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OPERATIONAL NOTE

PUBLIC HEALTH PESTICIDE USE IN CALIFORNIA: A COMPARATIVE SUMMARY

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ABSTRACT. California pesticide use summary data and use reports from local vector control agencies were reviewed to document public health pesticide use patterns. During the 15-year period 1993–2007, public health pesticide use averaged 1.75 million lb (0.79 million kg) (AI), accounted for <1% of reportable pesticide use statewide, and ranked below major crop uses and many nonagricultural uses. A review of reports from local vector control agencies (2004–07) indicated that their applications were principally for mosquito control and represented >99% of all reported public health pesticide use. Petroleum distillates, principally larviciding oils, accounted for 88% of public health pesticide use. Pyrethrins and naled, used as mosquito adulticides, increased substantially in recent years (post-2004), coinciding with increased West Nile virus control activities and availability of emergency funding.

KEY WORDS Pesticide use, adulticide, larvicide, mosquito control, active ingredient

Vector control in California is conducted by >70 special districts or other local government agencies. These agencies encompass about 70,000 mi^2 (181,000 km^2)—almost half the land area of the state—and provide services to >85% of Californians (California Department of Public Health [CDPH] 2008). The vector control programs vary in size (1 to >17,000 mi^2) (2.6 to >44,000 km^2), budget (no dedicated funds to >$11,000,000), and capabilities; many focus solely on mosquito control, whereas others include the surveillance and control of ticks and other vectors.

The sale and use of pesticides in California is regulated by the Department of Pesticide Regulation (CDPR) and County Agricultural Commissioners (CAC). The application of pesticides by vector control agencies is regulated by a special agreement between CDPR, CAC, and CDPH. The CDPH has specific oversight responsibilities for the local vector control agencies, including pesticide applicator certification. The CDPH and the local government agencies maintain Cooperative Agreements, which mandate specific requirements for safe handling and use of pesticides (Gerry et al. 2003). These Cooperative Agreements also mandate monthly summary reporting of pesticide applications to the CAC (reported under the Public Health category, Code 50). The CAC collate all these reports for their counties and forward them to CDPR.

Extensive pesticide use reporting in California began in 1990. Annual summaries are available from the CDPR Web site (CDPR 2009a). In addition to public health pesticides, all commercial applications to marketed agricultural commodities, pastures, rangelands, parks, golf courses, rights-of-way, and a variety of other sites must be reported. Prior to 1990, annual pesticide use for vector control was summarized by the Mosquito and Vector Control Association of California in collaboration with CDPH. Most, but not all, vector control agencies belong to this association. Vector control use patterns in California prior to the 1990s were previously summarized (Eldridge 1988).

Vector control operations in California have been significantly impacted by the introduction of West Nile virus (WNV) (Kramer et al. 2008). As WNV activity spread, local mosquito control programs were augmented with more than $21 million in emergency funding in 2005–07; approximately $9.4 million was used to purchase mosquito control pesticides (Kramer et al. 2008). Intensified WNV control efforts increased public scrutiny of pesticide use for mosquito control. More recently, increased regulatory oversight (e.g., National Pollution Discharge Elimination System permits) focused additional attention on vector control applications and has necessitated a comparative review of public health pesticide use.

The specific objectives of this pesticide use analysis include: 1) compare pesticide use for vector control with other reportable and nonreportable uses in California, 2) document pesticide use changes for mosquito control relative to WNV introduction (2004–07), 3) determine historical pesticide use trends by local vector control agencies, and 4) validate and improve CDPR data accuracy for public health pest control.

Vector control pesticide use data in this analysis were obtained from several sources, but ultimately originated from use summaries reported by local vector control programs. Total pesticide sales, including non-reportable uses, were used as a surrogate for total pesticide use in the state. Pesticide sales data are available from the CDPR Web site (CDPR 2008).

Data from 1963–65, 1973–75, 1983–85, and 1993–95 were used to document historical trends of vector control pesticide use. These data were obtained from annual yearbooks of the California Mosquito and Vector Control Association.

Summary data for reportable uses (public health, other sites, and total) from 1993 through 2007 were obtained from CDPR: Pesticide Use Annual Summaries (CDPR 2009a) and the CDPR California Pesticide Information Portal (CALPIP) (CDPR 2009b). Both sources are based on pesticide use reported by applicators via CAC, but data may differ because CALPIP data may be revised after Annual Summaries are published.

Vector control pesticide use data for 2004–07 were obtained either directly from local vector control agencies or from the CDPR database. Vector control data for this period that were taken from the CDPR database were sent to individual agencies for verification and correction as needed. Corrected data were used in this analysis, with copies forwarded to CDPR.

Pesticide use in this review was summarized in pounds of AI applied, unless otherwise noted. Relying on any single measure of pesticide use has limitations. In this case, using pounds of AI as an indicator of pesticide use may be misleading with respect to the amount of pesticide formulation applied, area treated, and relative toxicity when comparing pesticides.

Despite some limitations, the pesticide reporting system in California provides valuable access to extensive data. While every state requires commercial pesticide applicators to maintain pesticide application records, California is 1 of only 8 states that require extensive reporting (CDPH, unpublished data).

For the 15-year period 1993–2007, total pesticide sales in California averaged 637 million lb (289 million kg), ranging from 543 million lb (246 million kg) in 1995 to 743 million lb (337 million kg) in 2006. During the same period, reported pesticide use averaged 188 million lb annually (85 million kg), ranging from 151 million lb (68 million kg) in 2001 to 215 million lb (98 million kg) in 1998. Approximately two-thirds of annual pesticide use was not subject to reporting; significant unreported uses include home-use pesticide products and chlorine, used primarily for municipal water treatment (CDPR 2008).

Public health pesticide applications from 1993 to 2007 averaged 1.8 million lb (0.8 million kg) annually, ranging from 1.1 to 3.2 million lb (0.5 to 1.4 million kg) in 2002 and 1993, respectively. (The CDPR Annual Report Summaries for 2006 reflect reporting errors for petroleum distillates for 2 vector control agencies, totaling 2.4 million lb. These errors have been corrected in the CDPR CALPIP searchable database.) This average use for the Public Health category represents <1% of annual reportable pesticide use and ~0.3% of total estimated pesticide use statewide.

For comparison, sites with the highest annual reported pesticide use in California are agricultural commodities. During the 5-year period, 2003–07, the top 5 commodities for pesticide use were wine grapes, grapes, almonds, tomatoes for processing, and oranges, all averaging >10 million lb (4.5 million kg) annually. Nonagricultural sites averaged <5 million lb (2.3 million kg) annually. The nonagricultural sites that ranked highest in reportable pesticide use were structural (average rank 10th), rights of way (13th), and landscape maintenance (22nd). Public health use (Code 50, which includes vector control) ranked 25th.

Based on a review of corrected 2006 and 2007 data, <1% of reported public health pesticide use could not be attributed to a vector control agency or a commercial applicator applying pesticide under contract for a vector control agency.

During this same period, ~98% of reported public health pesticide use was for mosquito control (an exact percentage was difficult to determine because a few broad-spectrum insecticides could be used for multiple target species). Herbicides, used primarily to facilitate vector control (e.g., access to aquatic habitats and control of emergent vegetation) accounted for the majority of the remaining public health use.

Vector control applications made up a small percentage of the total use of some AIs such as permethrin and malathion (Table 1). For other AIs, such as pyrethrins and piperonyl butoxide (PBO), vector control applications constituted a significant percentage of reported use. Active ingredients with specificity for mosquitoes, such as *Bacillus thuringiensis* var. *israelensis* de Barjac (*Bti*) and *B. sphaericus* Neide (*Bs*), were used almost exclusively by vector control agencies.

During 2004–07, virtually all (>98%) public health pesticide use consisted of 15 insecticides (Table 2). Five of the top 10 AIs, and 93% by AI weight, were larvicides. Petroleum distillates (primarily mosquito larviciding oils) accounted for an average of 88% of public health pesticide use, by weight. Excluding these oils, more *Bti* was applied than all other larvicides combined. More PBO, a synergist, was applied than any other adulticide AI. Naled, pyrethrins, and malathion, applied for adult mosquito control, were used more than any pyrethroid insecticide.

As previously noted, reporting pesticide use in pounds of AI applied has limitations and may be misleading when comparing pesticides. The cur-

Table 1. Selected vector control pesticide use in comparison to all reported pesticide uses in California, 2007.

Pesticide (AI)	Public health use (lb) (kg)	All use (lb) (kg)	% public health
Bacillus sphaericus	17,638 (8,017)	17,640 (8,018)	>99.9
Bacillus thuringiensis var. *israelensis*	55,930 (25,466)	56,026 (25,466)	99.0
Sumithrin (phenothrin)	543 (247)	587 (267)	93.0
Piperonyl butoxide	70,429 (32,013)	97,499 (44,318)	72.0
Pyrethrins	9,200 (4,182)	17,357 (7,990)	50.0
Resmethrin	210 (95)	470 (214)	45.0
Petroleum distillates	1,117,490 (507,950)	2,755,294 (1,252,400)	40.0
Naled	42,349 (19,250)	132,900 (60,409)	32.0
Malathion	2,100 (955)	470,195 (213,725)	0.5
Permethrin	876 (398)	413,837 (188,108)	0.2
All public health	1,490,000 (677,273)	172,000,000 (78,181,800) (reported use)	0.9

rent Cooperative Agreement between CDPH and local agencies requires reporting the number of pesticide applications for each product but not the acreage treated, thus making use estimations based on area difficult. However, by using maximum label rates to estimate acreage treated (Table 2), it is evident that some AIs are much more widely applied despite much lower reported use by weight. Larviciding oils and methoprene provide a dramatic example: An average of 1,476,800 lb (669,900 kg) of larviciding oils and 4,300 lb (1,950 kg) of methoprene were applied annually between 2004 and 2007. If applied at the maximum legal application rates, ~41,000 acres (16,600 ha) would have been treated with oil compared to ~320,000 acres (130,000 ha) with methoprene (assuming all was in a liquid formulation). Similarly, for adulticides used at maximum application rates, 1 lb of the AI permethrin would treat ~25 times the area as the same amount of naled.

Short-term changes in mosquito control pesticide use from 2004–07 were examined more closely, as this time period coincided with the spread of WNV throughout California. There was a substantial increase in reported use of pyrethrins (and PBO) during 2005–07, peaking at nearly 13,000 lb (6,000 kg) in 2006 as compared to ~3,000 lb (1,400 kg) reported in 2004. This increase was principally due to increased WNV activity, which triggered additional ground and aerial adulticiding, and also the availability of $15 million in emergency funding for enhanced control activities in 2005–06 (Kramer et al. 2008). Pyrethrins use declined in 2007 despite a statewide WNV emergency declaration and an additional $4.3 million allocated for enhanced control (Kramer et al. 2008), but annual pyrethrins use remained well above that in pre-WNV years.

Although organophosphate use remained relatively steady during 2004–07, there was a decrease

Table 2. Top 15 insecticides reported for public health use in California (2004–07).

Pesticide (AI)	Pounds (lb) of average annual use (kg)	Acres at max. rate (ha)
Petroleum distillates (larviciding oils)	1,476,800 (669,900)	41,022 (16,600)
Bacillus thuringiensis var. *israelensis* (*Bti*)	68,500 (31,100)	Up to 2,537,000[1] (1,026,700)
Piperonyl butoxide	67,700 (30,800)	NA[2]—varies with primary toxicant
Naled	27,500 (12,500)	163,000 (66,000)
Bacillus sphaericus	15,400 (7,000)	10,270 (4,200)
Pyrethrins	8,700 (4,000)	3,480,000 (1,408,300)
Malathion	5,600 (2,600)	24,350 (9,900)
Mono-molecular films	4,400 (2,000)	580 (235)
Methoprene	4,300 (1,950)	Up to 320,000[3] (129,500)
Permethrin	1,000 (460)	148,860 (60,200)
Temephos	800 (360)	1,600 (650)
Phenothrin	400 (180)	111,100 (45,000)
Resmethrin	300 (140)	42,860 (17,300)
Diflubenzuron	60 (27)	1,200 (490)
Cypermethrin	25 (11)	NA—barrier treatment product

[1] Maximum application rates (lb AI) for *Bti* products vary with formulation and manufacturer. See individual product labels for maximum (lb/acre) application rates.
[2] NA = not applicable.
[3] Maximum application rates (lb AI) for methoprene vary with formulation. See individual product labels for maximum (lb/acre) application rates.

in malathion use, from >9,000 lb (4,100 kg) in 2004 to ~2,000 lb (900 kg) in 2007. During a declared statewide WNV emergency in 2007, reported use of the adulticide naled almost doubled to 43,000 lb (19,500 kg), from an average use of 22,000 lb (10,000 kg) during 2004–06.

Regional differences in the use of mosquito adulticides were notable during this period. Based on corrected data from 2004–07, an average of 97% of the organophosphate (naled and malathion) use and 91% of the pyrethrins and pyrethroids use occurred in 18 counties located in the Central Valley of California (extending from Kern County northward to Shasta County). In contrast, <0.1% of the naled and malathion use, and 7.7% of the pyrethrins and pyrethroids use was reported from 20 counties in southern California and along the central coast where a comparable number of vector control agencies are located. The Central Valley encompasses ~30% of the area covered by vector control agencies and 17% of the state's population (CDF 2009). A combination of factors likely contributed to greater use of adulticides in this region. The Central Valley includes the state's largest wetlands and agricultural areas where surface irrigation and commodities such as rice increase mosquito-producing habitat. The region also experienced extensive WNV activity, with >1,200 human cases reported between 2004 and 2007 (average annual incidence of 6.52 per 100,000 people versus 1.57 statewide) (CDPH, unpublished data). In addition to higher mosquito production in the Central Valley, the agricultural history of this region typically fosters greater acceptance of pesticide use.

From a historical perspective, the pesticides used for mosquito control in California have changed significantly (Fig. 1). During the 1970s and 1980s, vector control shifted from conventional pesticides to "insect-specific agents" (Eldridge 1988), and a trend toward greater use of biorational and/or less persistent larvicides and adulticides has continued over the last 20 years. Organophosphate (OP) and carbamate use declined dramatically by the 1980s and 1990s, respectively. Reductions in OP use have continued at a slower pace in the last decade and significant quantities, principally naled, are still used. Widespread use of pyrethrins and pyrethroids began during the 1980s. While pyrethrins use has increased, pyrethroids have remained relatively stable since the 1990s. The use of larviciding oils peaked in the 1970s and has been declining each decade, while biological or biorational larvicides (*Bti*, *Bs*, methoprene) have increased dramatically. Despite the movement away from oils, petroleum distillates remain the most used public health pesticide by weight. Use of the bacterial larvicide *Bti* increased from an

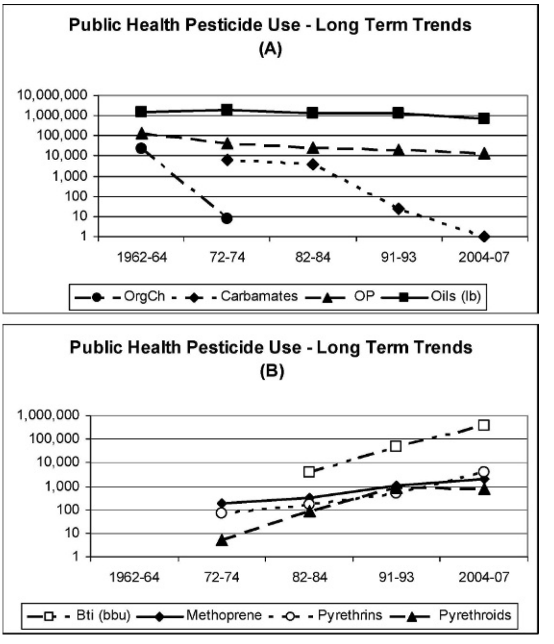

Fig. 1. Long-term pesticide use trends for mosquito control in California. All products, except *Bacillus thuringiensis* var. *israelensis* (*Bti*), are in pounds of AI. For comparison to historical information from Mosquito and Vector Control Association of California yearbooks, *Bti* is expressed in billions of biological units (bbu).

average annual use of ~5,850 lb (2,660 kg) during 1991–93 to >68,000 lb (30,800 kg) during 2004–07. Average methoprene use increased from 2,400 lb (1,100 kg) to 4,300 lb (1,950 kg) between the same time periods.

Historical changes in public health pesticide use in California have been driven by many factors. Pesticide resistance, registration of new products, concerns about health and environmental impacts, and regulatory changes have variously contributed to today's integrated approach, which relies on several active ingredients.

Despite limitations, the California reporting system provides documentation of public health pesticide use by vector control agencies and comparisons to other uses in the state. Through this review of the vector control agency reporting system, we are confident that the comprehensiveness and accuracy of reporting continues to improve. Future improvements to the system might include documenting the area of application for public health pesticides, georeferencing application sites, and the ability to view reported use information on a monthly or real-time basis.

Although many parameters are important for evaluating pesticide use, the general specificity, low persistence, and relatively limited amount of pesticides applied for mosquito control should be considered when determining the cost/benefit of public health pesticide use in California.

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