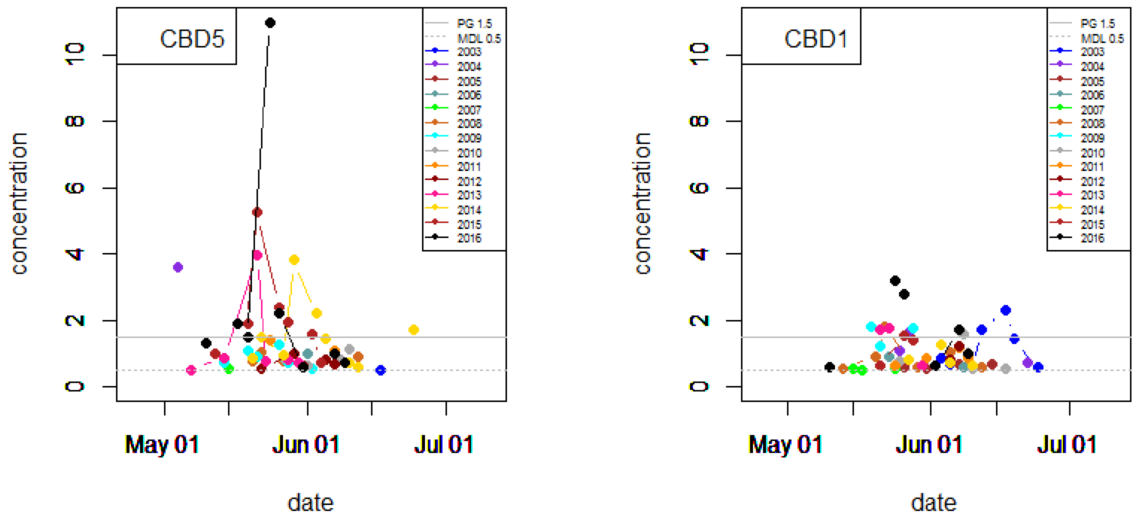


Figure 2 Thiobencarb Concentration at Site CBD5 and CBD1

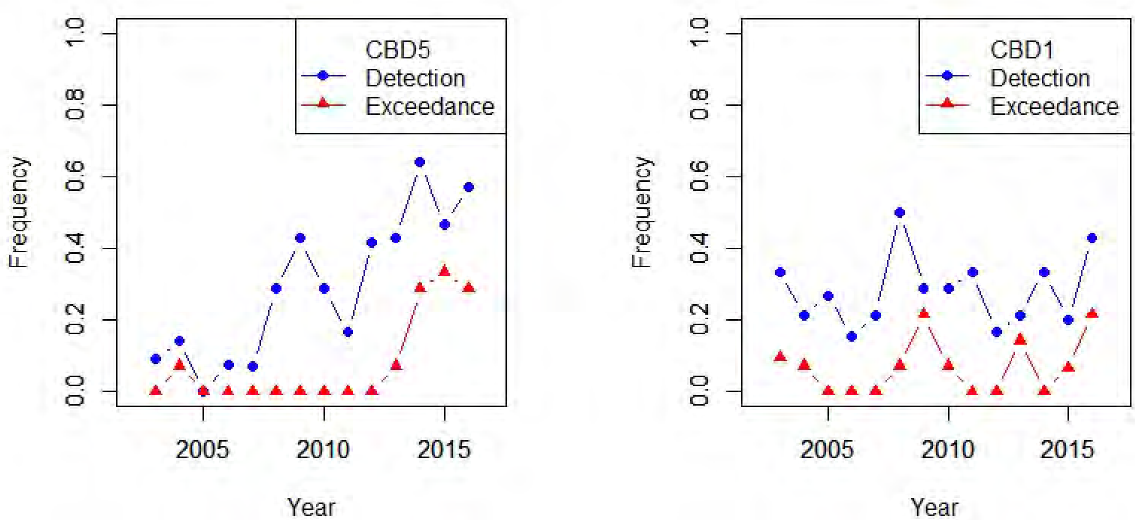


Figure 3 Thiobencarb Detection (≥ 0.5 ppb) and Exceedance (≥ 1.5 ppb) Frequencies at Site CBD5 and CBD1.

2. Thiobencarb Usage in the Sacramento Valley

The California Department of Pesticide Regulation (CDPR) has full use reporting on agricultural application of pesticides in the Pesticide Use Reporting Database (PUR) (http://www.cdpr.ca.gov/docs/pur/purmain.htm). A total of 14 pesticide products containing thiobencarb have been used in the area over the years (Table 1). These products can be grouped into two categories because of their similarity in formulation, application method and water management practices: granular products and emulsifiable concentrate products. A major difference in the two categories that might differentiate their fate and transport is their water holding time. The emulsifiable concentrate products have shorter water holding time than the granular products do (Newhart and Singhasemanon, 2015). Annual usage of the two categories of products and total use in the three counties that drain to site CBD5 and CBD1 are plotted in Figure 4. The usage data from 2003–2014 are extracted from PUR. However, usage data from year 2015–2016 have not been published in PUR yet. Instead, the usage data in 2015–2016 are estimated based on the estimated application acreage provided in CRC's Rice Pesticide Program (RPP) Annual Monitoring Report. CAC estimated the annual application acreage for the following groups of thiobencarb products: Abolish 8EC (PUR prodno 28048), Bolero 10G (PUR prodno 1143, 23273, 23678, 24756, 27627, 27628, and 28287), Bolero 15G (PUR prod no 46655), Bolero 8EC (PUR prodno 28049), Bolero 15G Ultramax (PUR prod no 55765 and 57151), and League MVP (PUR prodno 63548 and 64651). With a few exceptions, the CAC estimated annual application acreage matched the values extracted from PUR database for the years 2003–2014, which implies that the CAC's estimation for 2015–2016 would be reliable as well. The application rate (pounds thiobencarb applied per treated acre) for each of the six groups of products can also be extracted from the PUR database. The annual usage for each of the six groups in 2015 and 2016 is calculated as the sum of CAC's estimated application acreage and the average application rate over the years of 2012–2014. The usage of emulsifiable concentrate and granular products in 2015 and 2016 are then the sum of the corresponding groups. (Note that we recently received preliminary PUR data from the CRC and the total amounts of thiobencarb used in the three counties are comparable to our estimated values in Appendix B). In this process, an error in PUR has been identified: the application rate of Bolero 15G UltraMax in Colusa County in 2014 was reported to be 0.05 pounds thiobencarb per treated acre, much lower than the average application rate in previous three years (2011–2013) at 3.51 pounds per treated acre. The usage of this group of product in Colusa County in 2014 was corrected using the average application rate.

Table 1 Thiobencarb Pesticides Used on Rice Fields in Sacramento Valley

PUR prodno	product name	USEPA registration number	active ingredient	Formulation type
1143	BOLERO 10_G	239- 2449-AA	10% thiobencarb	granular/flake
23273	BOLERO 10G	239- 2449-AA-59639	10% thiobencarb	granular/flake
23678	BOLERO 10G	62499- 19-AA-59639	10% thiobencarb	granular/flake
24756	BOLERO 10G	62499- 19-AA	10% thiobencarb	granular/flake
27627	BOLERO 10G	63588- 5-AA- 59639	10% thiobencarb	granular/flake
27628	BOLERO 10 G	63588- 5-AA	10% thiobencarb	granular/flake
28048	ABOLISH 8 EC RICE HERBICIDE	59639- 79-ZA	84% thiobencarb	emulsifiable concentrate

28049	BOLERO 8 EC	59639- 79-AA	84% thiobencarb	emulsifiable concentrate
28287	BOLERO 10G	59639- 80-AA		
46655	BOLERO 15G	59639- 112-AA	15% thiobencarb	granular/flake
55765	BOLERO 15 G ULTRAMAX RICE HERBICIDE	59639- 112-ZA	15% thiobencarb	granular/flake
57151	BOLERO ULTRAMAX HERBICIDE	59639- 112-ZB	15% thiobencarb	granular/flake
63548	LEAGUE MVP HERBICIDE	59639-55017-EX	10% thiobencarb +0.43% imazosulfuron	granular/flake
64651	LEAGUE MVP HERBICIDE	59639- 189-AA	10% thiobencarb +0.43% imazosulfuron	granular/flake

As shown in Figure 4, the treated acreage and thiobencarb usage show almost identical pattern because the application rate of the emulsifiable concentrate products and granular products are similar. The usage of emulsifiable concentrate products is lower than that of the granular products but the two categories show similar trend in Glenn and Colusa counties. The Spearman correlation coefficient for the usage of the two categories of products is 0.8343 in Glenn County over the years 2003–2016; the coefficient is 0.8075 in Colusa County over the years 2004–2016 (excluding the extremely high use of granular products in 2003); the coefficient in Yolo County is lower (0.2543) because the usage of emulsifiable concentrate products have been low across the years. Colusa County has the highest total use among the three counties. Use in Glenn County was lower than that of Yolo County in 2003–2013, but higher in 2014–2016. In addition, the total use in Glenn County is correlated with the total use in Colusa County as indicated by Spearman's correlation coefficient of 0.6239; the coefficient between the total use in Colusa and Yolo counties is 0.4040; the coefficient between the total use in Glenn and Yolo counties is as low as 0.0362.

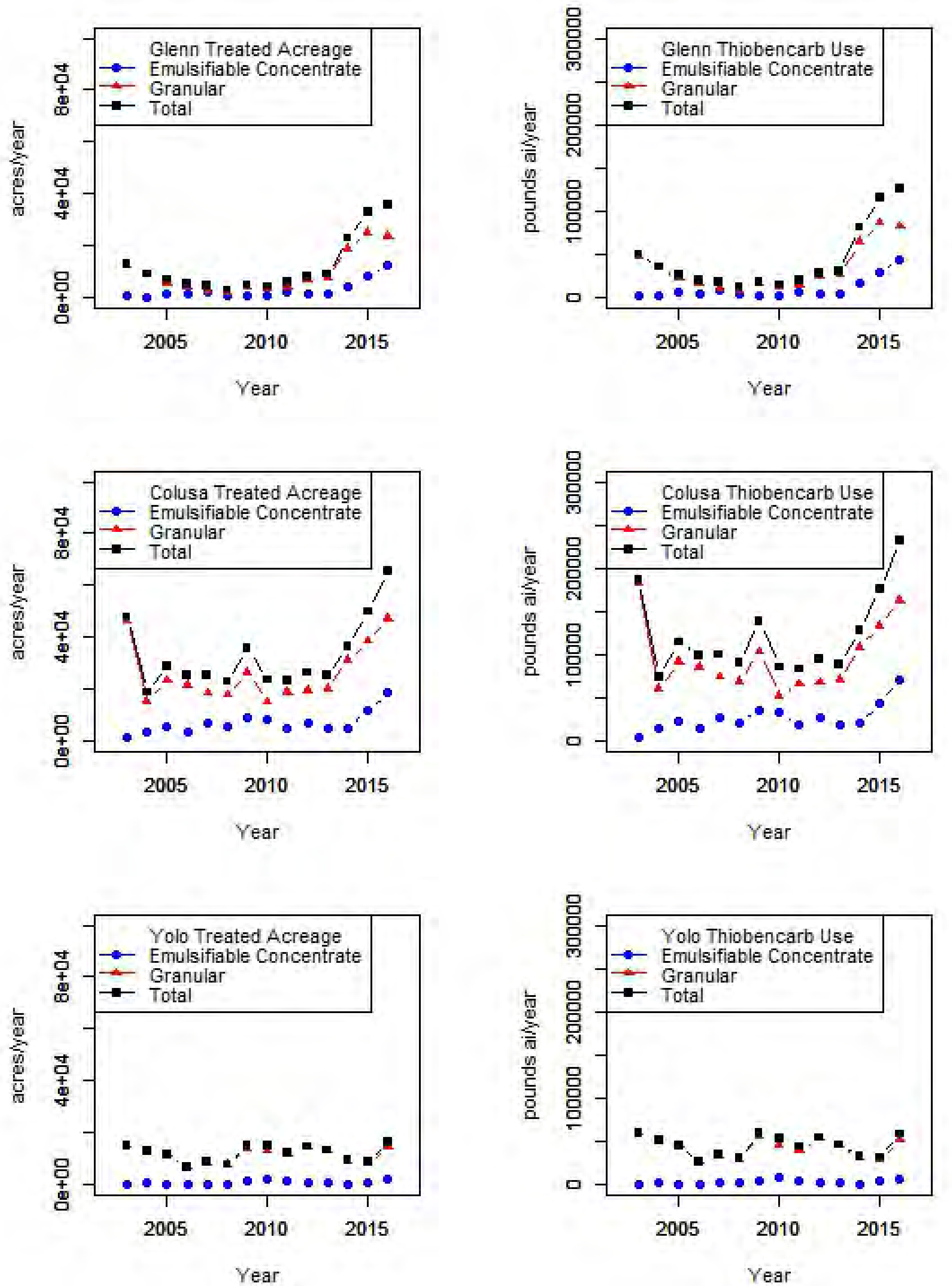


Figure 4 Thiobencarb Use in Glenn, Colusa and Yolo Counties. Left panels: treated acreage; right panels: usage of thiobencarb. Data for years 2003–2014 were extracted from PUR, data for years 2015–2016 were estimated based on applied acreage received from the CRCs' RPP Annual Monitoring Report.

3. Water Flowrate at the Colusa Drain near Highway 20 (Site CDR)

The drought condition was evaluated using water flowrate monitored at station CDR near the thiobencarb sampling site CBD5. Hourly discharge data at this station were downloaded from the California Department of Water Resources' California Data Exchange Center (http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=CDR). Average flowrate over the thiobencarb sampling period (April 24th – July 7th) was calculated for each year over 2003–2016 and plotted in Figure 5. The flowrate at CDR is negatively correlated with the thiobencarb usage in Glenn County (Spearman's correlation coefficient of -0.7530 in 2003–2016) and in Colusa County (coefficient of -0.5290 in 2004–2016). High usage co-occurred with drought condition in the last few years in these two counties. The correlation between the flowrate at CDR and usage in Yolo County is not significant because usage in Yolo County has been stable over the years.

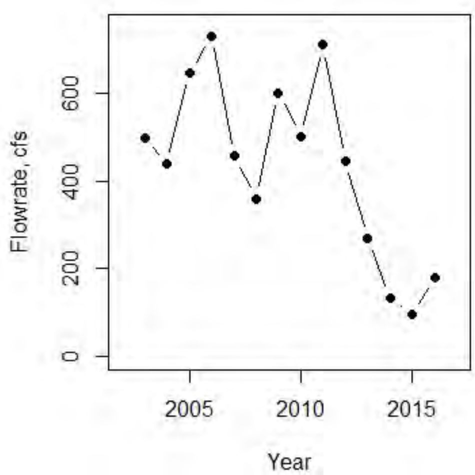


Figure 5 Average Flowrate at Station CDR over April. 24 – July 7.

4. Statistical Linkage between Exceedance Frequency and Contributing Factors

The statistical linkage between the exceedance frequencies at the two sites and the two contributing factors—usage and drought are investigated by linear regression. Collinearity exists among many explanatory variables (correlation between usage of the two categories of products, usage among different counties, and between usage and flowrate). Therefore, partial least square regression was used to build the models. Models were selected based on the basic physical concept that the usage should contribute positively to the exceedance (positive slope, higher usage leads to higher exceedance) while the flowrate should contribute negatively to the exceedance (negative slope, lower flowrate leads to higher exceedance).

The linear regression results for site CBD5 are listed in Table 2. Flow at CDR alone, total usage in the two counties plus flow at CDR, usage in Glenn County alone, or usage in Colusa County plus flow at CDR can explain significant amount of variance in the exceedance frequency (70.39%, 82.74%, 87.69%, and 77.15%, respectively). Separating emulsifiable concentrate products and granular products in the models adds very little to the amount of variance explained. Addition of flow at CDR to the usage data of the two counties or Colusa County alone increases the amount of variance explained (20.13% and 40.34% more, respectively). Addition of flow at CDR to the usage data of Glenn County does not significantly increases the amount of variance explained because these two variables are significantly correlated.

Table 2 Linear Regression Results for Exceedance Frequency at CBD5

Model	Explanatory variables	Variance explained	Notes*
1	flow at CDR	70.39%	
2	total use in Glenn and Colusa counties	62.61%	
3	emulsifiable concentrate products used in Glenn and Colusa counties + granular products used in Glenn and Colusa counties	65.58%	2.97% more than model 2
4	total use in Glenn and Colusa counties + flow at CDR	82.74%	*20.13% more than model 2*
5	emulsifiable concentrate products used in Glenn and Colusa counties + granular products used in Glenn and Colusa counties + flow at CDR	83.56%	0.82% more than model 4 *17.98% more than model 3*
6	total use in Glenn County	87.69%	
7	emulsifiable concentrate products used in Glenn County + granular products used in Glenn county	87.69%	0% more than model 6
8	total use in Glenn County + flow at CDR	91.83%	*4.14% more than model 6*
9	emulsifiable concentrate products used in Glenn County + granular products used in Glenn County + flow at CDR	91.84%	0.01% more than model 8 *4.15% more than model 7*
10	total use in Colusa County	36.81%	
11	emulsifiable concentrate products used in Colusa County + granular products used in Colusa county	43.13%	6.32% more than model 10
12	total use in Colusa County + flow at CDR	77.15%	*40.34% more than model 10*
13	emulsifiable concentrate products used in Colusa County + granular products used in Colusa county + flow at CDR	78.02%	0.87% more than model 12 *34.89% more than model 11*

*Separation of emulsifiable concentrate and granular products contributes little to explaining the variance; inclusion of flow at CDR, however, contributes significantly.

The linear regression results for site CBD1 are listed in Table 3. The explanatory power is lower for CBD1 than for CBD5. Flow at CDR or total use in Glenn County explain insignificant amount of variance in the exceedance frequency (8.052% and 10.02% respectively). Different combinations of usage data explain between 27.21% – 47.32% of the variance, with the highest value from the model of total usage in Colusa and Yolo counties. Separating emulsifiable concentrate products and granular products or adding flow at CDR in the models only added small amounts to the variance explained.

Table 3 Linear Regression Results for Exceedance Frequency at CBD1

model	parameters	Variance explained	Notes*
1	flow at CDR	8.052%	
2	total use in Glenn, Colusa and Yolo County	27.21%	
3	emulsifiable concentrate products used in Glenn, Colusa and Yolo counties + granular/flakes products used in Glenn, Colusa and Yolo counties	29.05%	1.84% more than model 2
4	total use in Glenn County	10.02%	
5	emulsifiable concentrate products used in Glenn County + granular products used in Glenn county	11.68%	1.66% more than model 4
6	total use in Glenn County + flow at CDR	10.49%	*0.47% more than model 4*
7	total use in Colusa County	28.09%	
8	emulsifiable concentrate products used in Colusa County + granular products used in Colusa county	35.03%	6.94% more than model 7
9	total use in Colusa County + flow at CDR	28.38%	*0.29% more than model 7*
10	total use in Yolo County	33.12%	
11	emulsifiable concentrate products used in Yolo County + granular products used in Yolo county	39.52%	6.4% more than model 10
12	total use in Yolo County + flow at CDR	45.67%	*12.55% more than model 10*
13	emulsifiable concentrate products used in Yolo County + granular products used in Yolo county + flow at CDR	49.34%	3.67% more than model 12 *9.82% more than model 11*
14	total use in Glenn County + total use in Yolo County	41.87%	
15	total use in Glenn County + total use in Yolo County + flow at CDR	45.83%	*3.96% more than model 14*
16	total use in Colusa County + total use in Yolo County	47.32%	
17	emulsifiable concentrate products used in Colusa County + granular products used in Colusa county + emulsifiable concentrate products used in Yolo County + granular products used in Yolo county	53.28%	5.96% more than model 16
18	total use in Colusa County + total use in Yolo County + flow at CDR	50.91%	*3.59% more than model 16*
19	emulsifiable concentrate products used in Colusa County + granular products used in Colusa county + emulsifiable concentrate products used in Yolo County	55.01%	4.1% more than model 18 *1.73% more than model 17*

	+ granular products used in Yolo county + flow at CDR		

*Separation of emulsifiable concentrate and granular products contributes little to explaining the variance; the same is true for the inclusion of flow at CDR.

5. Comparison of Timing of Applications and Detections in Surface Water

A comparison on the relative timing of thiobencarb applications in Glenn, Colusa and Yolo counties and thiobencarb detections at the two drainage sites was conducted in order to understand the type of processes that might contribute to the contamination in surface waters. Using 2013–2016 data in PUR (Figure 6 and 7), there appears to be a 1–3 weeks delay between the increase of thiobencarb applications and the time thiobencarb concentrations rise above the detection limit of 0.5 ppb at the downstream drainage site. See Appendix C for a clearer delineation for each year. On the other hand, delays involved with several contamination pathways include:

(1) Drift during aerial application: no extended delay, only the amount of time needed for the drift contaminated water to flow from the drift sites to the sampling site. Note that aerial application is the dominant application method and accounts for 93.9%, 96.5%, and 76.6% of total use in Glenn, Colusa and Yolo counties in 2012–2014, respectively (preliminary PUR data for 2015 and 2016 showed that aerial application accounts for 93.1% in both 2015 and 2016 in Colusa County; 85.0% in 2015 and 81.0% in 2016 in Glenn County; and 91.3% in 2015 and 100% in 2016 in Yolo County).

(2) Seepage and overflow from fields: continuous contribution from the time of application to the time of water release. However, its contribution will be most pronounced early on because the concentration of thiobencarb in the fields will be highest right after applications.

(3) Release of holding water from fields: delay that is the sum of water holding time and the amount of time needed for the released water to flow from the fields to the sampling site. Note that the required water holding time is about 14–30 days for the granular products and 14–19 days for the dominant emulsifiable concentrate product Abolish 8 EC Rice Herbicide (Newhart and Singhasemanon, 2015).

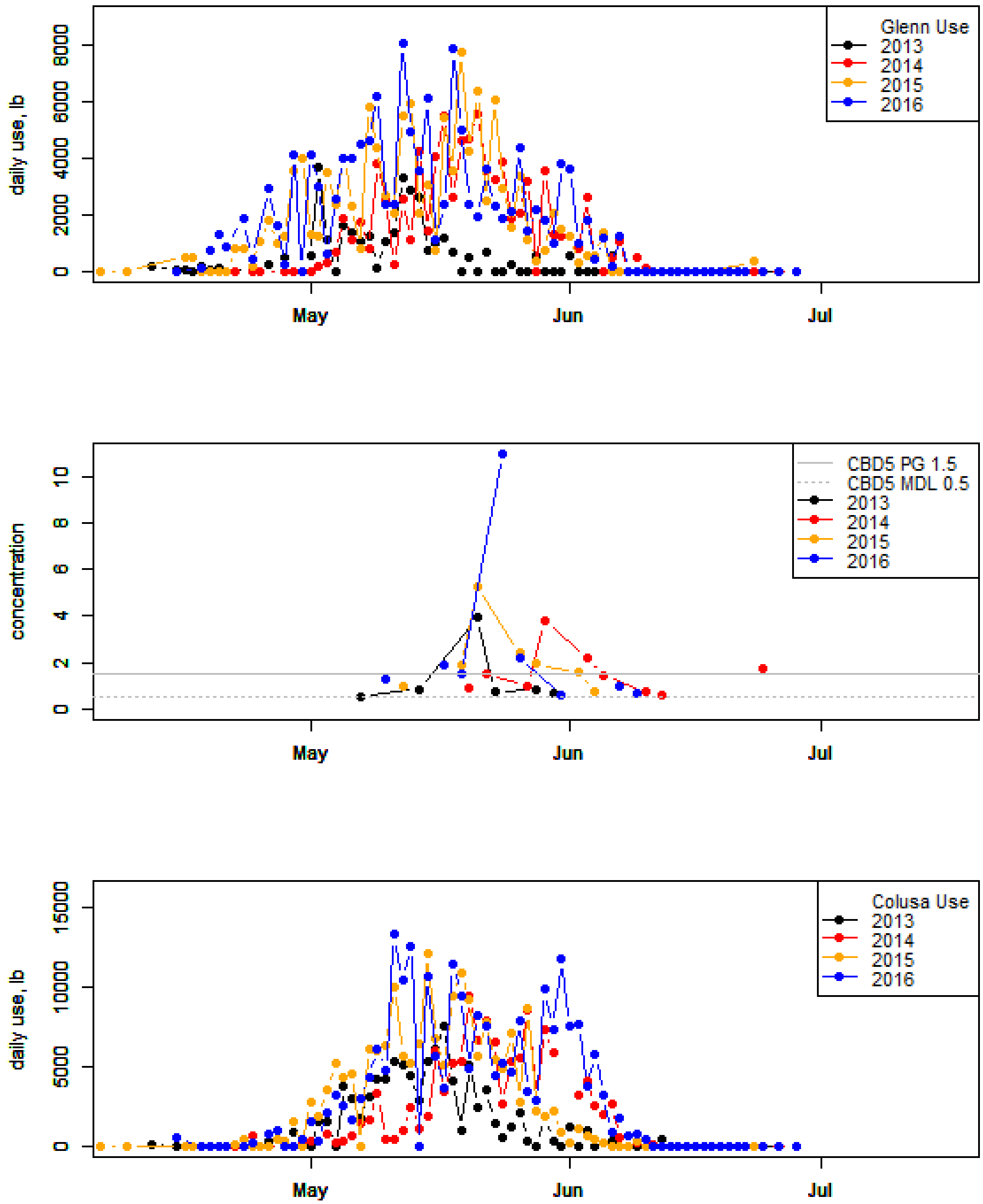


Figure 6 Comparison between Timing of Detections and Timing of Applications. Detections at CBD5 vs applications in Glenn and Colusa counties; separate plots for individual years are shown in Appendix C.

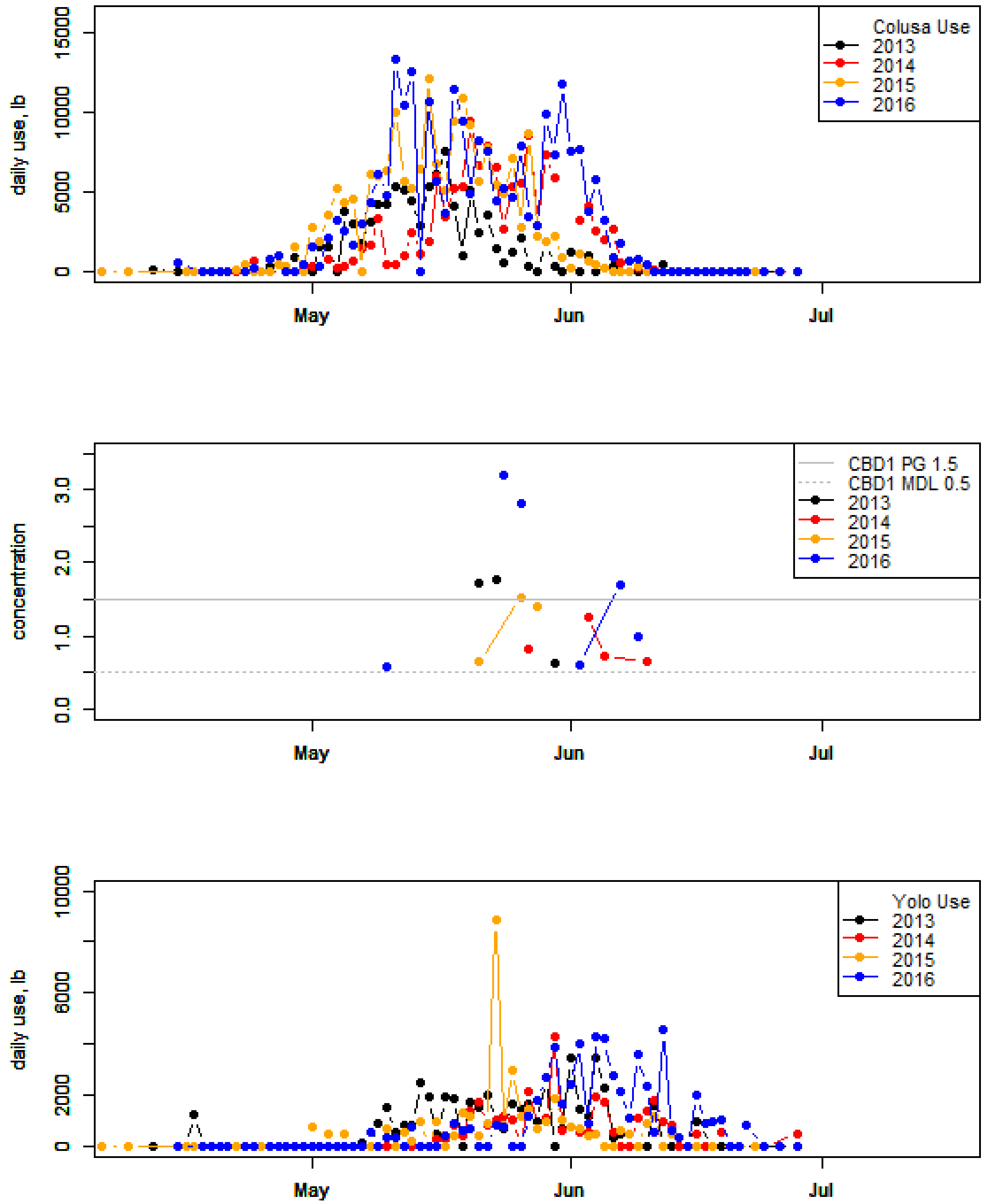


Figure 7 Comparison between Timing of Detections and Timing of Applications. Detections at CBD1 vs applications in Colusa and Yolo counties; separate plots for individual years are shown in Appendix C.

The drift effect was further evaluated using only aerial application data (Figure 8 and 9) and aerial applications of Abolish 8 EC (Figure 10 and 11) because pilots reported that this emulsifiable concentrate product has higher drift potential than the granular products (personal communication with enforcement branch). See Appendix C for a clearer delineation for each year. Only drift from fields close to the waterways will contaminate the surface water. However, according to the waterways map in Appendix A (Map 3), all fields are within 30 feet distance from the water ways. Therefore, all of the aerial applications are potential sources of drift. There is still a 1–3 weeks delay between the increase of thiobencarb aerial applications and the time thiobencarb concentrations rise above the detection limit of 0.5 ppb at the downstream drainage site.

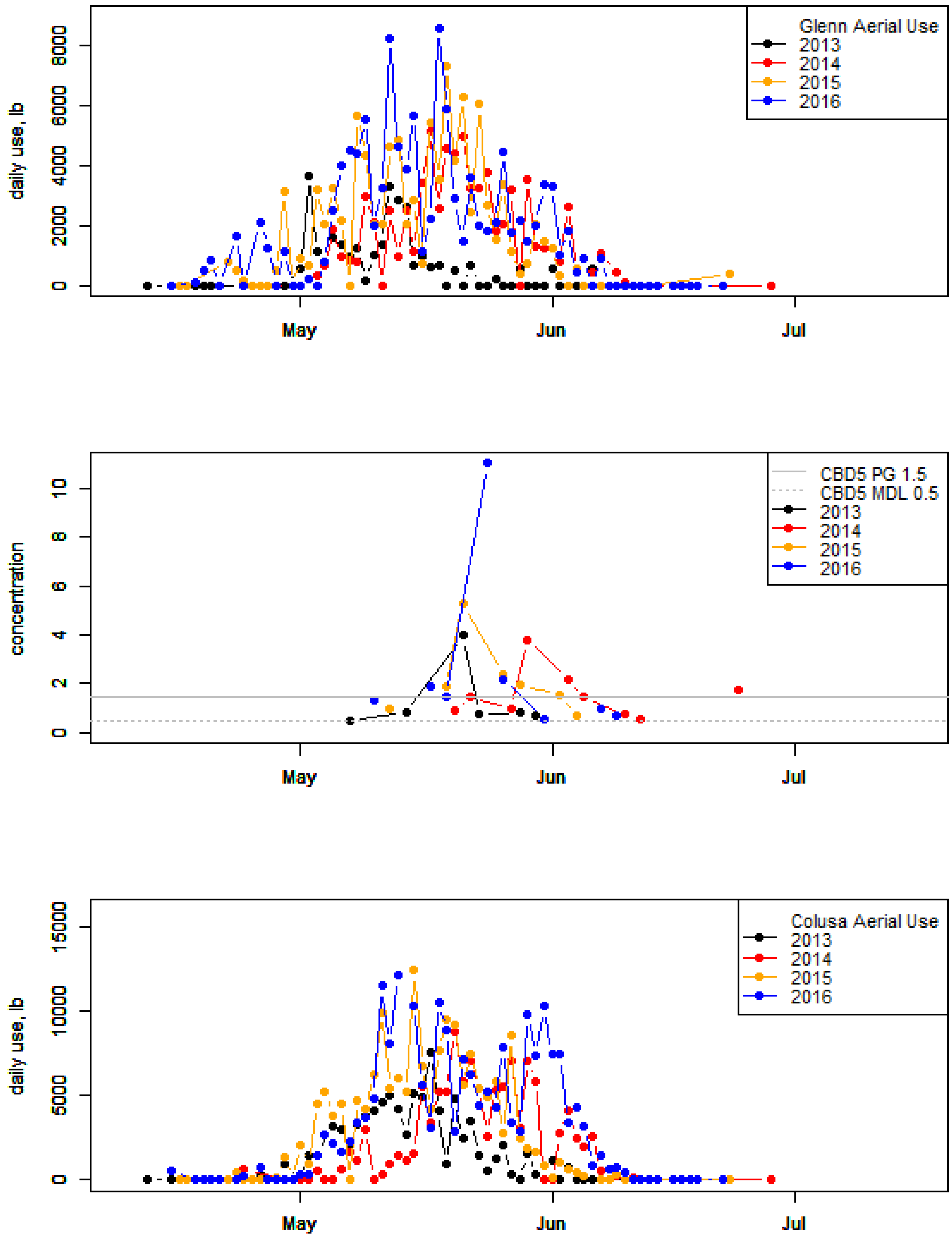


Figure 8 Comparison between Timing of Detections and Timing of Aerial Applications. Detections at CBD5 vs applications in Glenn and Colusa counties; separate plots for individual years are shown in Appendix C

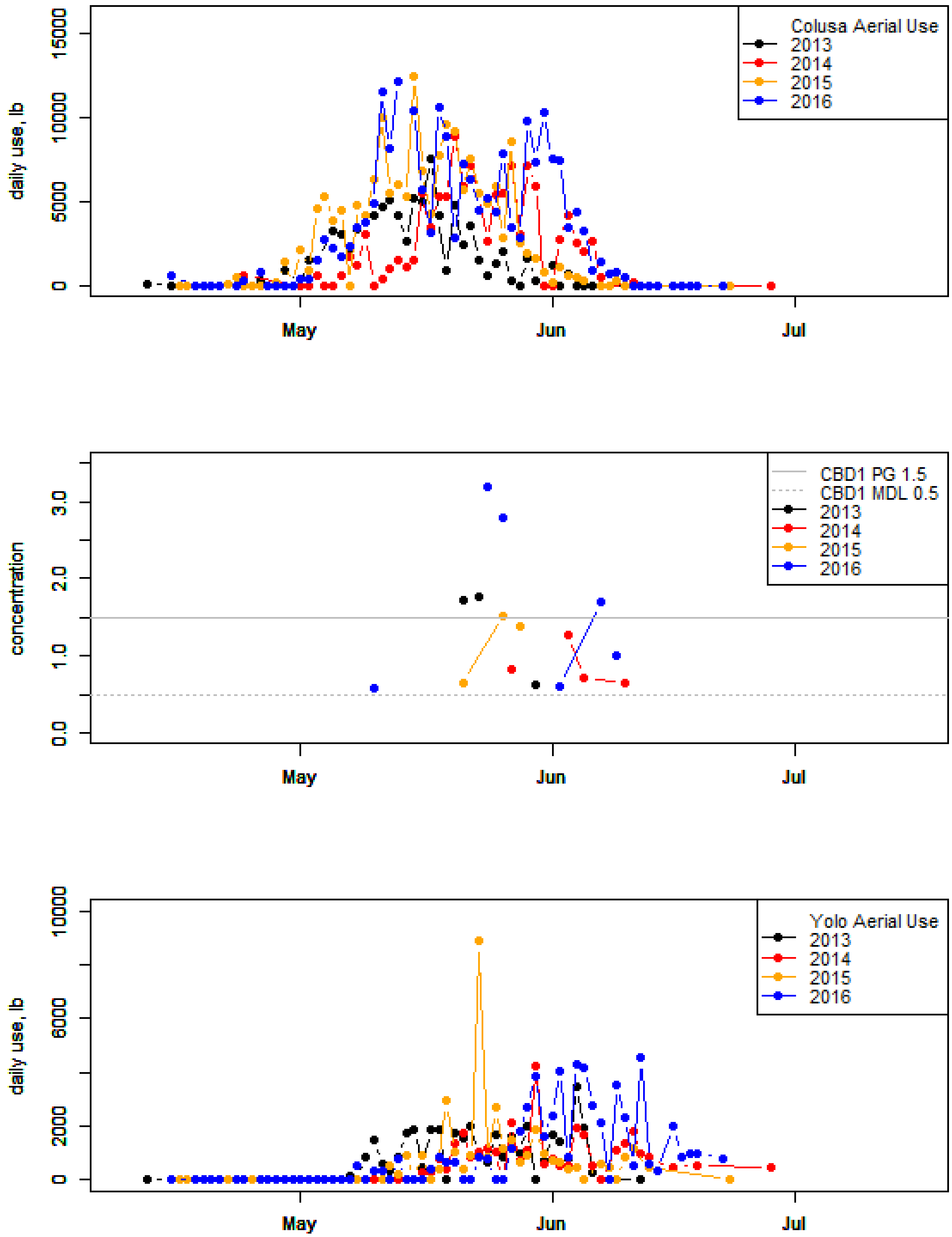


Figure 9 Comparison between Timing of Detections and Timing of Aerial Applications. Detections at CBD1 vs applications in Colusa and Yolo counties; separate plots for individual years are shown in Appendix C.

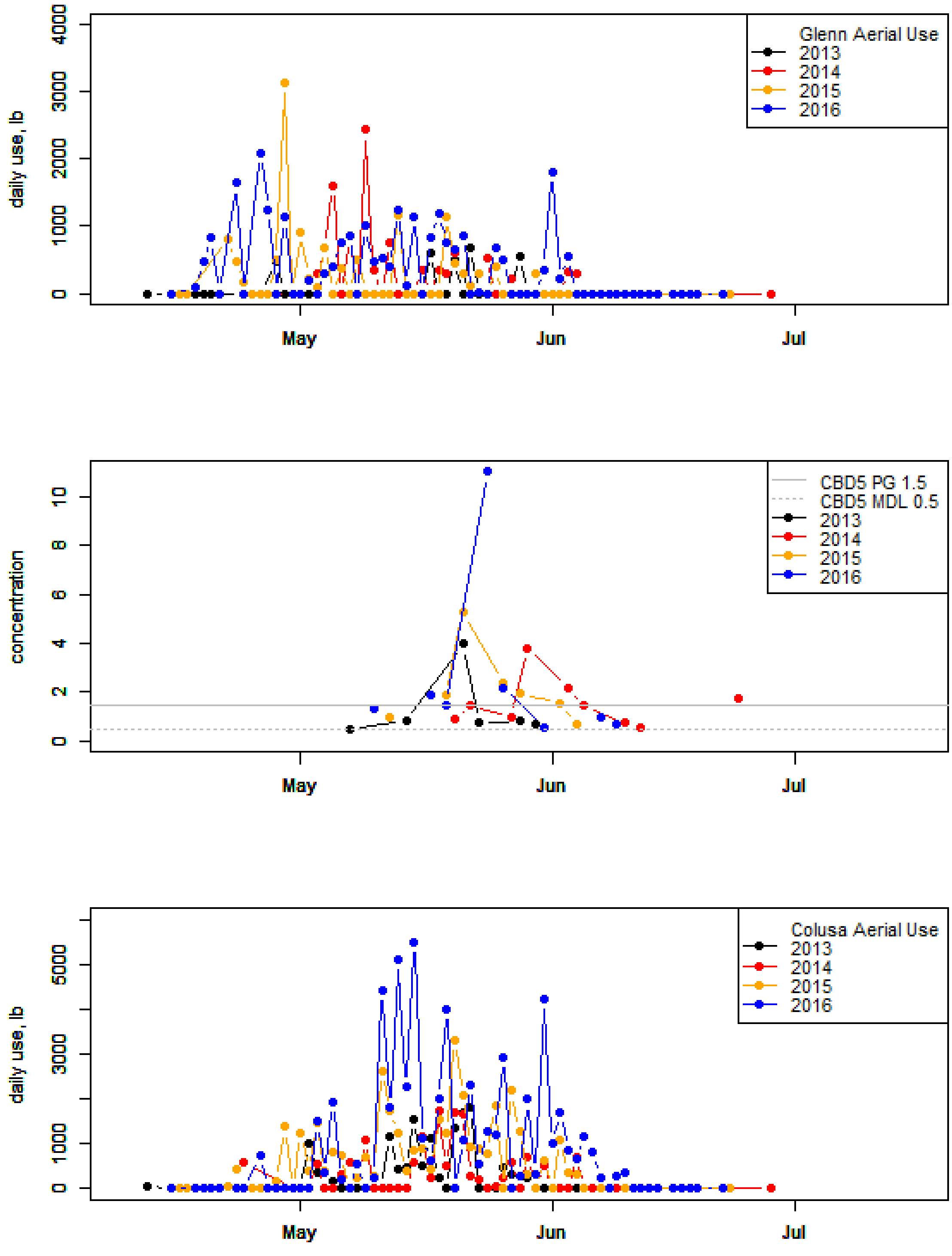


Figure 10 Comparison between Timing of Detections and Timing of Aerial Applications of Abolish 8EC. Detections at CBD5 vs applications in Glenn and Colusa counties; separate plots for individual years are shown in Appendix C

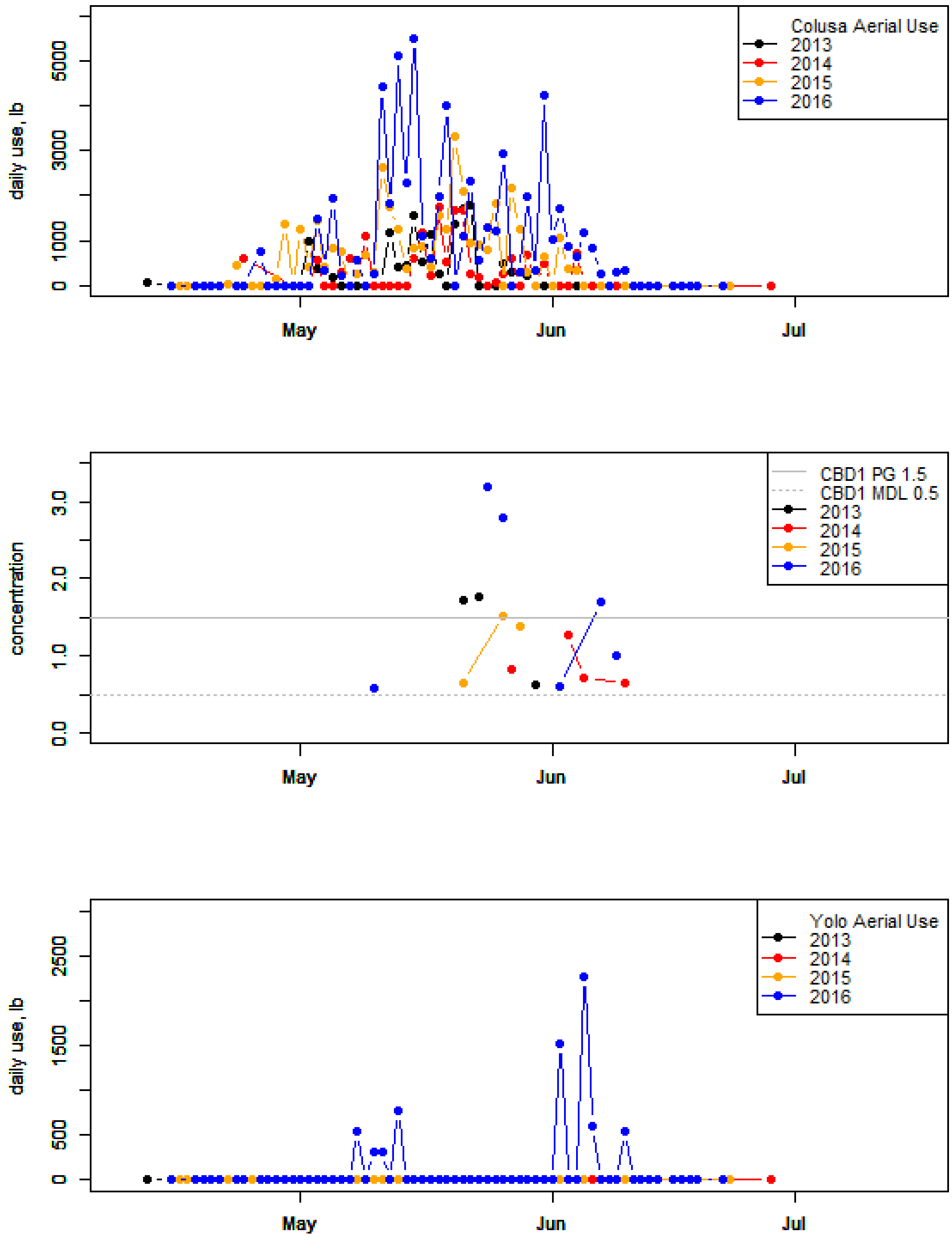


Figure 11 Comparison between Timing of Detections and Timing of Aerial Applications of Abolish 8 EC. Detections at CBD1 vs applications in Colusa and Yolo counties; separate plots for individual years are shown in Appendix C.

With the above information, we suspect that process #3 may be the dominant route for surface water contamination at CBD5 but we cannot completely exclude contributions from processes #1 and #2.

Summary

The existence of collinearity complicates the interpretation of the results. Firstly, the statistics show that usage data can explain a significant amount of variance in the exceedance frequencies (especially usage in Glenn County for CBD5, and total usage in Colusa County and Yolo counties for CBD1).

Secondly, the impact of drought, as indicated by flowrate at CDR, is significant at CBD5 but not clear at CBD1. One reason could be that CDR is much closer to CBD5 and its flowrate is significantly influenced by the flow from CBD5 during thiobencarb monitoring season. CBD1, on the other hand, seems to receive more drainage from fields closer to that site (personal communication, Roberta Firoved, CRC) but not from the CBD5. Therefore, the water management practice and the amount of water released upstream of the monitoring sites have a higher explanatory power than an overall drought indicator of the entire Sacramento Valley. We observed that the thiobencarb concentrations at drainage site BS1 did not exceed the performance goal while the uses in Butte/Sutter counties were comparable to the uses in Glenn and Colusa counties (results not shown). This could be a result of different water management in Butte/Sutter counties. A comparison on the water management practices may help identify why the thiobencarb concentrations were so high at CBD5 and CBD1.

Thirdly, the statistics cannot differentiate the impact of emulsifiable concentrate products and granular products on exceedance frequencies. The usages of the two categories of products in Glenn County and Colusa counties are highly correlated. Although their usages in Yolo County are not highly correlated, the statistics still cannot differentiate their impact because the usage of emulsifiable concentrate products is minimal compare to that of the granular products.

Fourthly, we investigated the three potential contamination routes (releasing of holding water, drift, seepage or overflow) through comparison on the timing of application versus detection at sampling sites. There is a 1-3 weeks of delay between the rising of applications and the detection of thiobencarb in the drainage sites. Detailed information on the hydrology in the water ways is needed before we can discern if the delay is mainly caused by water holding time in the fields or water travel time from the fields to the sampling sites. The delay caused by route #1 will be the sum of the two while the delay caused by route #2 and 3 will just be the water travel time. If holding water released from the fields is the major route, the impact of the two categories of products needed to be investigated by sampling the tail water at the fields according to their different water holding time. Note that the required water holding time is about 14–30 days for the granular products and 14–19 days for the dominant emulsifiable concentrate product Abolish 8 EC Rice Herbicide (Newhart and Singhasemanon, 2015). We found limited information on field dissipation characteristics of these products: the tail water concentration for Bolero 10G after 30 days water holding time may range from 4.8-38 ppb; for Abolish 8 EC is 6-13.9 ppb, for Bolero 8 EC may be as low as 1.2 ppb. The predominant products used in the recent years are Bolero 15G/Bolero 15G Ultramax and Abolish 8 EC. More field dissipation studies are needed to estimate the relative contribution of these two categories of products. If drift or seepage/overflow is the major routes, grounding of aerial application may be helpful. However, this may be difficult to implement considering that the majority of the applications were aerial applications and almost all the fields are within 30 feet distance from waterways.

Reference:

CH2MHill, 2016. 2016 Rice Pesticides Program Monitoring Summary, Report for the California Rice Commission

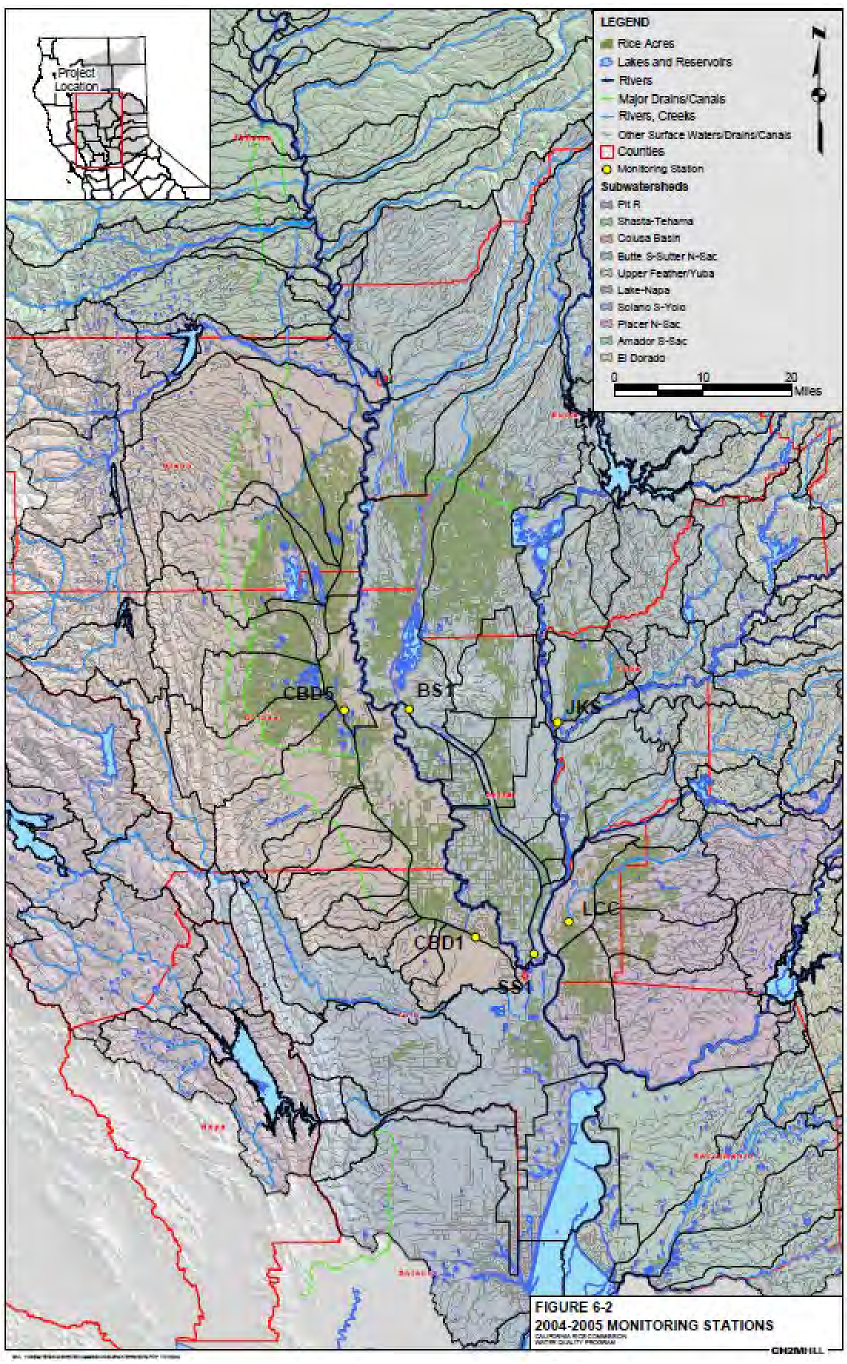
CRC, 2004. Basis for Water Quality Monitoring Program: Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands for Rice (CWFR).

Newhart, KayLynn. and Singhasemanon, N., 2015. Surface water evaluation report for Bolero Ultramax, (active ingredient: Thiobencarb), Tracking ID 272069. California Department of Pesticide Regulation (http://em/localdocs/pubs/rr_revs/rr1539.pdf)

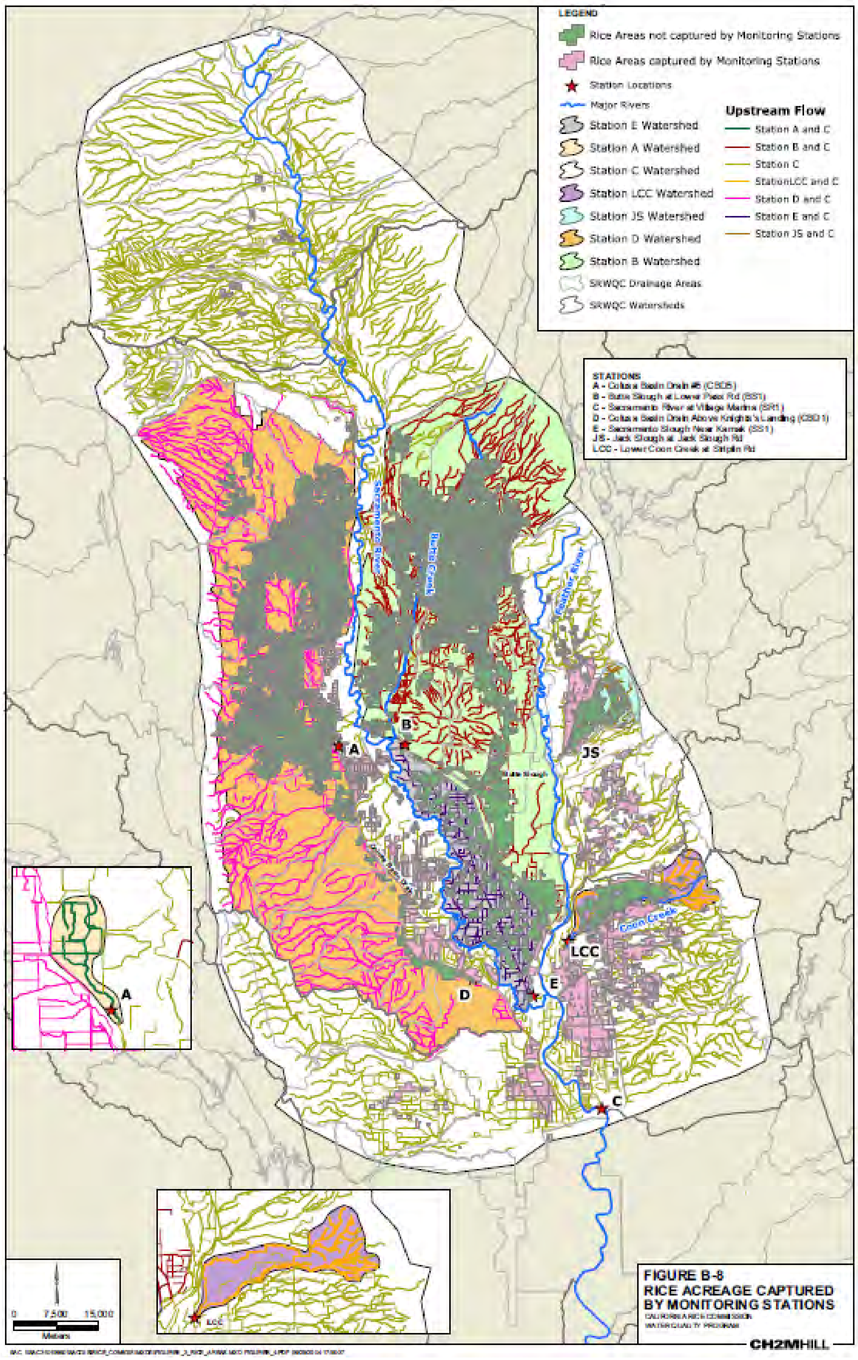
Appendix A: Watersheds Contributing to Sites CBD5 and CBD1.

The watershed drainage assessment the CRC completed for the Irrigated Lands Regulatory Program in 2004 (CRC, 2004) included the following two maps, which showed that site CBD5 received drainage water from Glenn and Colusa County while site CBD1 received drainage water from Glenn, Colusa and Yolo County.

Map 1

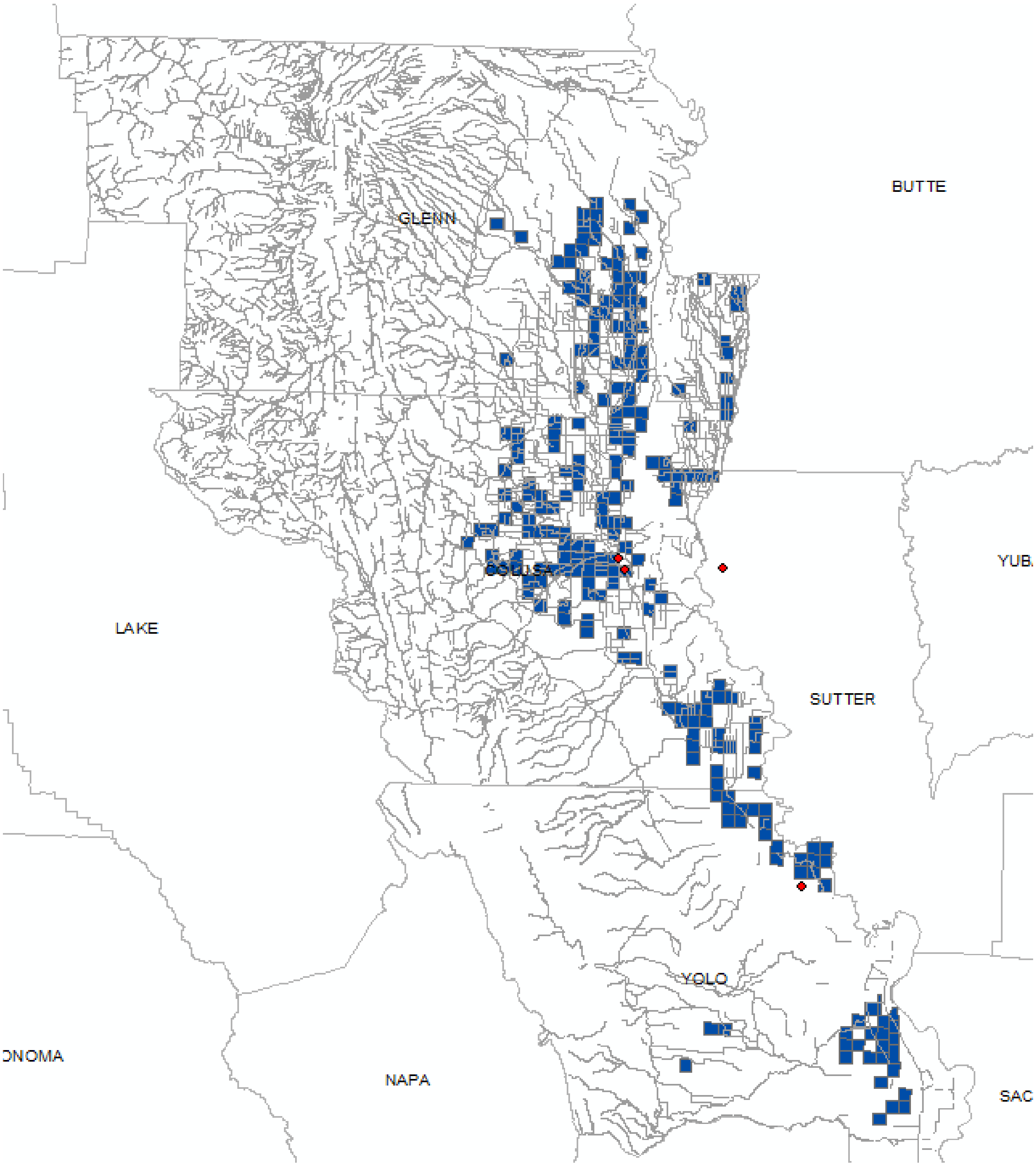


Map 2



Note: site codes used in Figure B-8 are A for CBD5, D for CBD1, B for BS1 and E for SS1.

Map 3 Waterway Map. (waterways as gray lines, rice fields as blue squares using 2013 application sites as example, and sampling sites as red diamonds in Glenn, Colusa, and Yolo counties.



Appendix B Comparison between Total Use Estimated from Application Acreage and Extracted from Preliminary PUR Data in the Three Counties in Years 2015 and 2016 (Pound/Year)

Year	County	Estimated	Preliminary PUR
2015	Colusa	175,608	175,920
	Glenn	114,688	116,474
	Yolo	30,618	34,674
2016	Colusa	231,636	230,049
	Glenn	125,760	129,238
	Yolo	57,927	56,477

Appendix C Comparison between Timing of Detections and Timing of Applications

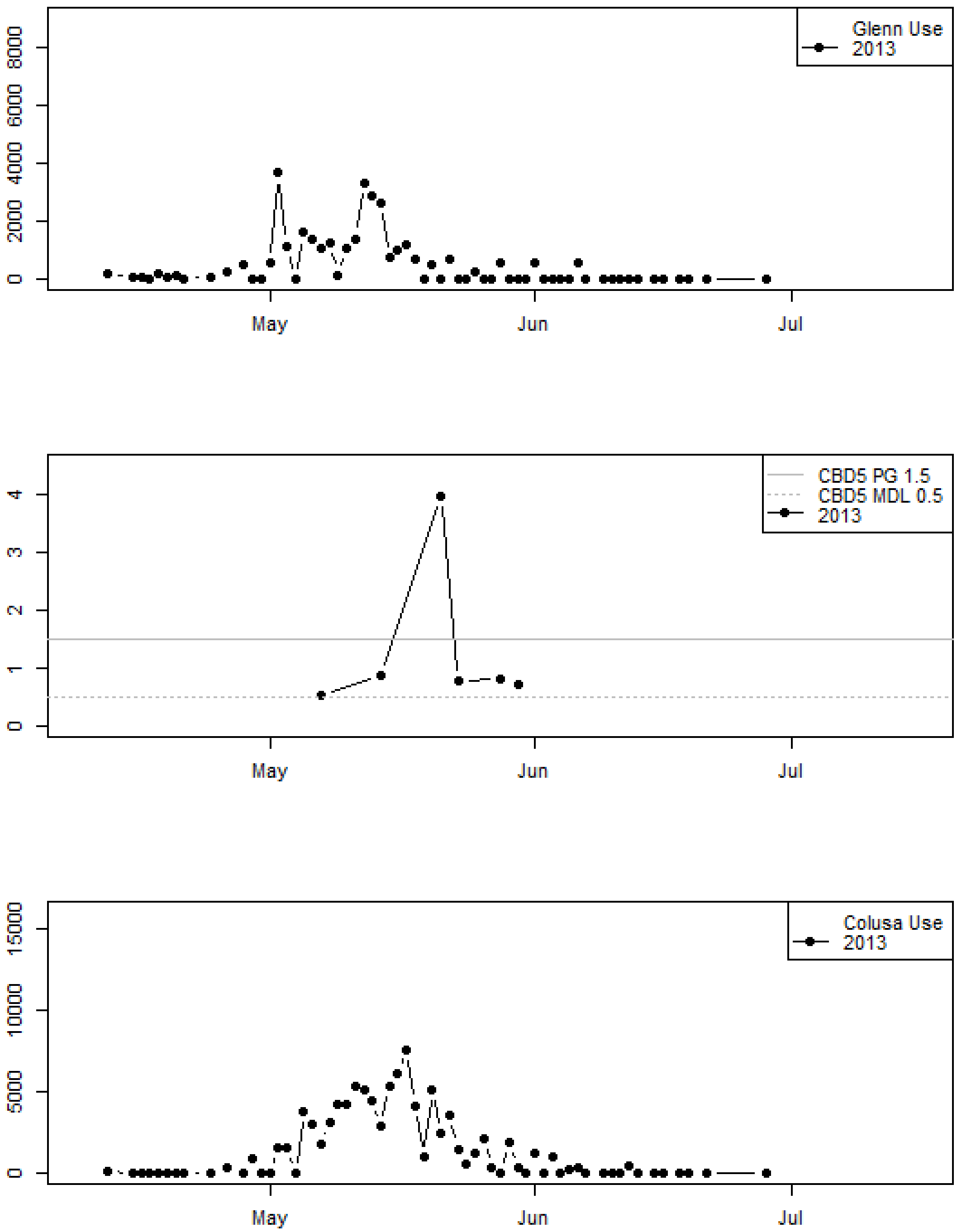


Figure B-1 Detection at CBD5 vs Applications in Glenn and Colusa counties, Year 2013

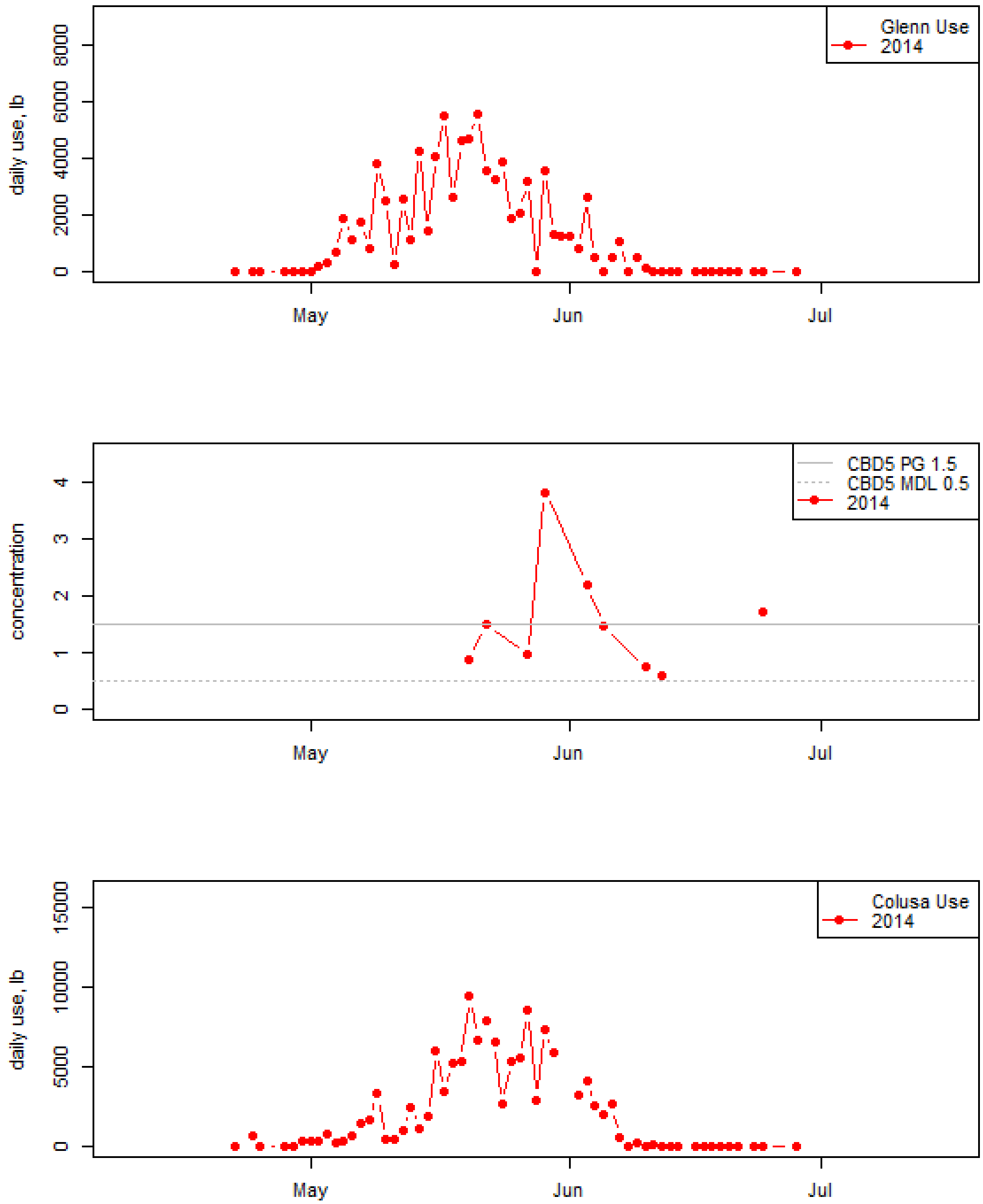


Figure B-2 Detection at CBD5 vs Applications in Glenn and Colusa counties, Year 2014

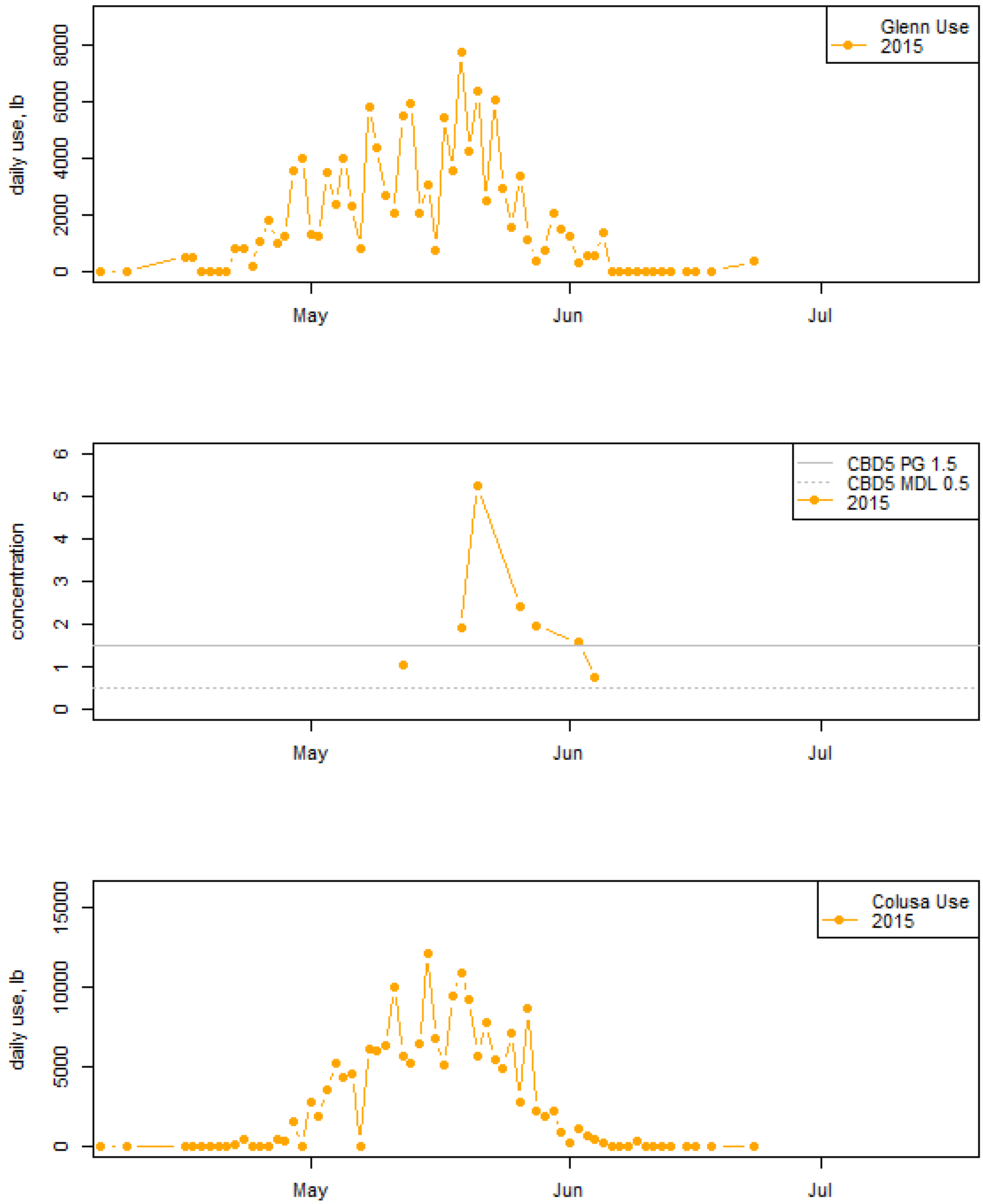


Figure B-3 Detection at CBD5 vs Applications in Glenn and Colusa counties, Year 2015

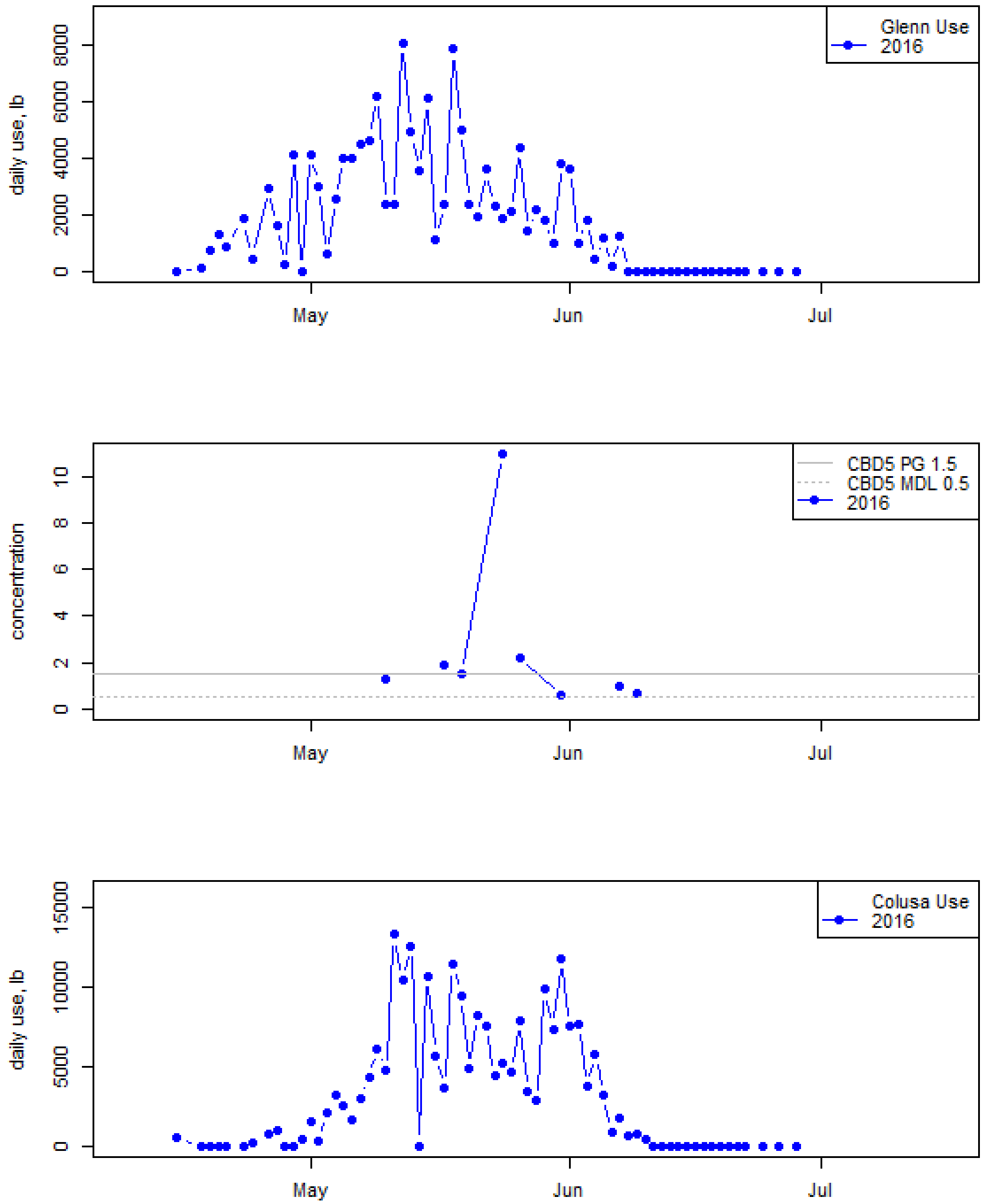


Figure B-4 Detection at CBD5 vs Applications in Glenn and Colusa counties, Year 2016

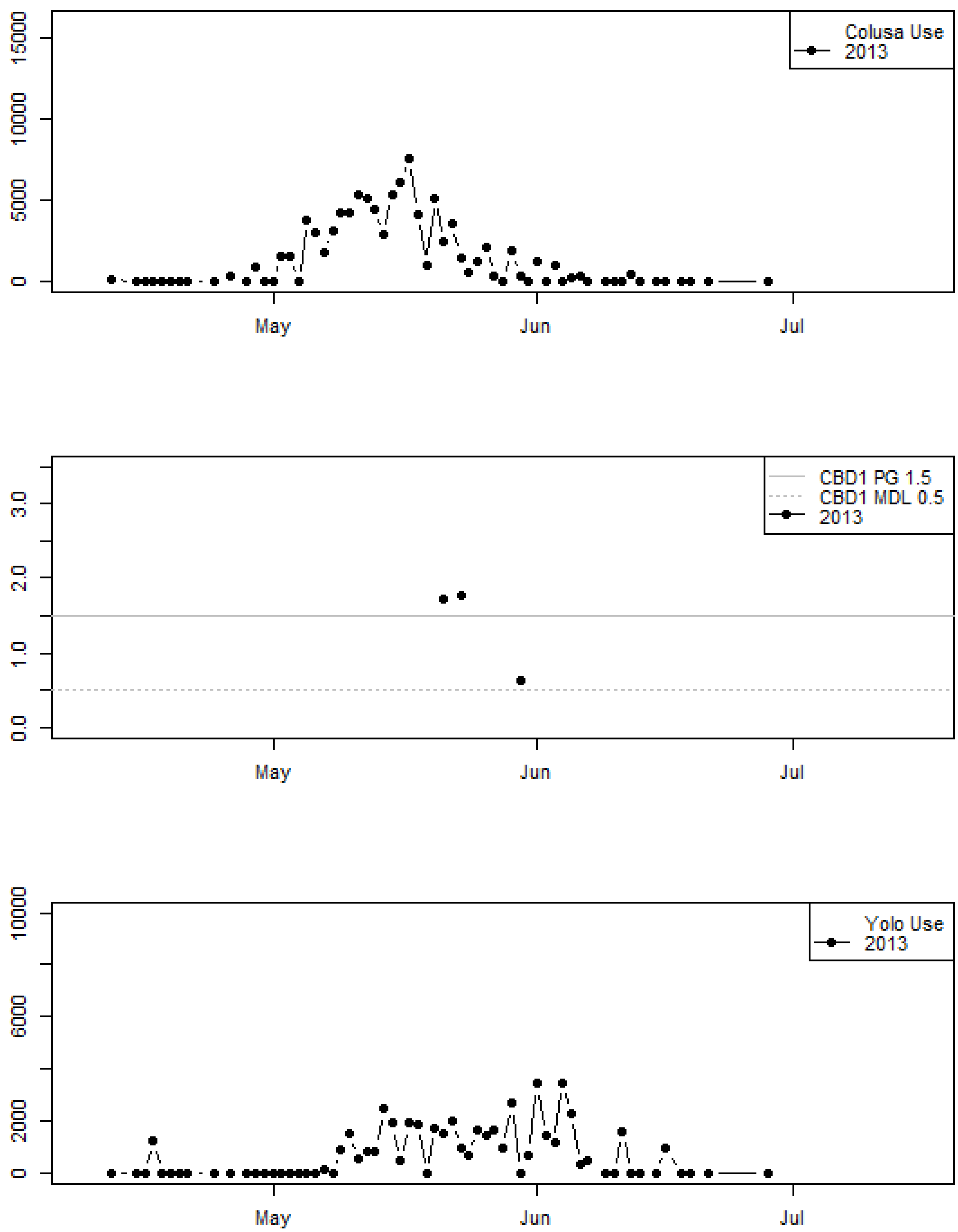


Figure B-5 Detection at CBD1 vs Applications in Colusa and Yolo counties, Year 2013

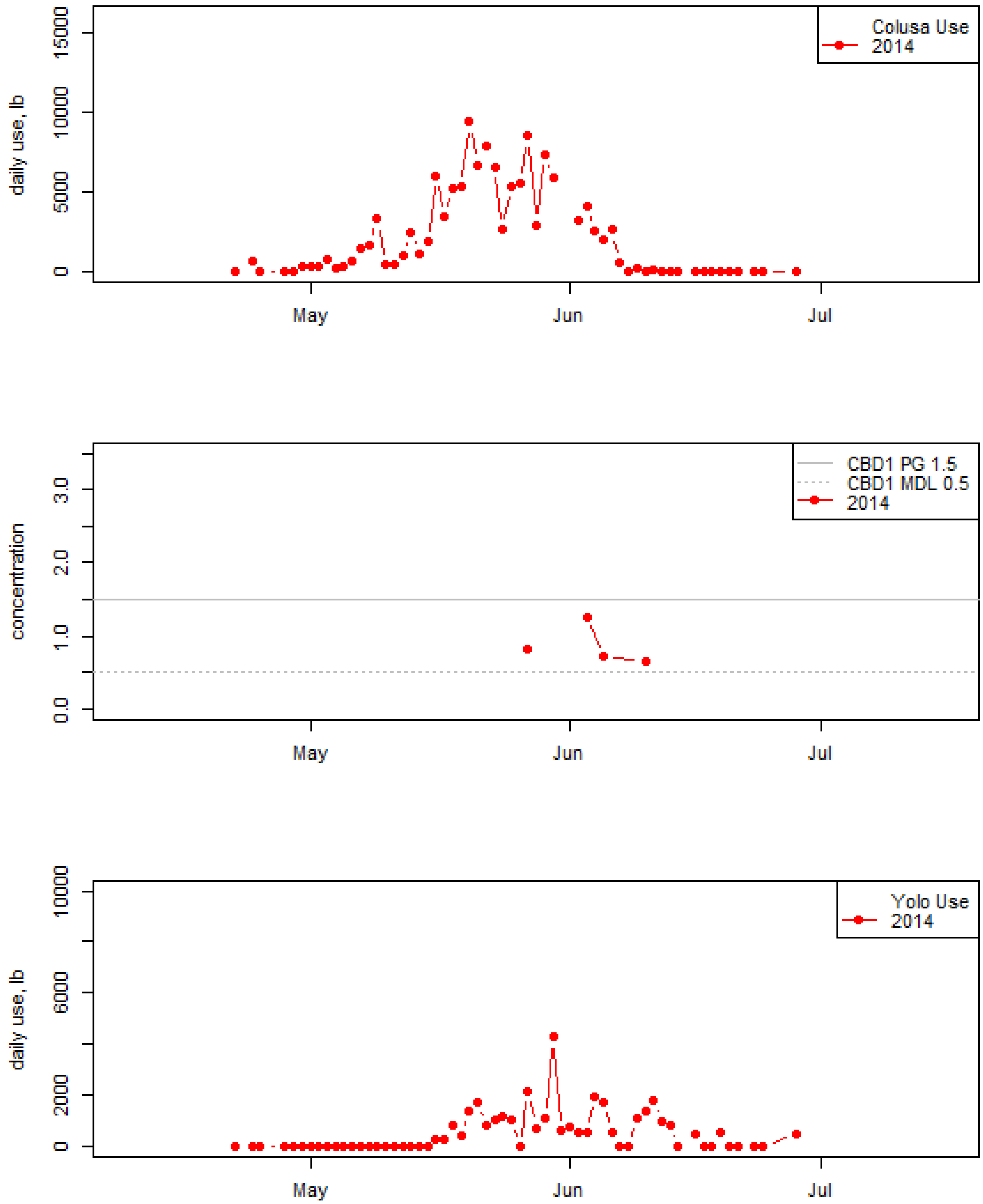


Figure B-6 Detection at CBD1 vs Applications in Colusa and Yolo counties, Year 2014

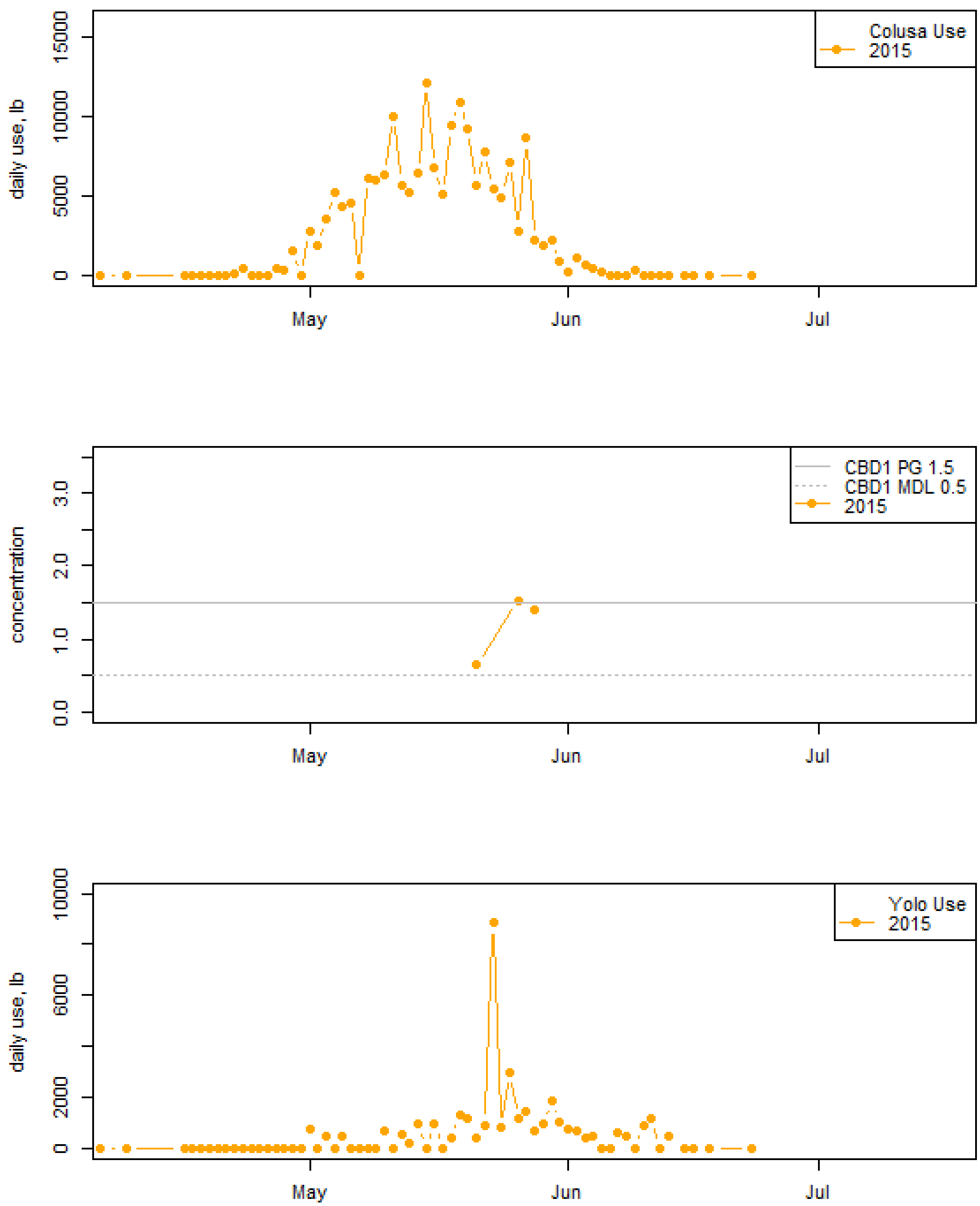


Figure B-7 Detection at CBD1 vs Applications in Colusa and Yolo counties, Year 2015

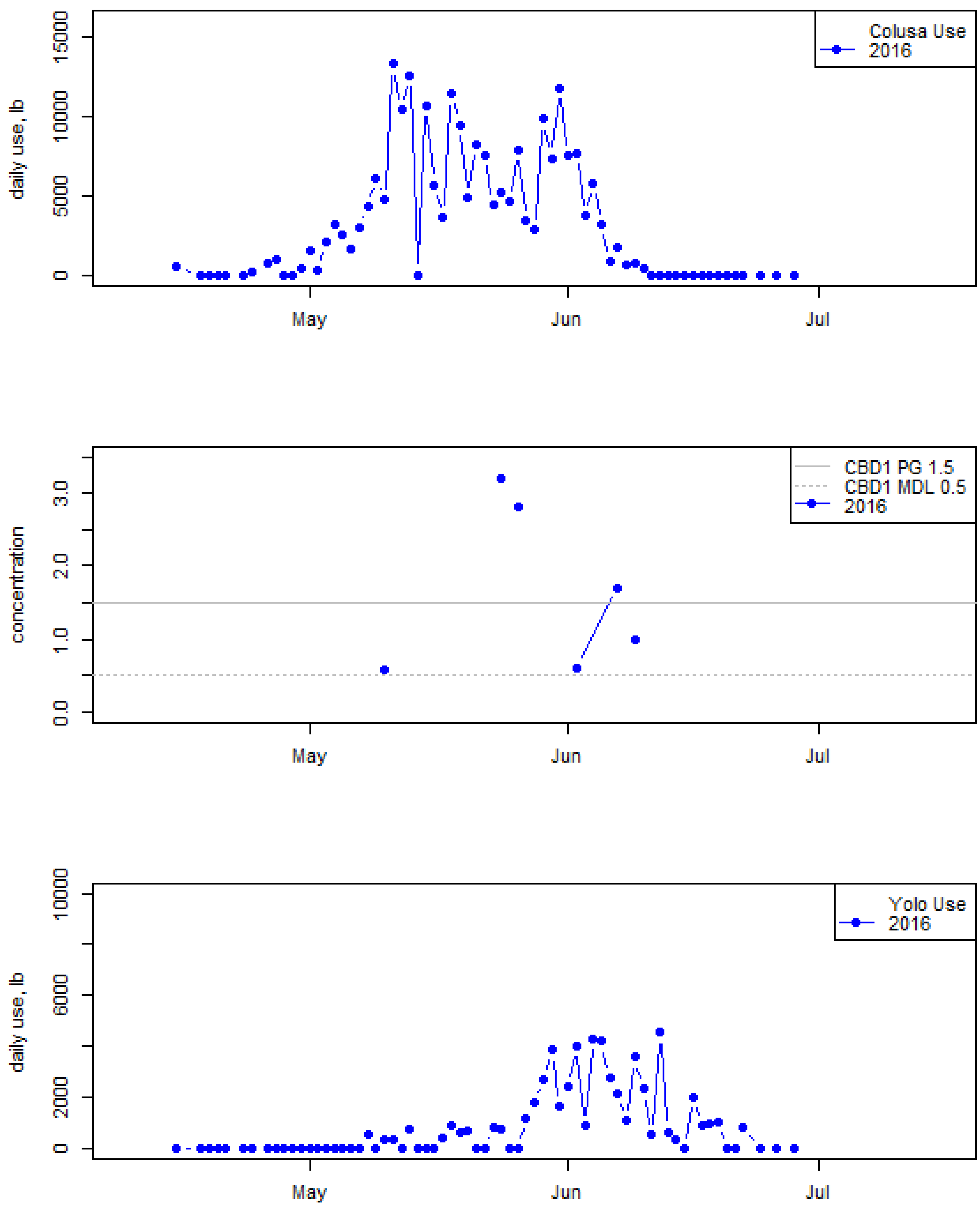


Figure B-8 Detection at CBD1 vs Applications in Colusa and Yolo counties, Year 2016

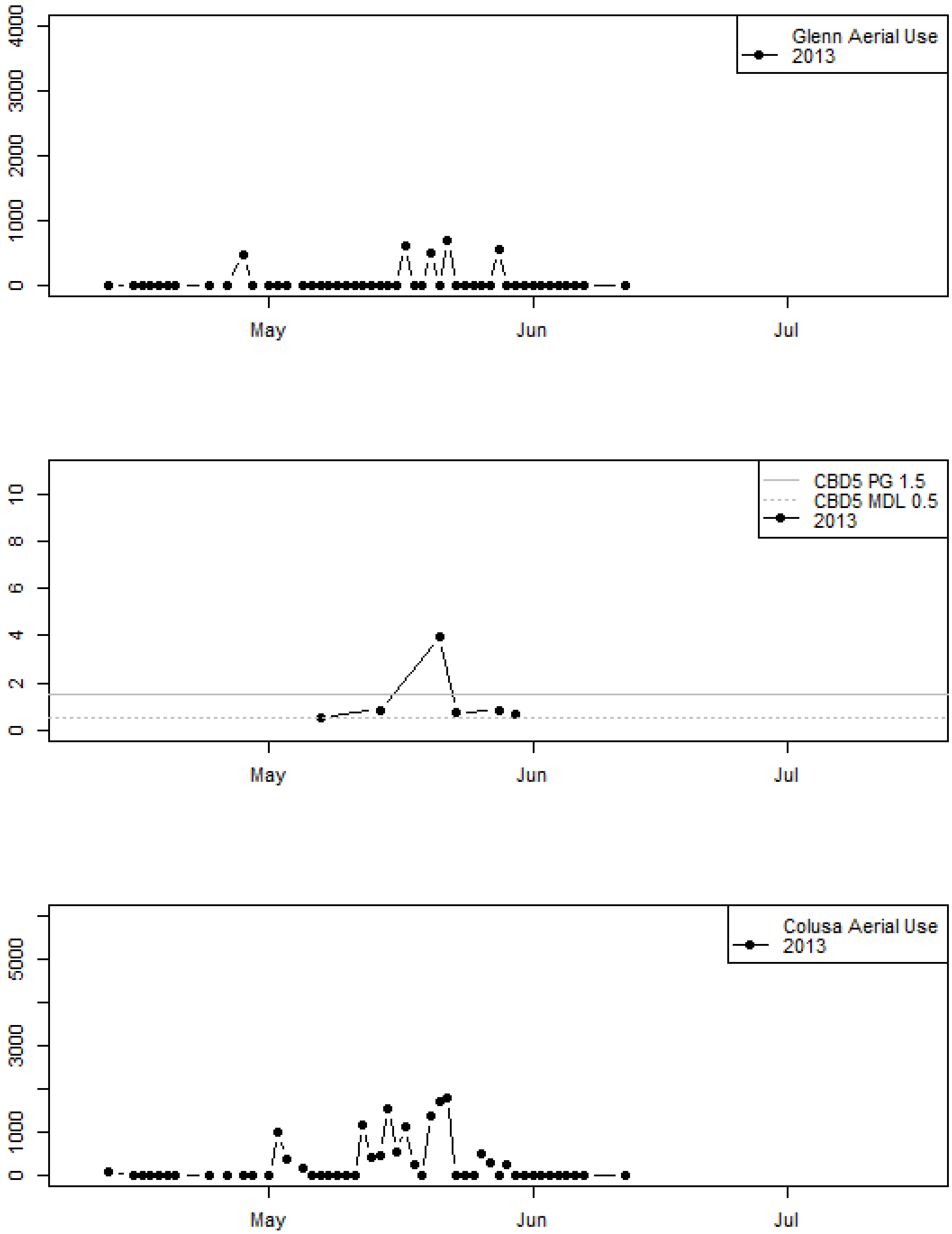


Figure B-9 Detection at CBD5 vs Aerial Applications of Abolish EC in Glenn and Colusa counties, Year 2013

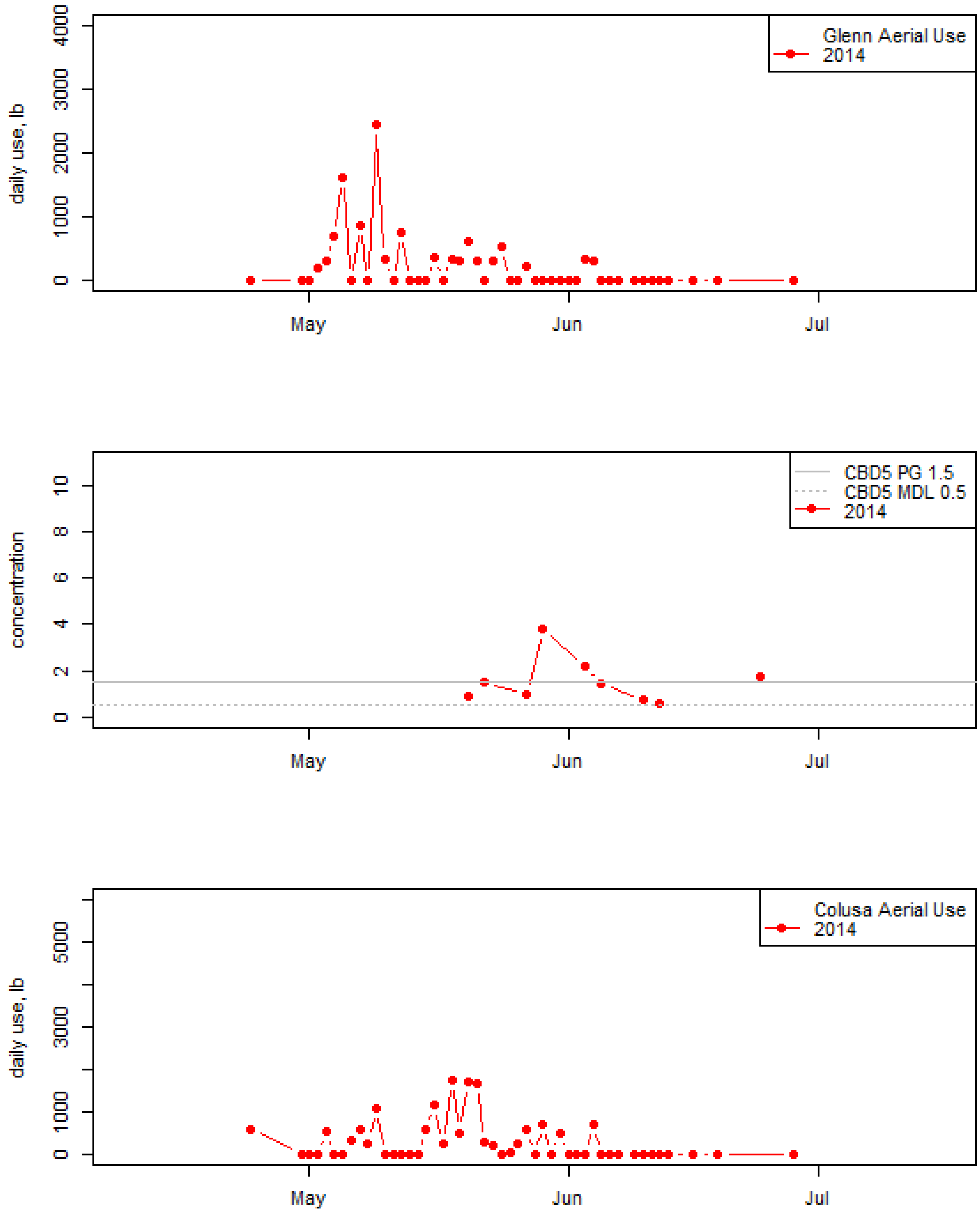


Figure B-10 Detection at CBD5 vs Aerial Applications of Abolish EC in Glenn and Colusa counties, Year 2014

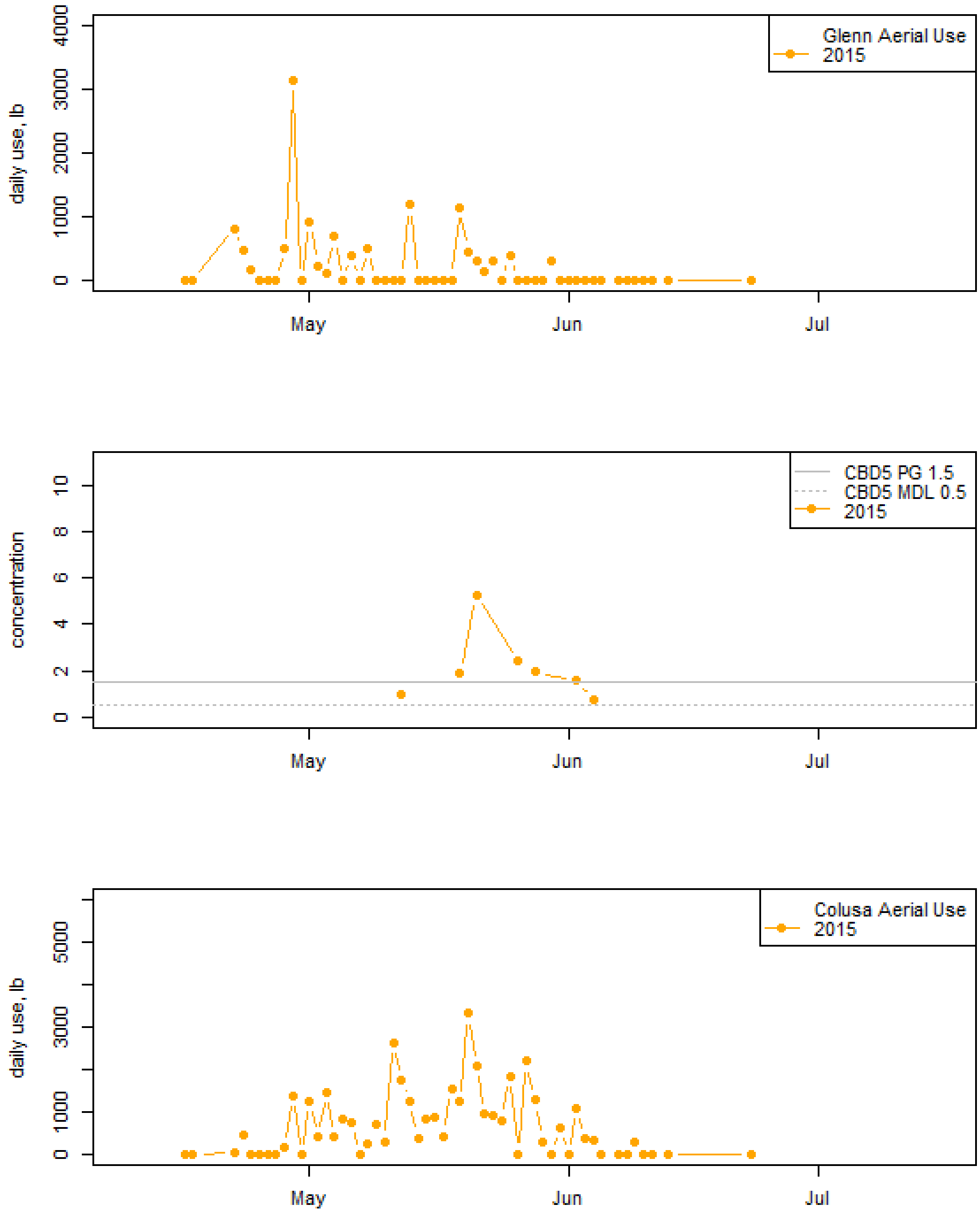


Figure B-11 Detection at CBD5 vs Aerial Applications of Abolish EC in Glenn and Colusa counties, Year 2015

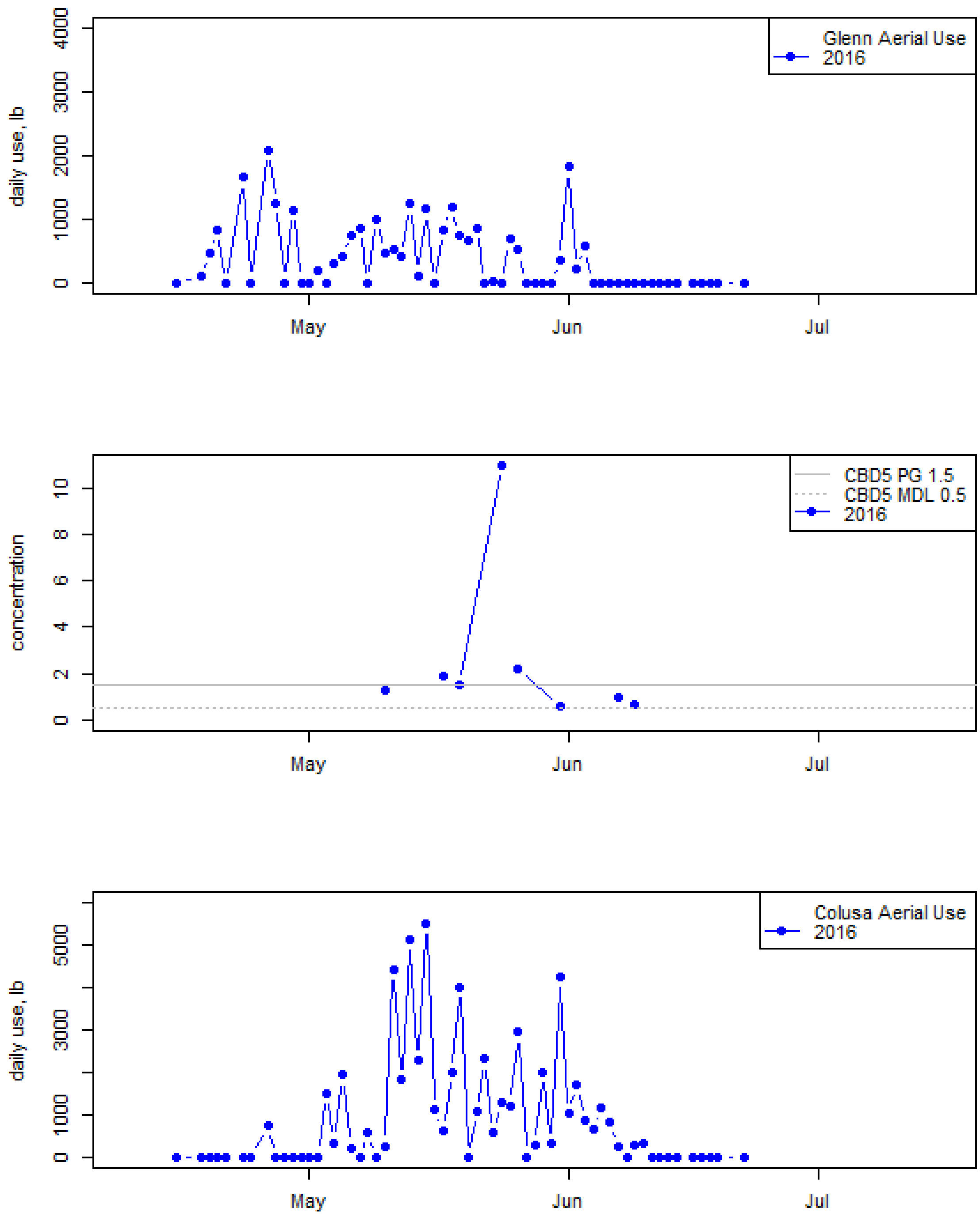


Figure B-12 Detection at CBD5 vs Aerial Applications of Abolish EC in Glenn and Colusa counties, Year 2016

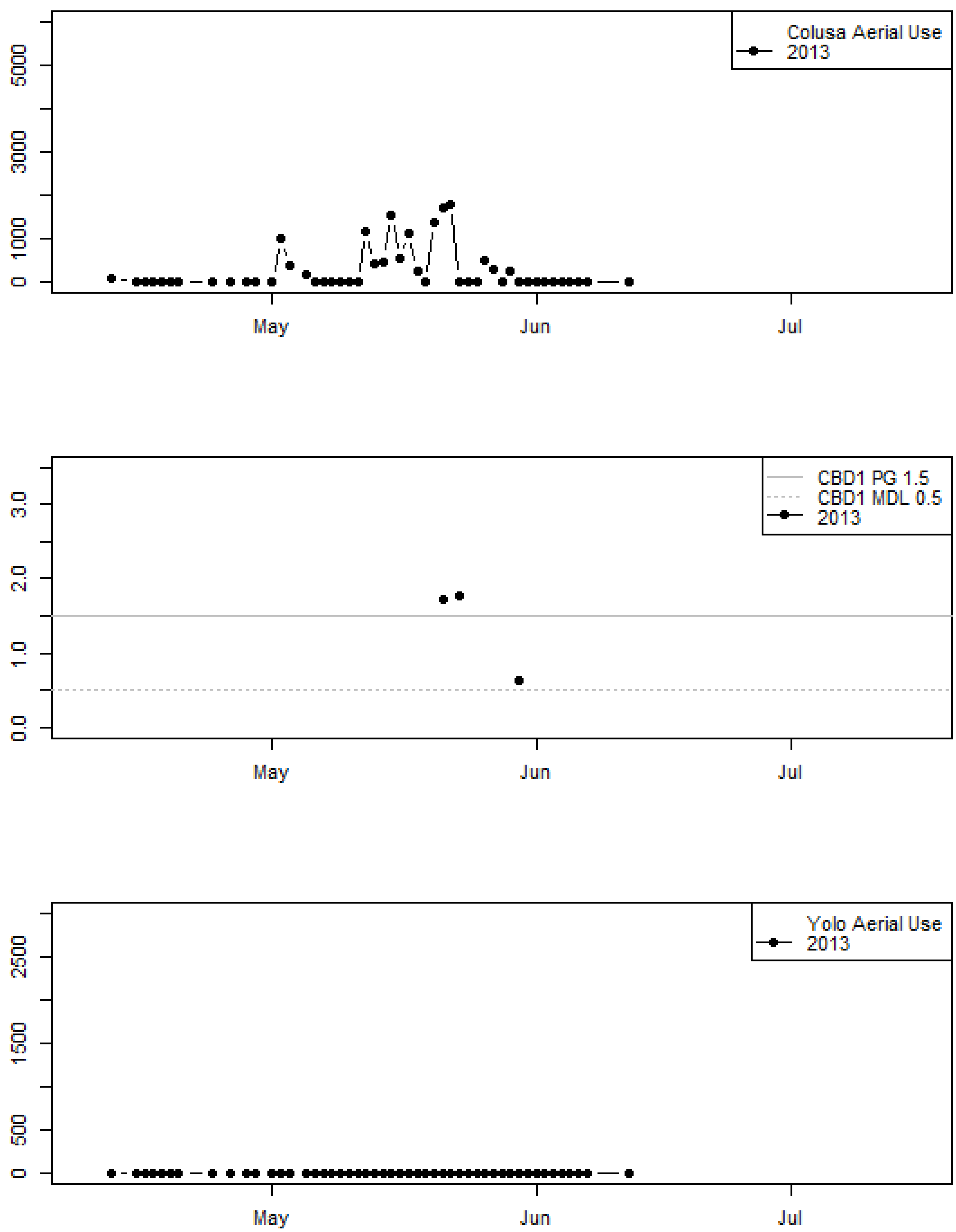


Figure B-13 Detection at CBD1 vs Aerial Applications of Abolish EC in Colusa and Yolo counties, Year 2013

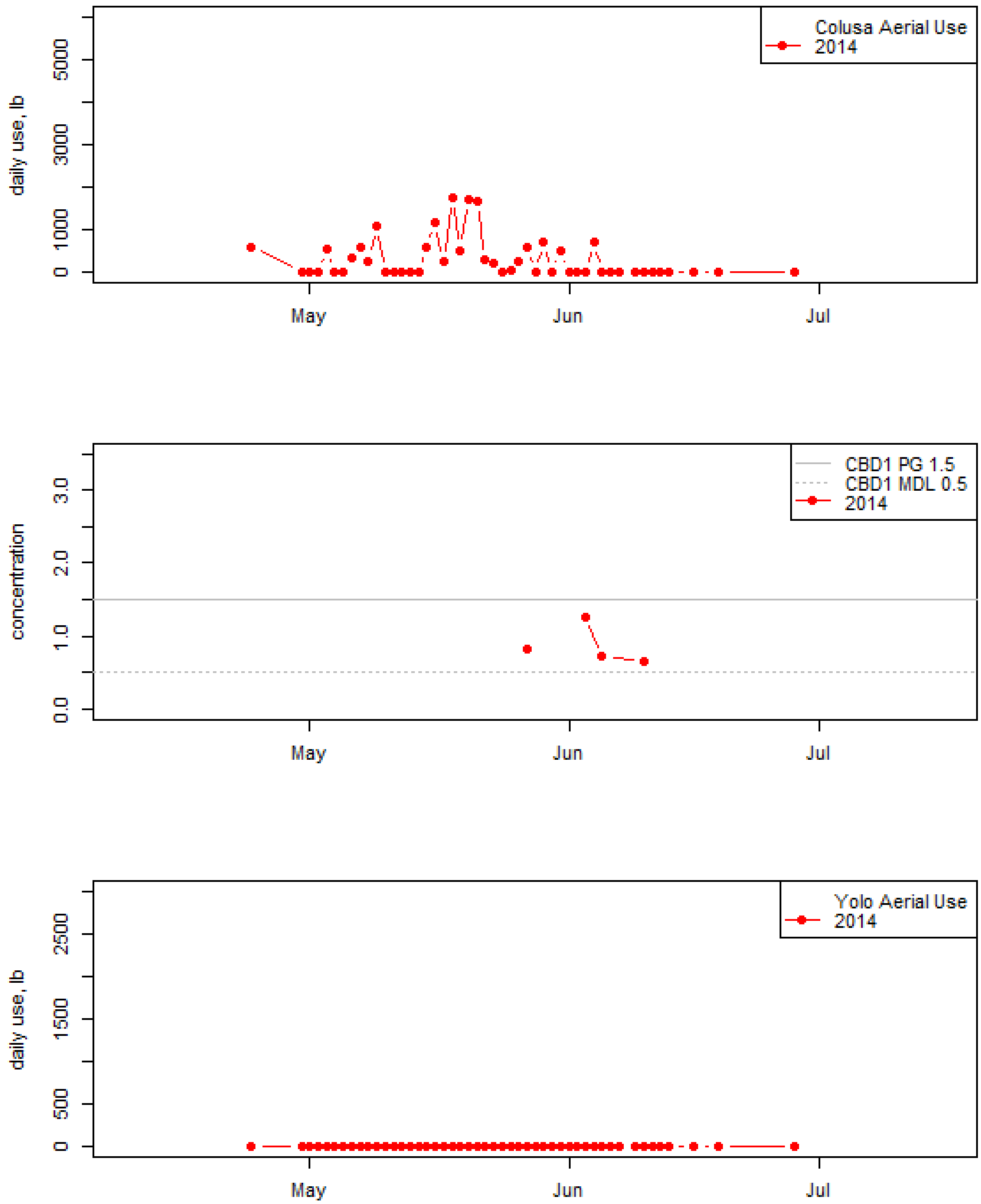


Figure B-14 Detection at CBD1 vs Aerial Applications of Abolish EC in Colusa and Yolo counties, Year 2014

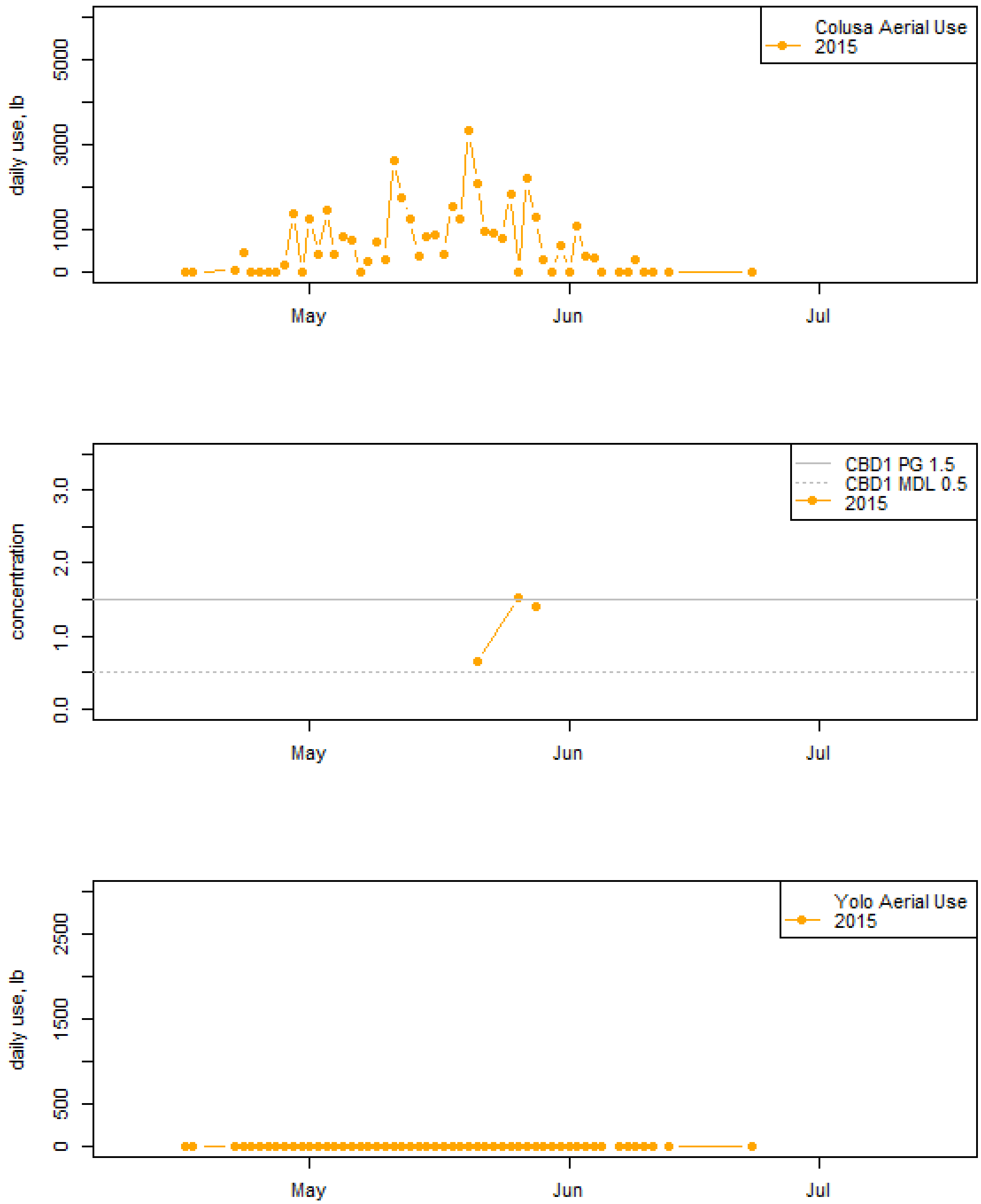


Figure B-15 Detection at CBD1 vs Aerial Applications of Abolish EC in Colusa and Yolo counties, Year 2015

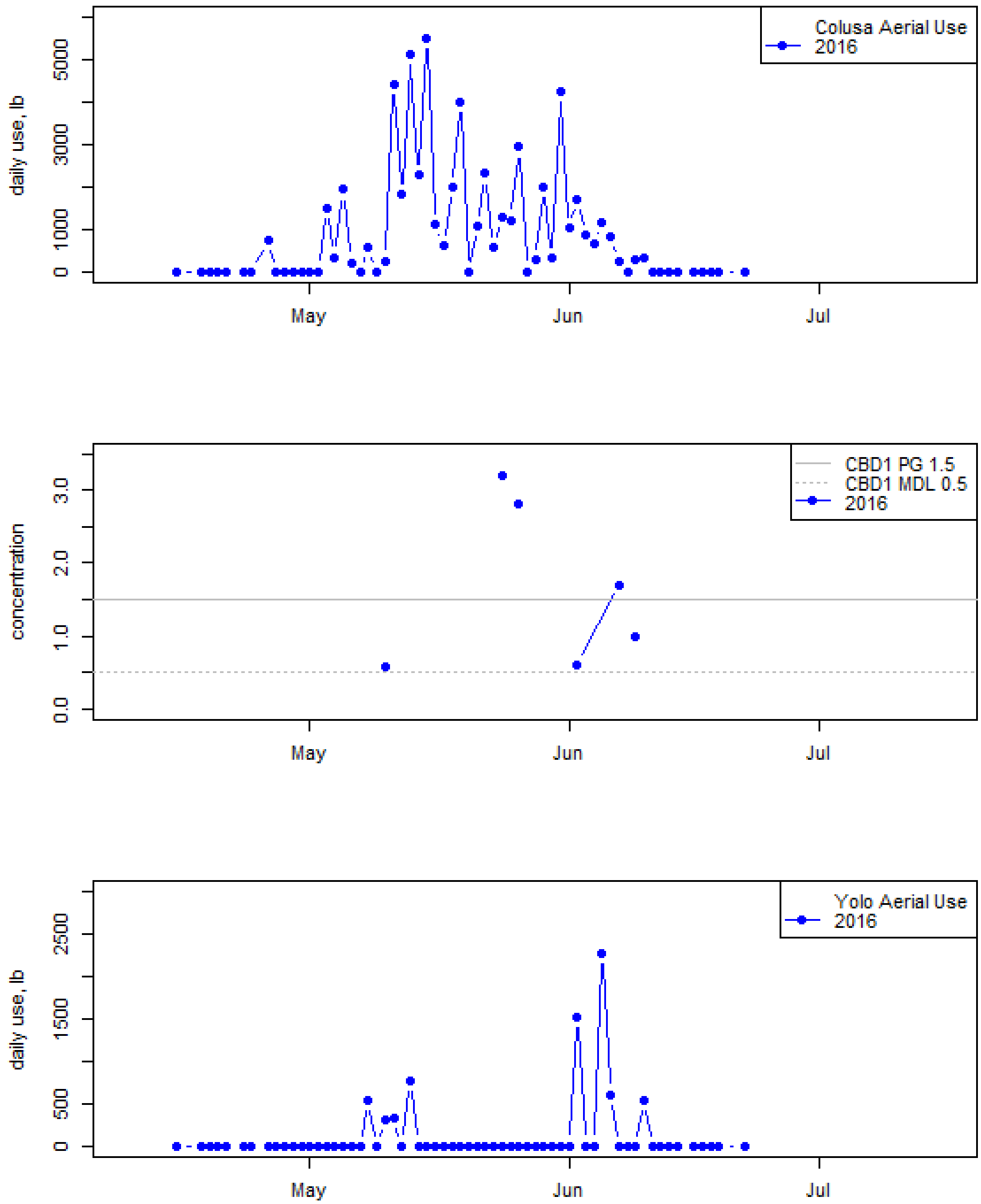


Figure B-16 Detection at CBD1 vs Aerial Applications of Abolish EC in Colusa and Yolo counties, Year 2016