Sustainable Cotton Project

Final Report

Nicole David, San Francisco Estuary Institute

San Francisco Estuary Institute
7770 Pardee Lane, 2nd Floor
Oakland, CA 94621

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1. Summary

Contamination from pesticide application to row crops is a major water quality issue in California. Cotton receives three to five times greater application of pesticide per acre than other row crops (USGS 2008). This Project included outreach, education, and technical support for growers to test alternatives to synthetic pesticides and inorganic fertilizers. In addition, water quality monitoring of cotton field runoff in the Central Valley of California was conducted during the 2007 and 2008 growing seasons. The goal of the study was to evaluate differences in pesticide and nutrient loads to receiving water bodies comparing biological and conventional growing practices. The types and concentrations of pesticides in the sampled tail water were similar for biologically and conventionally grown cotton. Average pesticide concentrations in water and estimated loads for diuron, glyphosate, chlorpyrifos, and prometryn were not statistically significantly different with BMP implementations at the biological sites due to sample size limitations. However, there was a trend toward lower pesticide concentrations for diuron and prometryn at the biological sites. Concentrations for most nutrient forms and loads were also generally similar within the two site types when compared to flow passing the site at the point of sampling. Nitrate and nitrite loads, however, were reduced at the biological fields by more than 70% compared to the conventional sites. Additionally, limited bioassessment samples showed slightly greater numbers of individuals and numbers of species collected at the biological sites.

2. Introduction

The Sustainable Cotton Project (SCP) conducted by the Community Alliance with Family Farmers (CAFF) is a multi-faceted effort that evaluates differences in pesticide and nutrient concentrations in cotton field drainage water. Within the SCP, cotton fields with conventional growing practices were compared to fields enrolled in the Biological Agricultural Systems in Cotton (BASIC) growing practices (Gibbs et al. 2005). Additionally, interested conventional growers were trained and mentored in BASIC farming practices to increase awareness of water and sediment contamination issues. The overall goal was to reduce pesticide and nutrient concentration in water discharging into streams and rivers included on the 303(d) List of impaired water bodies. The Project was funded by the California State Water Resources Control Board. Oversight for the Project was provided by the grant manager at the California State Water Resources Control Board.

The SCP’s goal is a cleaner cotton industry and the improvement of water quality by bringing growers, manufacturers, and consumers together to promote information sharing. Through education and outreach the SCP provides information on biological growing techniques and the importance of pesticide reduction in fiber production since cotton is one of the most widely grown and chemically-intensive crops in the Central Valley. BASIC cotton is grown using Best Management Practices (BMPs) that can be successfully and economically applied to effectively reduce the footprints for the acres of farmland, amount of water, and produced carbon (Figure 1). To produce the same amount of cotton, BASIC growers need approximately 65% of the cropland, 38 % of the amount of water, and have a carbon footprint that is approximately 19% of the footprint when compared to conventional growers. For example, growers use composted manures and cover crops instead of synthetic fertilizers in BASIC farming; innovative weeding strategies are used instead of herbicides; beneficial insects and trap crops are used to control harmful insect populations; and alternatives to toxic defoliants are used by growers to prepare plants for harvest (Gibbs et al. 2005).

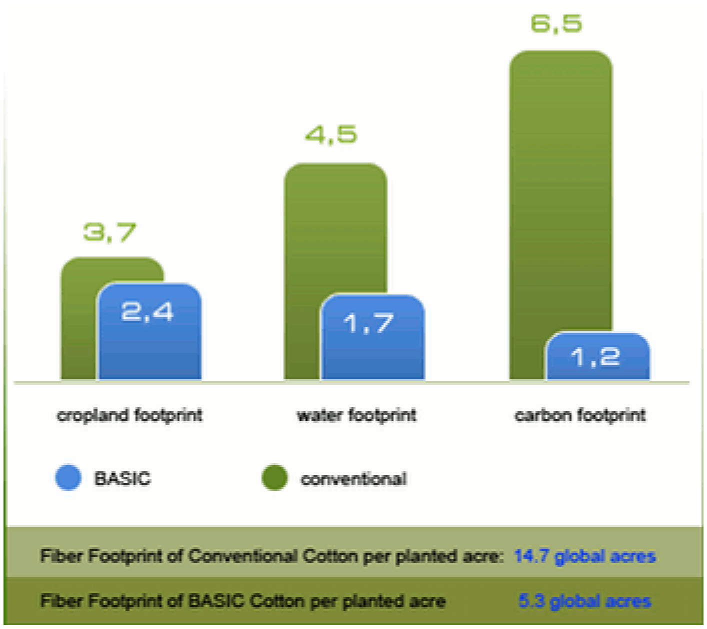

Figure 1. Comparison of optimal BASIC versus conventional growing practices in cotton and the potential calculated footprint of the different growing types. Source: SCP Footprint Calculator,
http://www.sustainablecotton.org/html/footprint_calculator/fiber_footprint.html

The SCP started in May 2006 with the preparation of the Project Assessment and Evaluation Plan, the Environmental Monitoring Plan, and the Quality Assurance Project Plan. Water and bioassessment sampling began in May 2007 and continued through August 2008 with the aim to evaluate the effectiveness of implementation of BASIC practices.

3. Background and Sampling Locations

The San Joaquin Valley spans approximately 140 miles from the Sacramento/San Joaquin Delta in the north to Tulare County in the south and includes eight counties. Agriculture is the primary economic activity in the San Joaquin Valley, producing more than $12 billion in crop value in 1995 (Umbach 2002). A variety of crops are grown in the Valley, including cotton, tomatoes, fruit and nut trees, melons, and other vegetables and fruits. Water for these crops is delivered from the Sacramento/San Joaquin Delta by the State Water Project and the Central Valley Project, from local groundwater, and from the San Joaquin River. Tail water is directed via sloughs and creeks back into the San Joaquin River.

The sampling sites (Table 1, Figure 2) were within the boundaries of the Westside San Joaquin River Watershed Coalition (Westside Coalition). This watershed generally lies on the west side of the San Joaquin River from approximately the Stanislaus River in the north to 10 miles south of Mendota and encompasses an area of 460,500 acres. There are approximately 4,000 landowners and 1,500 farmers within the watershed. Most of the watershed receives water supplies from the Central Valley Project, along with deliveries from the State Water Project, the San Joaquin River, and the Kings River. The Delta-Mendota Canal and San Luis Canal run through the center of the watershed. Water deliveries are made to Federal Central Valley Project contractors and to San Joaquin River Exchange contractors (including Central California Irrigation District and San Luis Canal Company) from these facilities.

Table 1. All monitored cotton fields with their specific locations, their sizes, and their type of growing practice.

Sample ID	**Latitude (°North)**	**Longitude (°West)**	**Size (acres)**	**Type**
Basic 1	36.5937.99	120.371958	30	BASIC
Basic 2	37.002562	120.372149	10	BASIC
Basic 3	37.01345	120.363264	90	BASIC
Basic 4	37.000765	120.5207.17	73	BASIC
Basic 5	37.089933	120.61549	30	BASIC
Conv 1	36.593799	120.371958	85	Conventional
Conv 2	37.0117.89	120.37191	102	Conventional
Conv 3	37.00572	120.86947	95	Conventional

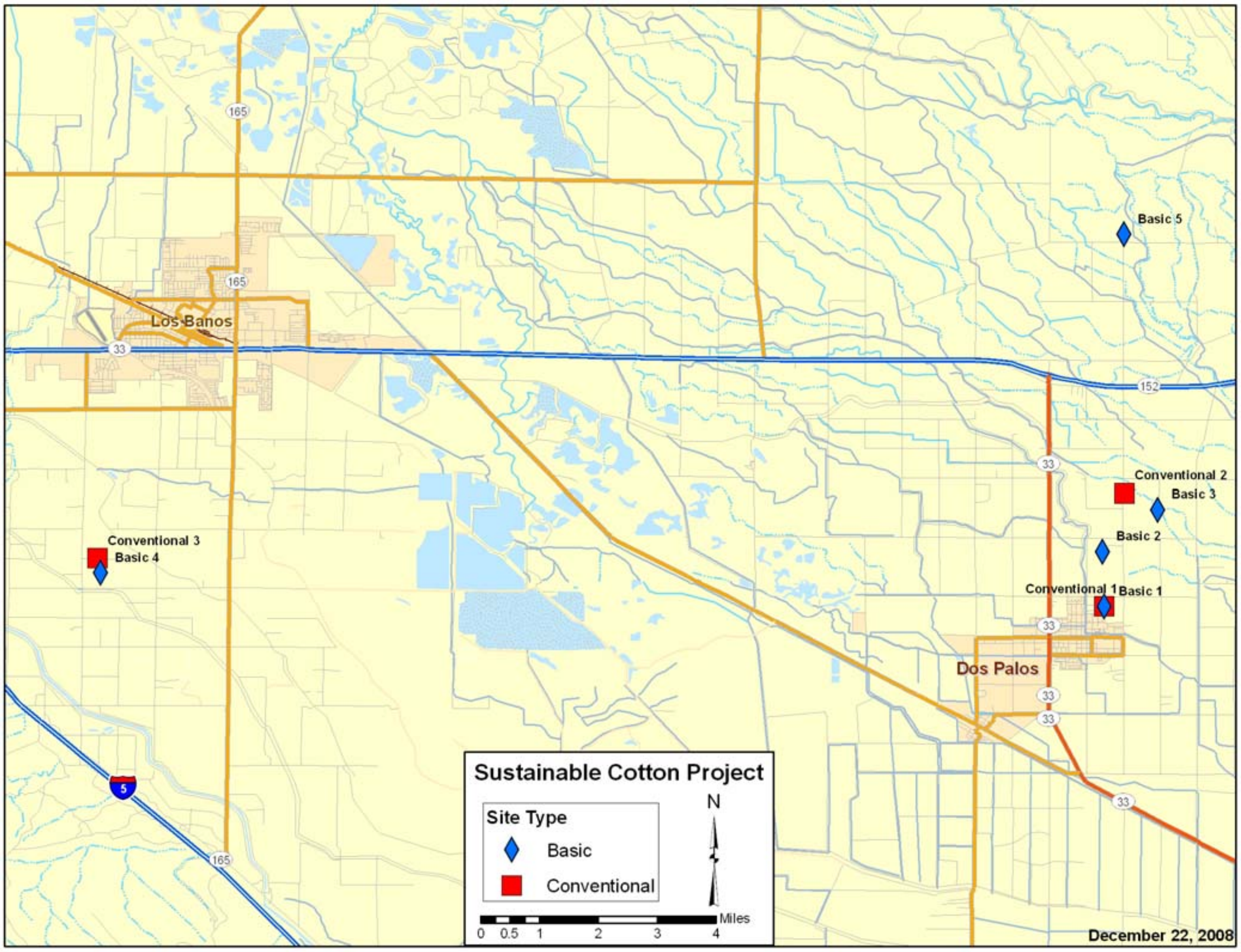

Figure 2. All sampling locations for the Sustainable Cotton Project in Fresno, Madera, and Merced County in the Central Valley including latitudes and longitudes in degrees decimal. Site Conventional 3 was added in 2008 replacing Conventional 1, since corn was planted at the Conventional 1 site during the second year of this study.

The last Census of Agriculture noted that there were 1,393 cotton farms in the Central Valley, with an average acreage of 500 acres each (USDA 2002). California is frequently the second highest producing state in the U.S., behind Texas. But California typically out-competes the rest of the country, and often the world, with its impressive yields. A yield of 1,200 to 1,300 pounds per acre is not uncommon, compared to the average U.S. yield of 615 pounds. California cotton producers must produce high yields, however. The cost of production in the state is estimated to be $800 to $1,000 per acre, which is possibly the highest production cost in the world. Profit margins are tight, and can be severely reduced by bad weather, insects, low yields, increased fuel costs, or declining prices.

The San Joaquin River receives substantial amounts of agricultural tail water or drainage that contributes salts, nutrients, pesticides, trace elements, sediments, and other substances that affect water quality. Regarding surface water quality in the San Joaquin River basin, the US Geological Survey concluded that (1) the potential exists for toxicity to aquatic organisms from water-borne pesticides because concentrations of seven pesticides have exceeded aquatic life criteria, and (2) the potential exists for adverse effects on aquatic life from pesticides in bed sediment and aquatic tissue samples.

This Project targeted several pesticides, including chlorpyrifos, which is particularly harmful to aquatic organisms. According to U.S. EPA Risk Quotients, a single application of chlorpyrifos poses risks to small mammals, birds, fish and aquatic invertebrate species for nearly all registered outdoor uses (US EPA 2002). According to the CA Department of Pesticide Regulation's Annual Pesticide Use Report (2002), cotton farmers were the highest users of chlorpyrifos statewide, with over 221,000 pounds of active ingredient applied. In addition, monitoring by the US Geological Survey, Department of Pesticide Regulation, and others has confirmed widespread occurrence of diazinon, chlorpyrifos and other OP-pesticides in the San Joaquin River and tributaries. Thus, reducing use and runoff of these pollutants would help improve the health of the targeted watershed.

The SCP sampling sites were located in Fresno, Madera, and Merced County in the San Joaquin Valley. The sites were selected to cover geographical areas with similar agricultural uses and site characteristics (e.g., soil types, pest pressure etc.) to provide a good comparison between BASIC and conventionally grown cotton. Seven cotton fields were monitored during 2007 and 2008 (Figure 2, Table 1). Five of the fields enrolled in the BASIC program were compared to two conventional cotton fields. Notified by the local pest control advisor, SFEI personnel mobilized when irrigation started and collected samples at all sites where runoff occurred. A second trip was made to catch runoff from the remaining sites within the same irrigation cycle in order to collect water samples from all sites within a short window of time. Water samples were collected at all sites during four irrigation events in the growing seasons of 2007 and 2008. Due to extreme water shortages, irrigation at the end of the 2007 cotton season was curtailed early and no representative fourth samples could be collected. In 2008, only one sample was collected late in the season to complete the sampling plan. Bioassessment samples were collected at two sites (one conventional and one BASIC) during three irrigation events.

Cotton Life Cycle. Cotton is an annual field crop commonly grown within California's San Joaquin Valley. It is grown in rows or furrows and is usually furrow irrigated with siphon or gated pipe, but can also be irrigated with sprinklers or subsurface drip irrigation systems. The cotton growing season begins in late winter or early spring with pre-irrigation. Prior to planting, the cotton field is irrigated to leach salts and provide soil moisture to germinate the seed. The cottonseed is planted mechanically in the furrows and emerges from the soil within a week of planting. During the growing cycle, the plant grows to its mature height (30" to 48") and set bowls. The last irrigation occurs in late summer, after which the plant dies and the bowls open, exposing the cotton fiber. A defoliant is sprayed to cause the leaves to drop off and open the remaining bowls. The fiber is mechanically harvested in the fall.


Photo: Cotton plants during irrigation in July.

4. Methods
4.1 Field Methods

4.1.1 General Methods

Each selected site was visited during field reconnaissance and mapped. Once sampling started, the general area of stations was located, GPS coordinates were assigned to each station using a hand-held global positioning system (GPS), and then the station location was confirmed on a map. At each site, Physical Habitat Quality Field Forms for lotic systems (see QAPP for this Project; David and Yee 2007) were completed to document site characteristics and land use. Information recorded included station ID, date, time, station depth, weather conditions, water color/clarity, latitude, longitude, and estimated position error. Flow rate, flow diversions, flow volumes, anthropogenic impacts, wildlife presence were noted. Profiles of the water body from both aerial and cross-section views were drawn.

All sampling bottles were labeled prior to transport to the field according to each site-specific sampling plan. Spare bottles and labels were also taken to the field. Water quality measurements were collected at every station during every sampling event using portable field meters. SFEI personnel using the meters were trained on their use and care prior to field use.

a. A multifunctional water quality meter (e.g., WTW Multi 340 or equivalent) with several probes, was submerged into the water column to collect the following readings:
    i. dissolved oxygen
    ii. pH and temperature
    iii. specific conductance and salinity
    iv. redox potential (Eh) of soil.

   Water depth was recorded for each measurement. At a minimum, surface readings were taken at one-meter depth or mid water column for sites shallower than two meters. Where possible, data (particularly DO) from the bottom, middle and top portions of the water column were also taken.
b. Turbidity was measured either in the field or samples were placed in pre-cleaned containers, stored on ice in a cooler, and in a refrigerator at 4ºC on return to the Institute. Samples measured at the Institute were processed within two weeks of collection. For laboratory turbidity measurements, the containers were removed from the refrigerator and stored in the dark until they reached ambient temperature (approximately one hour). Turbidity measurements were then completed using the same procedures as in the field.

Photo: SFEI staff taking water quality measurements.

4.1.2 Bioassessment Sampling

For bioassessment, a Petite Ponar grab was used to collect 0.005 m^3 sediment samples. Two to three sediment grabs were taken and composited from each site. The composited sediment was washed in a 0.5 mm mesh sieve bucket, with large debris being cleaned manually to retain attached invertebrates in the sample. The material remaining in the bucket was transferred to the sample jar using a wash bottle, followed by transfer with forceps and by hand. Samples were preserved with 95% v/v ethanol in the field, and then transferred to 70% ethanol two to three days after collection. Samples were processed within five months after collection. Processed samples that needed longer storage for QA and other reanalysis (e.g., remnant examination) were supplemented with 10% glycerol to help reduce sample deterioration.

4.1.3 Water Sample Collection

Water samples were collected at one-meter depth or mid-water column (if water body was less than 2 m deep) at each sampling site. A portable peristaltic pump was used to transfer water from the water body being sampled to the appropriate sample container. For collection of water samples for chemical analyses all tubing was cleaned prior to use at each sampling location. To avoid aerosol contamination, the sample tubing inlet and outlet was kept covered with clean foil until truck engines were turned off, and the engines remained off until sampling was completed and the tubing inlet and outlet were once again covered. The inlet of the sampling pump tubing was attached to an extendable sampling pole and deployed upstream (and upwind if possible) of the sampling site. Before filling sample containers, tubing was flushed with site water for at least two minutes. Each sample container was triple rinsed with site water unless the container contained a preservative. The outlet tubing of the water sampling pump was positioned at the mouth of the sample container very carefully not to touch the inside of the container or the lid with the tubing. The containers were filled completely to eliminate any headspace. Care was taken to minimize exposure of samples to sunlight. Immediately after collection, the containers were closed and placed on ice in a cooler.


Photo: SFEI staff collecting water samples.

4.2 Analytical Methods

4.2.1 Bioassessment

The processing of macroinvertebrate samples was conducted like an initial stream screening method. Due to the very low number of individuals in each sample, every individual was counted and keyed. Because of the low numbers of organisms found at each site, the bioassessment results cannot be used as an indicator of stream ecosystem health or for identifying potential impairment at conventional sites when compared to the BASIC sites. Three biological metrics that were quantified in this study.

- Number of total taxa (designating an organism or a group of organisms)
- Number of total individuals
- Percent very tolerant taxa

Quality assurance in bioassessment samples was ensured through re-counts of total relative abundance, species richness, and species diversity in one out of every 10 bioassessment samples. All re-counts were within 10% of the original numbers. The bioassessment counts therefore met the scoring guidelines outlined in the QAPP (David and Yee 2007). All samples were counted and re-counted by the same practitioner for consistency.

4.2.2 Analytical Methods and Quality Assurance for Pesticide Samples
Water samples were analyzed for the following chemical groups and pesticides, generally applied by growers during the production of cotton.

1. Organophosphorous pesticides: Chlorpyrifos (insecticide, nematicide), profenofos (insecticide)

2. Carbamates: Aldicarb (insecticide, nematicide), carbaryl (insecticide, nematicide, plant growth regulator), carbofuran (insecticide, nematicide)

3. Urea: Diuron (herbicide)

4. Phosphonoglycine: Glyphosate (herbicide) and its main metabolite AMPA (aminomethylphosphonic acid), including the surfactants nonylphenol and nonylphenolethoxylate

5. Triazine: Prometryn (herbicide)

6. Dinitroaniline: Trifluralin (herbicide)

7. Unclassified: Propargite (insecticide)

Samples were shipped to and received at the laboratories in good conditions between May 2007 and July 2008. All of the coolers containing water samples for pesticide and nutrient analysis were received at the lab at the recommended temperature of approximately 4ºC.

The analytical methods for OP-pesticides (EPA 8140, 8141AM), for most herbicides (WPCL Method 42), for glyphosate (EPA 547M), and for surfactants (JACR97_3247-3272) were chosen to ensure that measured concentrations were above the detection limit for the method. Three pesticides (aldicarb, profenofos, and propargite) were not detected in this study. But according to the pest control advisor, the application rates for these pesticides were negligible or pesticides were not used at all in 2007 and 2008.

Organophosphorus pesticides were analyzed with a modified EPA Method 8140, 8141AM for trace level concentrations in surface water using liquid-liquid extraction and high-resolution gas chromatography with Flame Photometric Detector (FPD) in phosphorus mode and Thermionic Bead Specific Detector (TSD). In summary, a measured volume of a sample was extracted with methylene chloride (DCM) using a separatory funnel. The DCM extract was dried with sodium sulfate, evaporated using Kuderna-Danish (K-D) and solvent exchange into petroleum ether. The extract was concentrated with microsnyder (micro K-D) apparatus and adjusted with iso-octane. The extracts were analyzed by gas chromatography using conditions which permit the separation and measurement of the target analytes in the extracts by FPD and TSD detection.

Carbamate pesticides were analyzed using a modified EPA Method 632, which is described in detail in the CDFG WPCL SOP #46. Liquid-liquid extraction and chromatography quadrapole system (LC-MSD) coupled to a diode array UV-Vis Detector (DAD) were utilized to analyze trace levels of carbamates in runoff water. In summary, a measured volume of a sample was extracted with methylene chloride (DCM) using a separatory funnel. The DCM extract was dried with sodium sulfate, concentrated and solvent exchanged by rotary evaporation and adjusted with acetonitrile. The extracts were analyzed by liquid chromatography using conditions, which permit the separation and measurement of the target analytes in the extracts by MSD detection.

Selected herbicides were detected in runoff water samples using a modified EPA Method 619. Liquid-liquid extraction and high-resolution gas chromatography with mass spectrometer-ion trap detector (GC-MS-ITD) were used to detect trace level concentrations of herbicides. In summary, a measured volume of a sample was extracted with methylene chloride (DCM) using a separatory funnel. The DCM extract was dried with sodium sulfate evaporated using Kuderna-Danish (K-D) and solvent exchanged into petroleum ether. The extract was concentrated with microsnyder (micro K-D) apparatus and adjusted with iso-octane. The extracts were analyzed by gas chromatography using conditions, which permit the separation and measurement of the target analytes in the extracts by GC/MS/MS.

Quality Assurance Results for Pesticides

The Relative Percent Differences (RPDs), calculated as the difference in concentration of a pair of analytical duplicates divided by the average of the duplicates, were within the target range of +/-25% without exception. The Percent Recoveries (PRs) for Laboratory Control Solution (LCS) and Laboratory Control Solution Duplicates (LCSDs) were within the target range of 75-125%, with the exception of a batch for the surfactants (nonylphenol and nonylphenol ethoxylate) and one batch of glyphosate and trifluralin that were marginally outside the desirable range. The quality assurance samples included one to two method blanks for each analytical batch and in all cases no pesticide concentrations were detected in the method blank samples. Also, all field blank samples were below the MDL for all pesticides. No blank correction factor had to be applied to the results. Table 2 shows all QA results for the measured pesticides.

Table 2. Quality Assurance results for pesticides measured in the SCP. All blanks were below detection limits.

Parameter	Detection Limit (MDL)	Reporting Limit (RL)	% of Field Samples below MDL	Relative Percent Difference (RPD) +/- 25%	Percent Recovery of Lab Control Solution (LCS and LCSD)
Aldicarb	0.010	0.050	100	0.5 - 2.1	75 - 105
Carbofuran	0.010	0.050	97	0.2 - 1.3	80 - 115
Chlorpyrifos	0.005	0.020	60	0.4 - 6.1	80 - 101
Diuron	0.002	0.005	8	NA	NA
Glyhosate	2.00	5.00	18	1.8 - 2.8	71 - 112

Nonylphenol	0.500	2.00	90	1.8 - 3.6	61 - 96
Nonylphenol ethoxylate	0.500	2.00	97	2.0 - 8.1	69 - 115
Profenofos	0.050	0.100	100	3.0 - 3.0	82 - 102
Prometryn	0.200	0.500	40	1.1 - 1.1	80 - 98
Propargite	0.200	0.500	100	9.2 - 9.2	88 - 103
Trifluralin	0.050	0.100	97	1.4 - 1.4	74 - 93

4.2.3 Methods and Quality Assurance for Nutrient Samples

Samples delivered or shipped to the laboratory for nutrient analysis were all in good condition with a temperature of approximately 4ºC. Analytical methods selected for nutrients were California Department of Fish and Game methods QC 10107041B for nitrate and nitrate, QC 10107062E for total kjeldahl nitrogen, QC 10115011D for total phosphorus, and QC 10115011M for dissolved-ortho phosphate (see QAPP for details).

For the analysis of inorganic compounds Lachat QuikChem Flow Injection Analyzer (FIA) methods were used. Orthophosphate was determined using a modified EPA Method 365.1. During FIA analysis, the orthophosphate ion produced reacted with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex was reduced with ascorbic acid to form a blue complex, which absorbed light at 880 nm. The absorbance was proportional to the concentration of orthophosphate in the sample.

Nitrite and Nitrate (NOx) were analyzed using EPA Method 353.2. Nitrate was quantitatively reduced to nitrite by passage of the sample through a copperized column of cadmium granules. The resulting nitrite (in addition to the nitrite initially present in the sample) was determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye had a magenta color, which was read colorimetrically at 520 nm. Nitrite alone could be determined by performing the same analysis with the exception of removing the cadmium reduction column step. Once nitrite had been quantified, this amount could be subtracted out of the nitrate plus nitrite results to yield the nitrate concentration alone.

Total Kjeldahl Nitrogen (TKN is the sum of organic and ammonia nitrogen) was analyzed by EPA Method 351.2. The sample was heated for two and a half hours in the presence of sulfuric acid and potassium sulfate, to convert nitrogen compounds to ammonium. During FIA analysis the sample pH was raised wherein the ammonium ion was converted to ammonia. The ammonia was heated with salicylate and hypochlorite to produce a blue color, which is proportional to the ammonia concentration. Total nitrogen was calculated by summing total Kjeldahl nitrogen (TKN) and nitrate plus nitrite nitrogen (NO_3+NO_2).

Total Phosphorus was analyzed using EPA Method 365.4. This method utilized an off-line digestion to convert all forms of phosphorus into orthophosphate using an acidic persulfate digestion. During FIA analysis, the orthophosphate ion produced reacted with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex was reduced with ascorbic acid to form a blue complex, which absorbed light at 880 nm. The absorbance was proportional to the concentration of orthophosphate in the sample.

Quality Assurance Results for Nutrients

The RPDs for nutrients ranged from 0 to 16 and were all within the desirable target range for high quality samples. The Percent Recoveries (PRs) for Laboratory Control Solution (LCS) and Laboratory Control Solution Duplicates (LCSDs) were within the target range and span from 90-107%. The quality assurance samples included one to two method blanks for each analytical batch and were in all cases below the detection limit. Also, all field blank samples were below the method detection limit and no correction factor had to be applied to the results. Table 3 lists all results for quality assurance for nutrient analysis.

Table 3. Quality Assurance results for nutrients measured in the SCP. All blanks were below detection limits.

Parameter	Detection Limit (MDL)	Reporting Limit (RL)	% of Field Samples below MDL	Relative Percent Difference (RPD) +/- 25%	Percent Recovery of Lab Control Solution (LCS and LCSD)
Nitrate + Nitrate	0.100	0.200	0	0.0 - 4.3	98 - 102
TKN	0.25	0.40	0	2.3 - 14	92 - 107
Total Phosphorus	0.0250	0.0300	0	0.5 - 16	80 - 92
ortho-Phosphate	0.0050	0.0100	0	0.0 - 1.0	90 - 99

All monitoring efforts were compatible with the Surface Water Ambient Monitoring Program (SWAMP) data collection effort and the SCP database was developed with full consideration of current SWAMP requirements.

5. Results and Discussion

The goals set for this Project in the Project Assessment and Evaluation Plan (PAEP) of pesticide reductions by 60% was not achieved when comparing biological and conventional cotton fields in this study but was achieved when comparing monitored cotton fields to Ag Waiver sites (Figure 11). In general, the observed pesticide concentrations were low at both, biological and conventional, site types of the studied cotton fields and significantly lower ($p = 0.001$, t-test) when compared to Ag Waiver sites in the same region. Therefore, water quality at all monitored sites in this study show improvements due to BMP implementation. Several reasons could account for biological sites showing similar concentrations to conventional sites:

- Growers enrolled one field into BASIC Program but recognized the benefits of biologically grown cotton and did not treat their conventional cotton field differently.

- Participating growers in general (conventional and biological) had high awareness of environmental problems from pesticide applications and were ambitious to reduce their overall pesticide use.
- Growers only enrolled smaller fields into BASIC Program and spray and wind drift from adjacent conventional cotton fields caused biological sites to also show low concentrations for the same pesticides. A similar study (David and McKee 2009) that compared runoff from organic walnut orchards to conventional orchards showed that almost all pesticides applied to conventional walnuts were also detected in the runoff of the organic sites. The organic growers had not used any synthetic pesticides for approximately 10 years.
- Spray and wind drift could also carry pesticides from other fields and orchards to irrigation channels and cause a low background concentration of pesticides in the irrigation water. This study did not monitor water quality of irrigation water.

An additional goal set in the PAEP was the improvement of the Index of Biological Integrity (IBI) score. Biological monitoring is a method for measuring biological condition. The IBI measures the stream biota and provides a direct assessment of resource conditions because the characteristics of the biota reflect the influence of human activity in the surrounding watershed. Biological integrity has been specified in the Clean Water Act and is a synthesis of diverse biological information, which numerically depicts associations between human influence and biological attributes. It is composed of several biological attributes or 'metrics' that are sensitive to changes in biological integrity.

The calculation of an IBI score for this study was challenging since the drainage ditches are only filled with water temporarily during irrigation and many organisms cannot tolerate this fast changing environment, disregarding pesticide levels (see Bioassessment discussion below). As a results, all monitored ditches scored low, between 10 – 16, indicating very poor stream conditions. However, a trend was observed that showed an improvement in the IBI score, reflected in the total number of taxa (richness) and total number of organisms (abundance). Additionally, an improvement in population attributes or percent dominance from 100% at the conventional sites to 91% at the BASIC sites was observed.

5.1 Bioassessment

The bioassessment part of this study was different from standard bioassessment studies in very important ways. Typically these studies are performed in permanent water bodies and not in intermittent systems like the irrigation tail ditches. When looking at the bioassessment results from this study, interpretations and conclusions have to be drawn carefully, taken into consideration the temporary and altered habitat from which the samples were collected. The tailwater ditches at the lower end of the cotton fields are artificially created to carry surface runoff from irrigation off the field. They are dry throughout most of the cotton season, which adds another stressor to the habitat of the organisms that try to live in these ditches. Water is passing through the tail ditches during irrigation for about 36 hours approximately twice a month. A comparison of aquatic benthic organisms from site to site is therefore challenging and numbers should be interpreted as trends only instead of an evaluation of habitat conditions due to chemical exposure.

A clear trend from graphic comparison in increased biodiversity and abundance of organisms at the BASIC sites was observed (Figure 3 and 4). Biodiversity was measured by number of taxa present at the sites, and BASIC sites had approximately twice the diversity of aquatic organisms compared to the conventional sites. Abundance was measured by the number of organisms per taxa, and BASIC sites had approximately three to five times higher counts of organisms compared to the conventional sites. Bioassessment results from this study are displayed in. Due to a low sample number (n = 6), statistical analysis was not conducted.

Benthic organisms found in the bioassessment samples predominantly belonged to the taxonomic classes of polychaeta and oligochaeta. It is assumed that these organisms represent highly tolerant species, however, identification to genus or species was not performed. In a few samples, diving beetles (*coleoptera*) and fly larvae (*tipulidae*) were also identified, even though they are not part of the benthic community and were just floating on top of the sample.

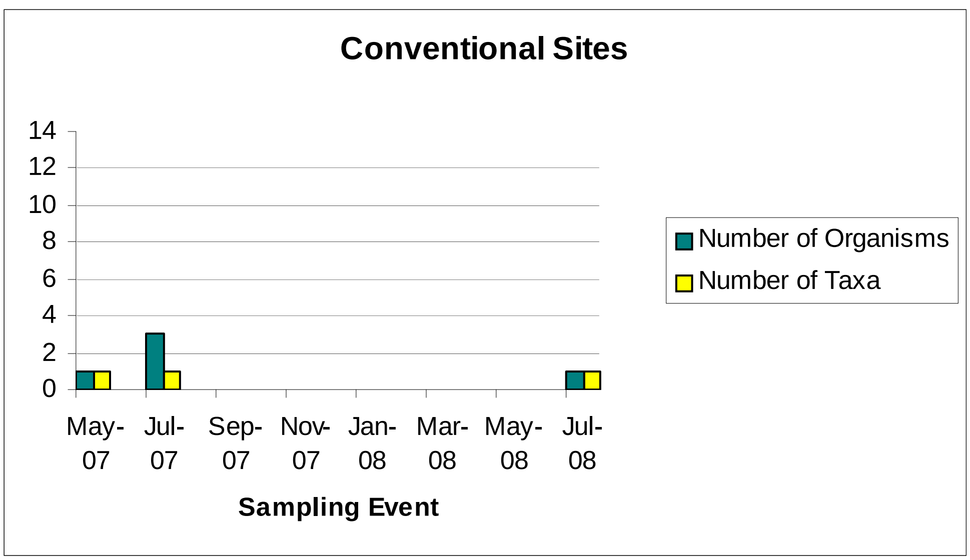

Figure 3. Number of organisms and number of taxa found at conventional sampling sites.

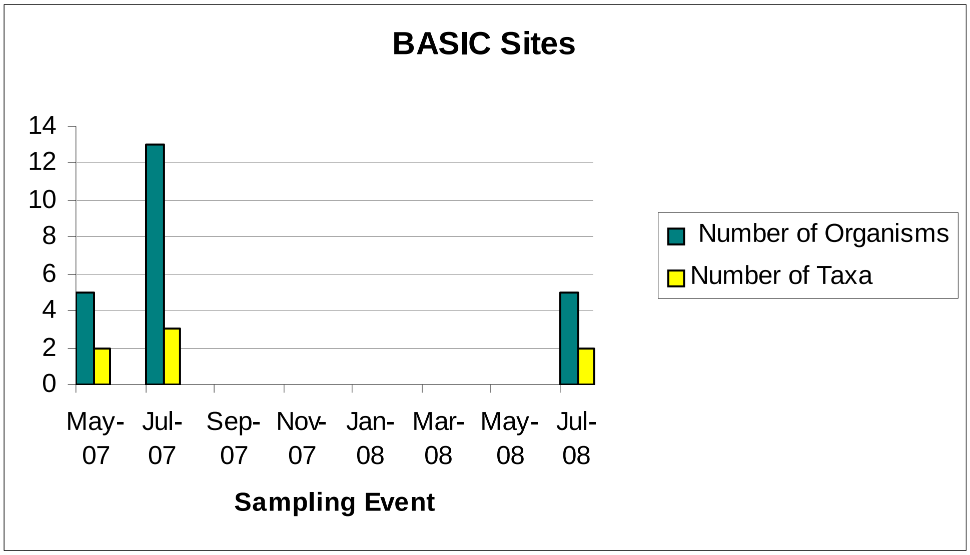

Figure 4. Number of organisms and number of taxa found at BASIC sites.

5.2 Pesticides

Six out of 13 pesticides were analyzed above the MDL in whole water samples collected during the cotton growing seasons of 2007 and 2008. Figure 5 shows all pesticides that were detected during this study and the relative number of samples that showed pesticide concentrations versus non-detects. A total of 40 samples were collected for each parameter over the course of the two growing seasons. The chart neglects individual concentrations of samples and only compares the number of samples in which a pesticide was detected to the number of samples in which the pesticide was below the MDL.

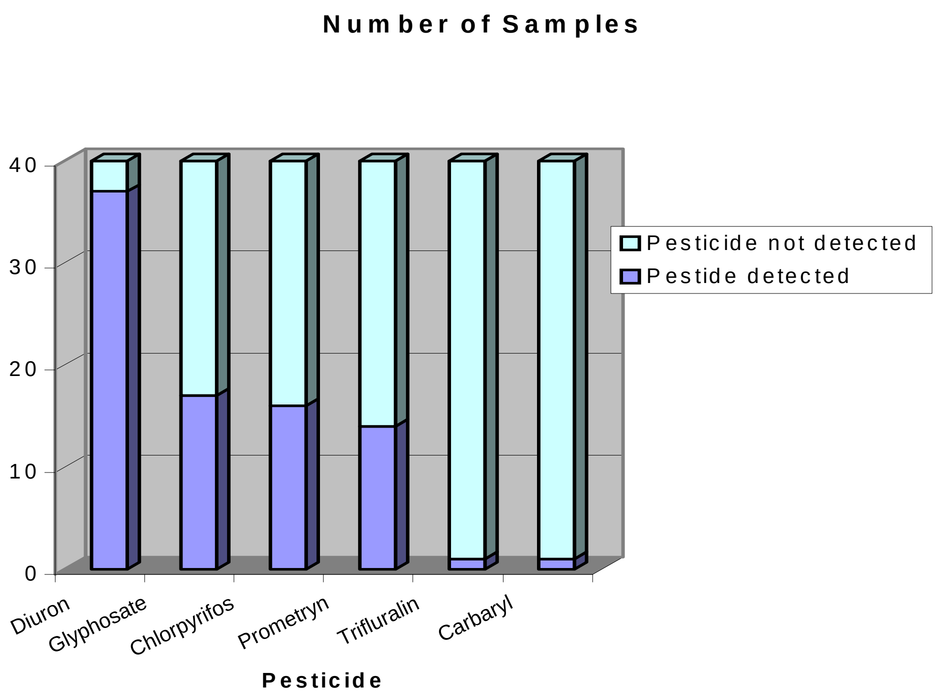

Figure 5. Number of samples with pesticide concentrations above and below the MDL. Six out of 13 pesticides were detected in samples collected in the SCP.

Diuron was detected in 37 out of the 40 collected samples and was the most frequently detected pesticide in this study. Glyphosate, chlorpyrifos, and prometryn were detected in approximately 25 - 50% of the samples collected, while trifluralin and carbaryl were only detected in one sample out of 40, during the last sampling event at two BASIC sites.

Diuron

Diuron concentrations ranged from below the MDL to 382 ug/L at the BASIC sites and from below the MDL to 252 ug/L at the conventional sites. The average concentration for all samples collected was 68±25 (std. error) ug/L for the BASIC sites and 49±22 (std. error) ug/L at the conventional sites. All samples were well below the LC50 for aquatic invertebrates (2,500 ug/L) and also below the LC50 for fish (4,300 – 42,000 ug/L; rainbow trout 3,500 ug/L). As an herbicide, diuron is extremely toxic to algae and was above the EC50 of 2 ug/L for *Selenastrum capricornutum* in 38% of the BASIC samples and 44% of the conventional samples.

Figure 6 depicts diuron concentrations at conventional sites and BASIC sites. Overall the concentrations were very similar and slightly higher at the BASIC sites. The trend showed relatively high diuron concentrations at the beginning of the season at both site types and a steady decrease of diuron concentrations over the period of the growing season.

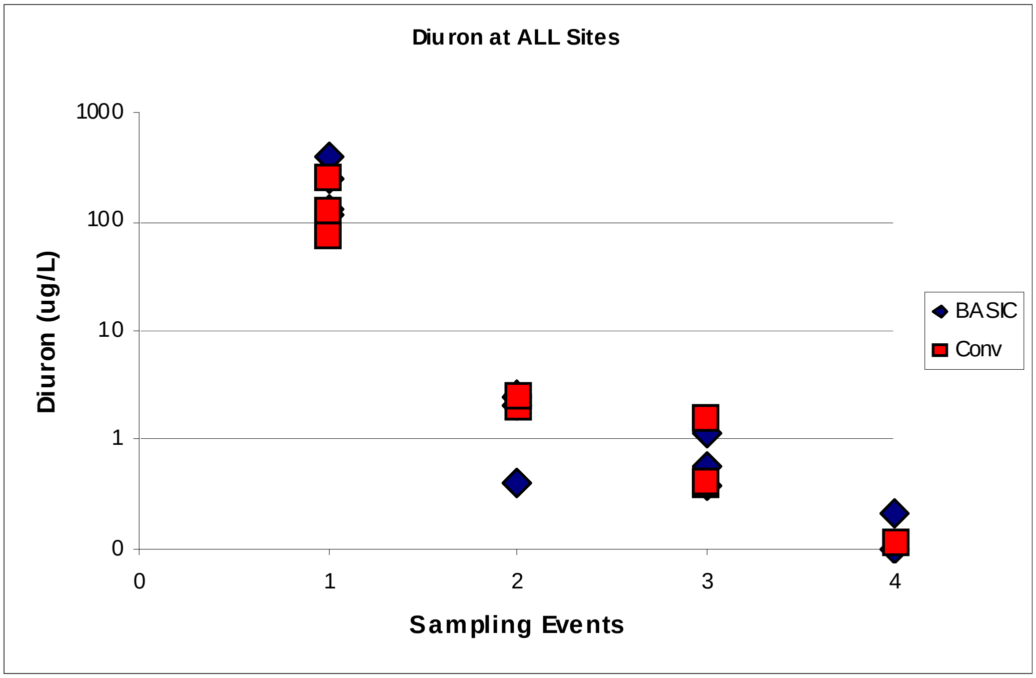

Figure 6. Diuron concentrations at all sites. Please note logarithmic scale on y-axis.

Glyphosate
Glyphosate is the herbicide that is predominantly used in cotton in combination with the defoliant before harvest in late September or early October. Its purpose is to kill any weeds that otherwise could get picked up by the harvesting machines and that could stain and spoil the cotton with chlorophyll. Glyphosate is also used to kill all weeds in the fall to decrease re-emerging of weeds in the following season. Most cotton plants are "roundup ready", which means they are immune to glyphosate. Glyphosate concentrations ranged from below the MDL to 29.5 ug/L at the BASIC sites and from below the MDL to 22.9 ug/L at the conventional sites (Figure 11). All observed concentrations were far below lethal or effect concentrations for fish and zooplankton (Pesticide Action Network Database). AMPA (aminomethylphosphonic acid), the main metabolite of glyphosate, was not detected in any of the samples collected for this study.

Glyphosate is usually mixed with different adjuvants before application to improve the spreading on the plants and the overall performance of the pesticide. The adjuvant nonylphenol was detected in three BASIC site samples and one conventional site sample, ranging from below the MDL to 2.16 ug/L. Even the maximum concentration seen in this study was well below the effect concentration for fish (97 ug/L for fathead minnow) and for zooplankton (90 ug/L for *daphnia*) (Pesticide Action Network Database) (Figure 7). The second surfactant tested for in this study, nonylphenol ethoxylate, was only detected once at a conventional site at a concentration of 0.95 ug/L. No aquatic toxicity data could be found for nonylphenol ethoxylate.

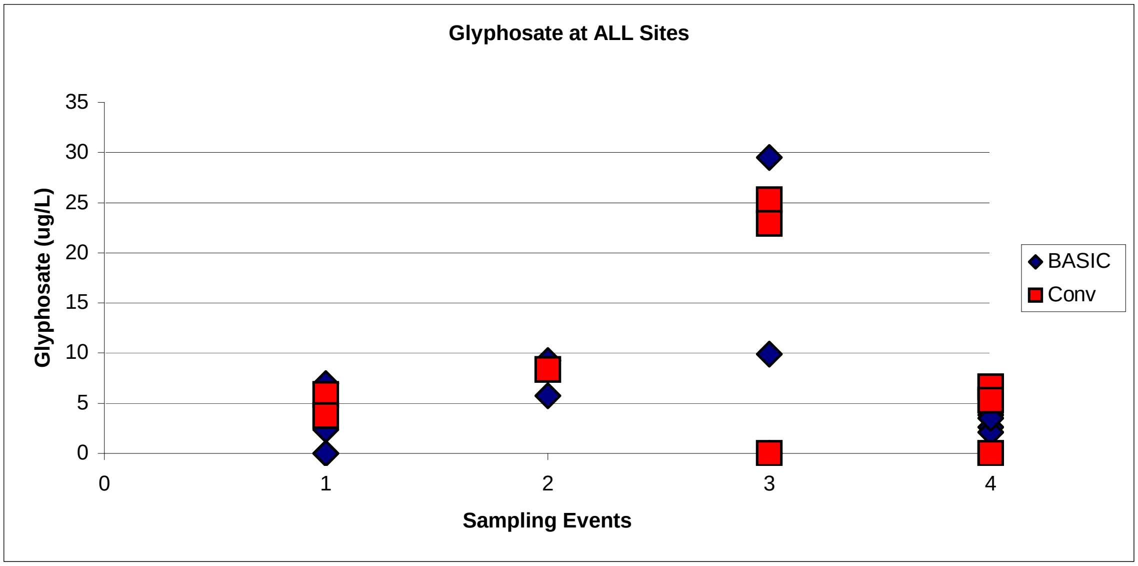

Figure 7. Glyphosate concentrations at BASIC and conventional sites.

Chlorpyrifos

Chlorpyrifos concentrations ranged from below the MDL to 0.01 ug/L at both, BASIC and conventional sites (Figure 8). The reporting limit for chlorpyrifos is 0.02 ug/L and all results should have been qualified as "data not quantifiable" due to their very low concentrations. All results were below the LC50 for *daphnia* (0.3 ug/L) and the more sensitive LC50 for silversides of 0.09 ug/L. Even the LC50 for *ceriodaphnia* (0.06 – 0.08 ug/L) was not exceeded during this study (Pesticide Action Network Database).

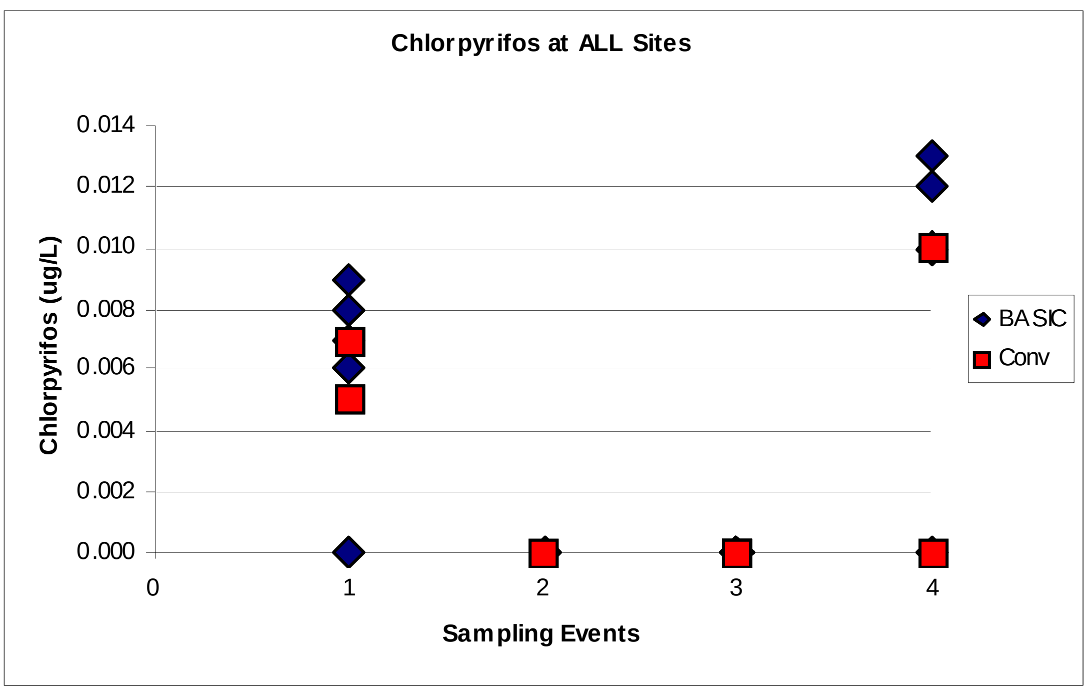

Figure 8. Chlorpyrifos concentrations at all sites

Prometryn

Prometryn concentrations ranged from below the MDL to 1.1 ug/L at BASIC sites and from below the MDL to 1.2 ug/L at the conventional sites (Figure 9). The average prometryn concentration was 0.5 ug/L for the conventional sites and the BASIC sites (std. error = 0.2 for conventional samples and 0.1 for BASIC samples). The LC50s for rainbow trout (2,500 ug/L) and *daphnia* (18,900 ug/L) were nor exceeded (Pesticide Action Network Database).

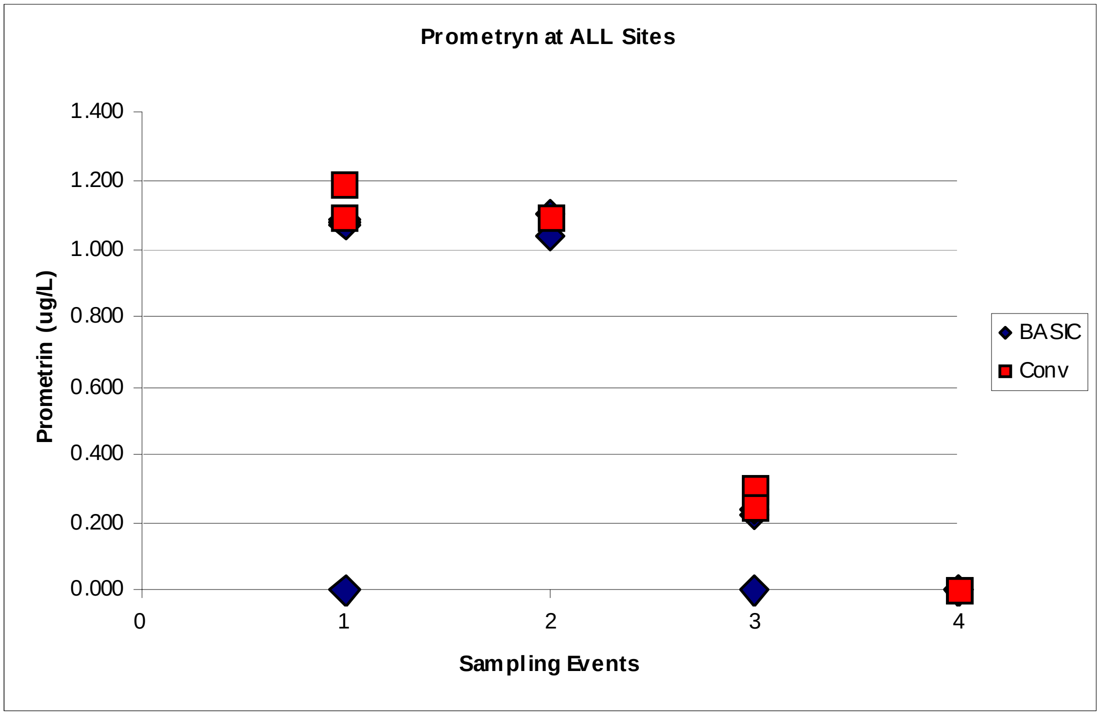

Figure 9. Prometryn concentrations at all sites.

Trifluralin and Carbaryl

Trifluralin was detected only once at a BASIC site (BASIC 5 in July 2008) at 0.07ug/L and was below the LC50s for rainbow trout and *daphnia* of 20 and 500 ug/L, respectively (Pesticide Action Network Database). Carbaryl was also detected once during this study at a BASIC site (BASIC 4 in July 2008) at 0.1 ug/L and was below the LC50s for rainbow trout and *daphnia* of 1,300 and 6.0 ug/L, respectively (Pesticide Action Network Database).

5.3 Risk Quotients (RQ)

A different way of reporting the data is to compare the results regarding concern for an ecological risk instead of lethal or effect concentrations. An ecological risk assessment is conducted to evaluate the ecological risk of a certain pesticide by calculating the Risk Quotient (RQ). This risk characterization integrates exposure and effects data and states a potential for risk, expressed by the Level of Concern (LOC). The RQ is calculated as follows.

RQ = Exposure / Toxicity

- Exposure = Field data concentrations
- Toxicity = Published toxicity endpoint (LOEC, NOEC, EC50, LC50, MATC)

Where:

LOEC is the "lowest observed effect level," or the lowest level (concentration) at which adverse effects are observed.

NOEC is the "no observed effect level (concentration)," or the level below which, no adverse effects are observed.

EC50 is the effective concentration of the pesticide in mg/L or ug/L that produces a specific measurable effect in 50% of the test organisms within the stated study time. The measurable effect is lethality for zooplankton and a reduction in photosynthetic activity by 50% for phytoplankton.

LC50 is defined as the amount of pesticide present per liter of aqueous solution that is lethal to 50% of the test organisms within the stated study time.

MATC is the "maximum acceptable toxicant concentration" and is a hypothetical threshold concentration that is the geometric mean between the NOEC and LOEC concentration.

Table 4. Toxicity data for detected pesticides. Source: Pesticide Action Network Pesticide Database http://www.pesticideinfo.org/

Pesticide	**Rainbow Trout**	**Bluegill Sunfish**	**Fathead Minnow**	**Water Flea (*daphnia*)**	***Selenastrum***
Chlorpyrifos (Insecticide)	LC50 9.0 ug/L	LC50 10 ug/L	LC50 330 ug/L	LC50 0.01 ug/L	
Diuron (Herbicide)	EC50 4,300 ug/L	LC50 5,300 ug/L	LOEC 3,400 ug/L	EC50 1,000 ug/L	EC50 0.018 ug/L
Prometryn (Herbicide)	LC50 2,140 ug/L	LC50 6,200 ug/L		EC50 9,700 ug/L	
Trifluralin (Herbicide)	BCF 1.0 ug/L		BCF 1.5 ug/L	LC50 193 ug/L	
Carbaryl (Insecticide)	LOEC 400 ug/L			LC50 1.25	EC50 1,000

Using the field data, the Risk Quotients were calculated for detected chemicals as follow:

RQ (chlorpyrifos) = 0.013/9 = 0.0014 (rainbow trout)
RQ (chlorpyrifos) = 0.013/0.01 = **1.3 (water flea)**

RQ (diuron) = 382/3,400 = 0.11 (fathead minnow)

RQ (diuron) = 382/1,000 = 0.382 (water flea)
RQ (diuron) = 382/0.018 = **21,222 (selenastrum)**

RQ (prometryn) = 1.19/2,140 = 5.56 e^{-4} (rainbow trout)
RQ (prometryn) = 1.19/9,700 = 1.23 e^{-4} (water flea)

RQ (trifluralin) = 0.07/193 = 0.0004 (water flea)

RQ (carbaryl) = 0.103/400 = 0.0003 (rainbow trout)
RQ (carbaryl) = 0.103/1.25 = 0.082 (water flea)

The Risk Quotient for each chemical was then compared to a unitless value, called the Level of Concern (LOC) (Table 5). The LOCs showed exceedances for two pesticides (bold above). The LOC was exceeded for chlorpyrifos for acute risk for water fleas, indicating that there is a potential threat to aquatic invertebrates at chlorpyrifos concentrations found at BASIC and conventional sites. It has to be stated though that this conclusion was derived from results that were qualified as below the reporting limit. The other exceedance was calculated for diuron, indicating that there is a high ecological risk for green algae. Considering that diuron is an herbicide the high risk for phytoplankton is not surprising.

Table 5. Risk Quotient (RQ) compared to Level of Concern (LOC) for four different risk presumptions.

Risk Presumption	RQ	LOC
Acute Risk	LC50 or EC50	0.5
Acute Restricted Use	LC50 or EC50	0.1
Acute Endangered Species	LC50 or EC50	0.05
Chronic Risk	MATC or NOEC	1

The LOC calculation is considering a worst-case scenario since the maximum concentration detected in the entire period of the study is used to evaluate the potential ecological risk. This very conservative approach is a good balance to comparing detected pesticide concentrations to LC50s alone. But it must also be kept in mind that it is possible that the spot sampling technique used during this study missed the highest concentrations in runoff from the cotton fields.

5.4 Pesticides used in BASIC vs. Conventional Growing Practice

When split into different chemical categories, the 2006 data showed that BASIC growers and their enrolled fields were below the application intensity for conventional fields regarding hard chemicals (e.g., aldicarb, chlorpyrifos, glyphosate, profenofos, prometryn, propargite, and trifluralin) (Figure 10). The application intensity for all pesticides totaled was higher at the BASIC sites and for the enrolled fields than at the conventional sites in 2006. However, the total number reported by the pesticide use report includes sulfur and copper, two naturally occurring elements that are also used in organic farming.

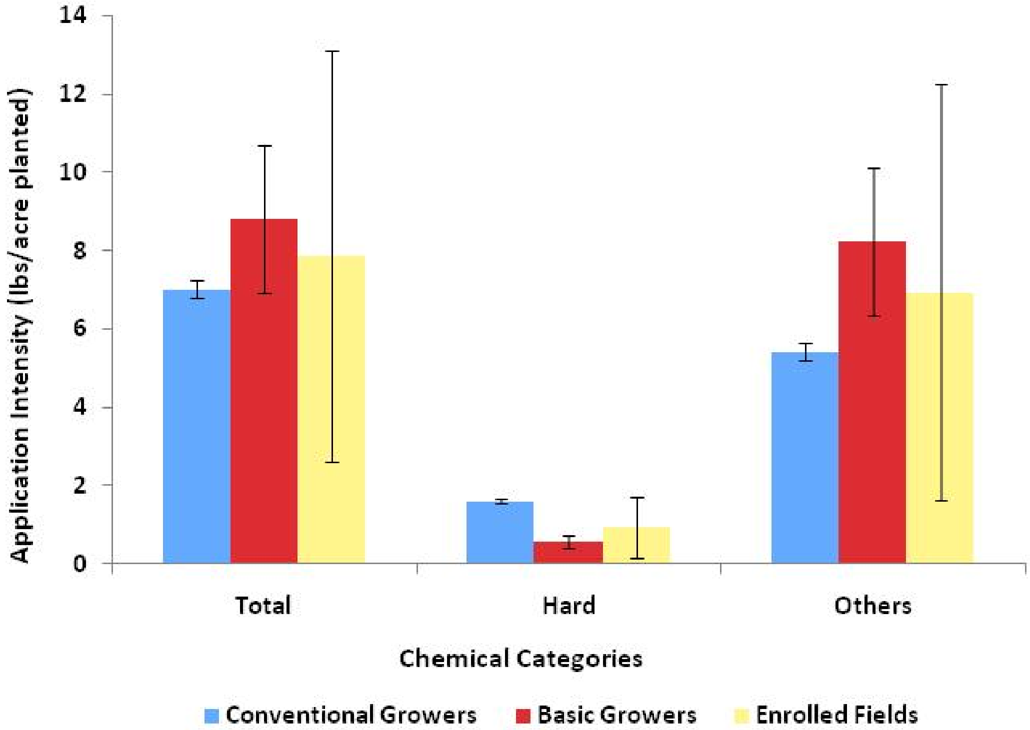

Figure 10. Different pesticide categories and their application intensity for conventional and BASIC growers, as well as for the enrolled fields.

Overall, efficient and careful management of all the monitored cotton fields could explain very low and non-detectable results for pesticides in this study. High irrigation efficiency at monitored sites, conscientious pesticide choice, limited pesticide use and low application rates all contributed to low chemical concentrations in cotton runoff.

Figure 11 shows chlorpyrifos data for all SCP sites (BASIC and conventional) compared to several Ag Waiver data points collected in the vicinity of the study area, at Salt Slough, Mud Slough, Newman Wasteway, and Oristimba Creek, all receiving agricultural return flow. The monitored drains in the Ag Waiver program are regional drains and not end of field drains like the ones that were sampled in the SCP. Concentrations would be expected to be somewhat lower in the regional drains due to dilution when compared to the end of field data from this project but an accumulation factor due to pesticides running off into the regional drain from multiple fields could also come into effect. However, all Ag Waiver monitoring sites had higher chlorpyrifos concentrations during the same time period when the last sample collection for the SCP was conducted too, suggesting that the biological cotton made an impact on water quality. Between 1992 and 2004, chlorpyrifos concentrations in samples from the Oristimba Creek site exceeded the chronic threshold for sensitive species in 34% of the samples and the acute threshold in 27% of the samples (http://www.waterboards.ca.gov/centralvalley/resources/data_databases/). Only slightly less exceedances occurred at the Newman Wasteway, Mud Slough, and Salt Slough sites.

Maximum chlorpyrifos concentrations in the San Joaquin River near Vernalis and Stevenson were reported at 0.055 and 0.140 ug/L, respectively in 2004. This suggests that the impairment from the monitored cotton fields for the SCP in general was already relatively low compared to other locations.

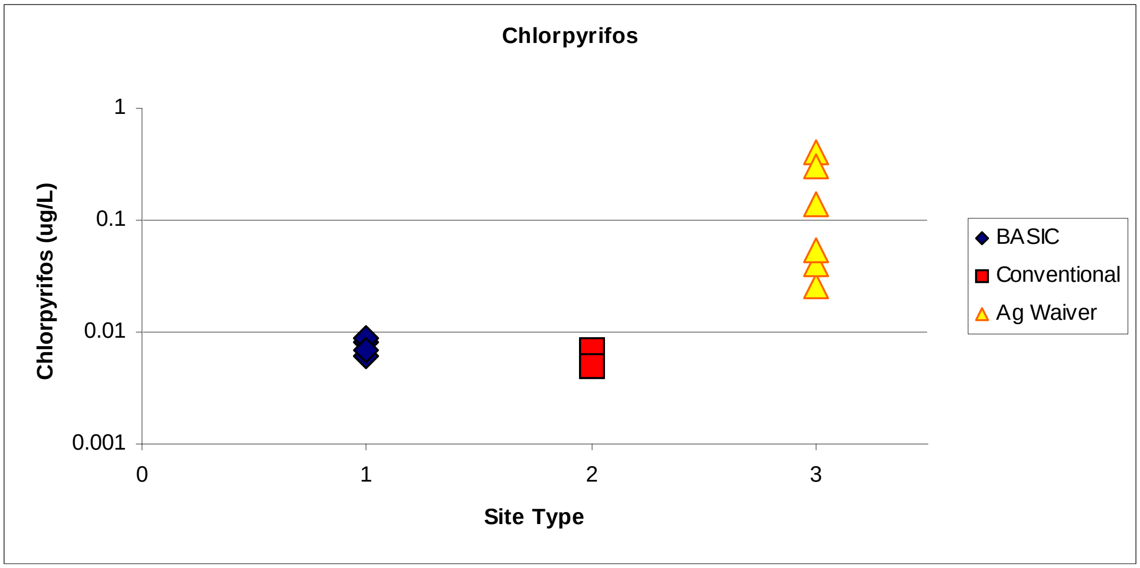

Figure 11. Comparison of SCP chlorpyrifos concentrations to Ag Waiver sites.

5.5 Nutrients

Nutrient concentrations in this study were relatively high and did not vary greatly between different farming practices. Nitrate + nitrite (NOx) concentrations ranged from 0.1 – 21 mg/L at BASIC sites with an average of 4.0 mg/L (n = 28), while the conventional sites had a NOx concentration range of 0.1 – 17 mg/L with an average of 6.0 mg/L (n = 12) (Figure 12). The EPA's reference conditions for ecoregion 1, subregion 7 (California Central Valley) recommend 0.1 mg/L for NOx in the ambient water quality criteria for rivers and stream (US EPA 2001). Total Kjeldahl nitrogen (TKN) concentrations at BASIC sites ranged from 0.3 – 7.8 mg/L with an average of 2.9 mg/L (n = 28), while concentrations for TKN at the conventional sites ranged from 0.2 - 5.2 mg/L with an average of 2.5 mg/L (n = 12) (Figure 13). EPA reference conditions recommend TKN at 0.2 mg/L (US EPA 2001). EPA reference conditions are used as guidelines only and are not enforced regulation. However, concentrations within the range observed in this study indicate that nitrogen represents a potential water quality concern.

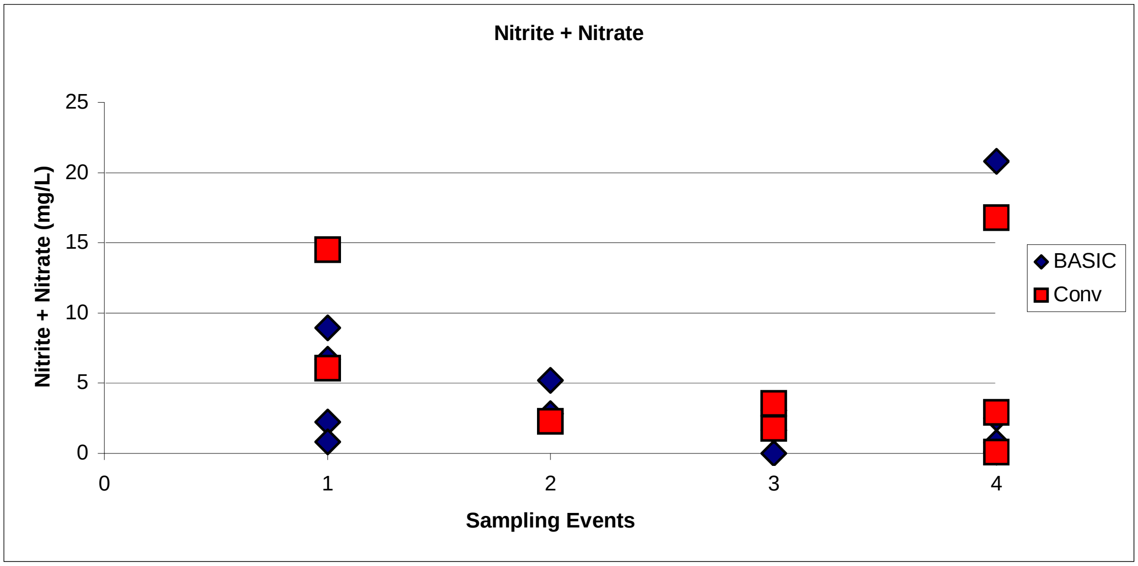

Figure 12. Nitrite + nitrate concentrations at BASIC and conventional sites measured during the study period of the cotton growing season in 2007 and 2008.

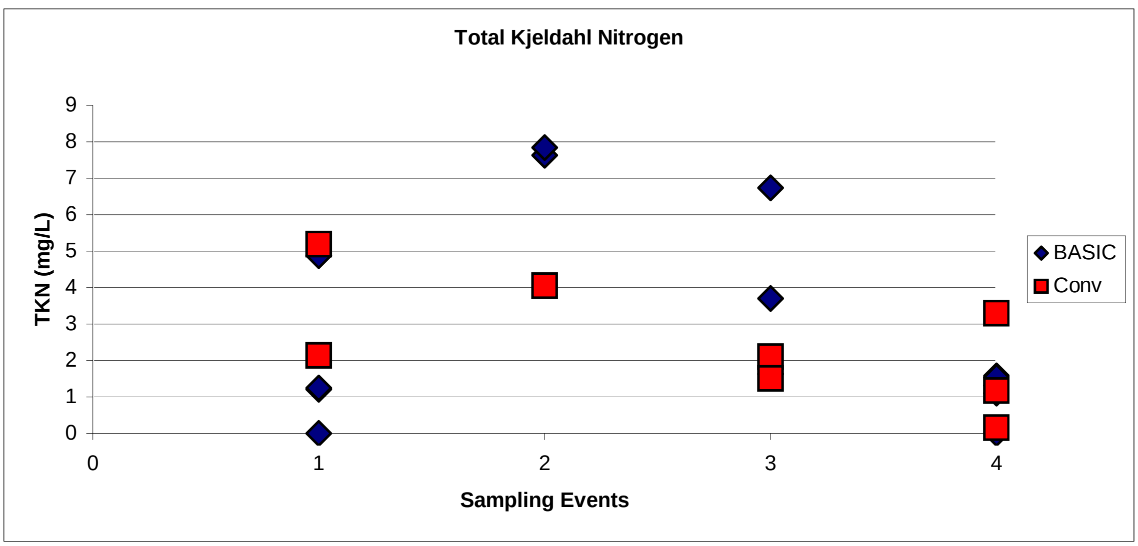

Figure 13. Total Kjeldahl Nitrogen concentrations at BASIC and conventional sites measured during the study period of the cotton growing season in 2007 and 2008.

Ortho-phosphate (PO_4) concentrations ranged from 0 - 1.9 mg/L at BASIC sites with an average of 0.6 mg/L (n = 28), while ortho-phosphate concentrations at conventional sites ranged from 0.1 – 0.6 mg/L with an average of 0.4 mg/L (n = 12) (Figure 14). Total phosphorus (TP) concentrations at BASIC sites ranged from 0.1 – 3.4 mg/L with an average of 1.2 mg/L while total phosphorus concentrations at conventional sites ranged from 0.2 – 1.6 mg/L with an average of 0.8 mg/L (Figure 15). EPA recommendations for TP are reported at 0.08 mg/L (US EPA 2001), also indicating that phosphorus represents a potential water quality concern at the sampled locations.

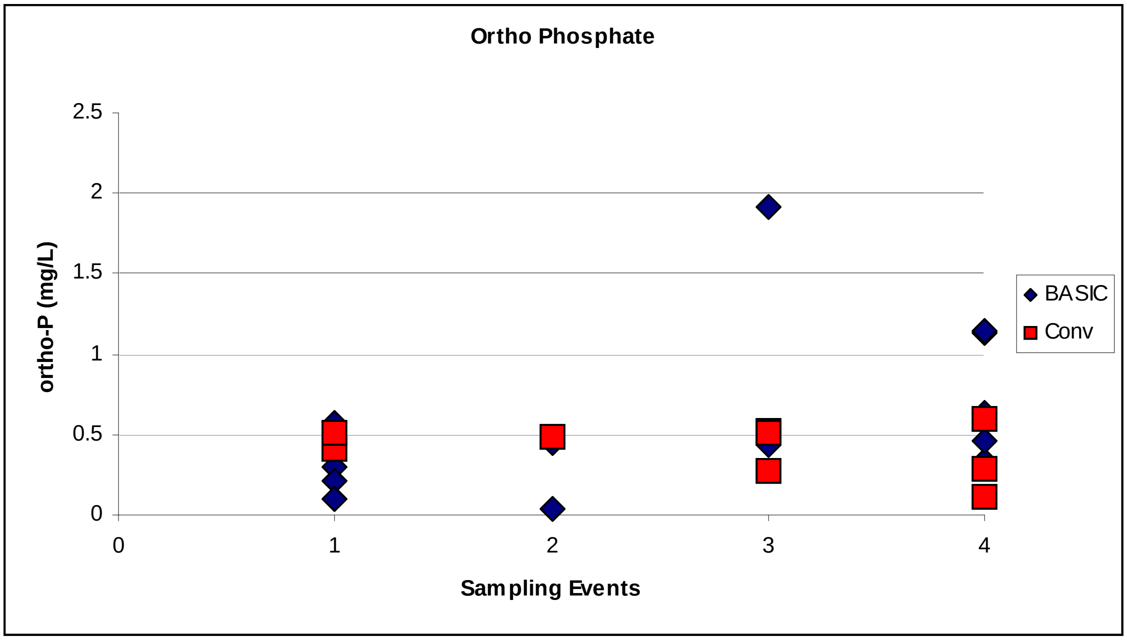

Figure 14. Ortho-phosphate concentrations at BASIC and conventional sites measured during the study period of the cotton growing season in 2007 and 2008.

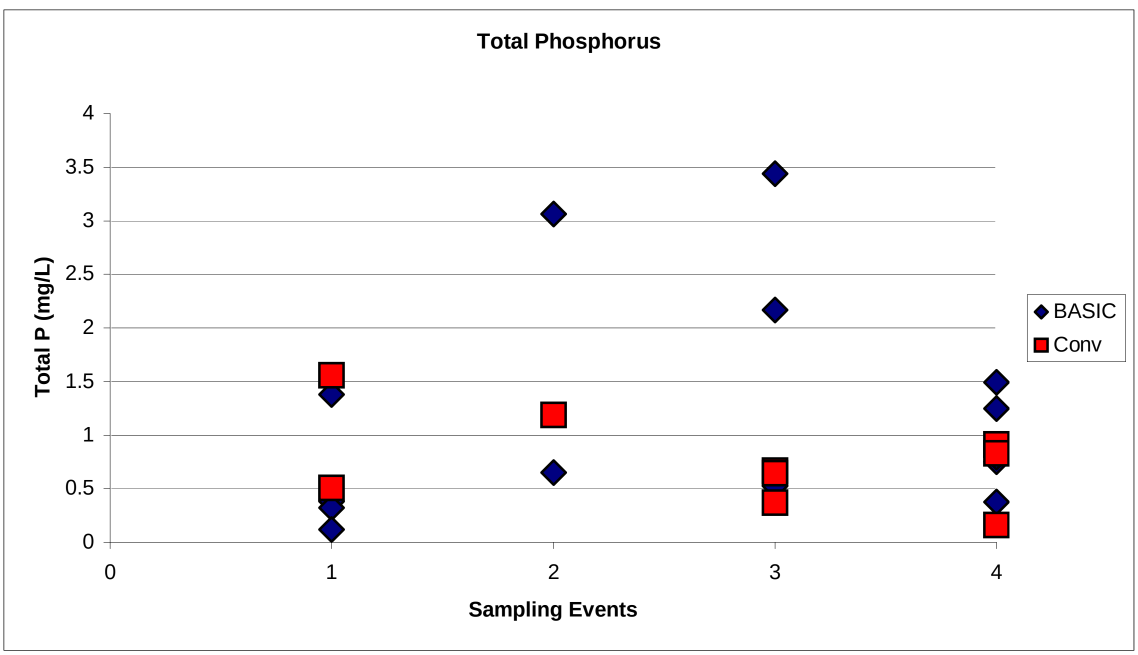

Figure 15. Total phosphorus concentrations at BASIC and conventional sites measured during the study period of the cotton growing season in 2007 and 2008.

Nutrient inputs from nitrogen fixation, rainfall, soil and bedrock weathering, and potentially from human waste to the BASIC and conventional cotton fields are probably very similar given the relatively small size of the study area and the similar site characteristics represented by the sampling locations. The only difference in nutrient input would be expected to come from differences in fertilizer applications. Sustainable soil management for the BASIC cotton fields includes the application of poultry manure and compost, while synthetic fertilizers are predominantly used on the conventional fields.

In 85% of the BASIC samples, NOx to TN (total nitrogen) ratios were slightly lower compared to conventional samples, indicating a lower organic portion of the applied fertilizer. In 57% of the BASIC samples, PO_4 to TP ratios were slightly lower, additionally indicating a lower organic content in the fertilizer. Compared to the conventional sites, the BASIC site's NOx:TN ratio was 7 – 52% lower, and the PO_4:TP ratio at the BASIC sites compared to the conventional sites was lower approximately half of the time but with a more dramatic difference (19-75%).

Average nutrient concentrations measured in this study were slightly higher than those found in other studies investigating nutrients in cotton runoff. For example, nitrate runoff losses from cotton fields in limestone soil regions in northern Alabama were measured with an annual mean of 1.3 – 2.2 mg/L (Soileau et al. 1994). In the Mississippi Delta, runoff from cotton in silty clay soil showed nitrate and phosphorus mean concentrations of 3.2 and 0.3 mg/L, respectively (McDowell et al. 1984).

In general, the majority of samples (75%) collected in this study had low total nitrogen to total phosphorus ratios (1 – 15:1). High nitrogen to phosphorus ratios (20 – 50:1) favor the development of *Chlorococcales* while lower ratios frequently lead to communities dominated by *Cyanophyta* (Smith 1983). Since blooms of cyanobacteria, especially of the most toxic and stable form *Microcystis*, have become an increasing threat to fresh and brackish waters, it is important to be aware of this increased risk. This is particularly a concern when the drainage ditch empties into a water body under low-flow conditions. Many uncertainties still remain about the pathways leading to cyanobacterial blooms and how important N:P ratios are under site specific conditions.

5.6 Pesticide and Nutrient Loads

So far the data have been presented as concentrations and compared to various water quality guidelines. The calculation of loads (mass of a substance flowing through each sampling channel cross section) provides an alternative method for evaluation of potential impacts. Loads are also useful for the growers as they can be compared to the amount of chemical applied to provide a first order approximation of proportional losses. Pesticides loads in g/day were calculated using the following equation:

Load (g/day) = Pesticide Conc. (ng/L) x flow rate (cfs) x 0.00245 (multiplier for unit conversion into g/day)

Tailwater flows were highly variable throughout the day (often greater than 50% variability). Without real-time flow data (not feasible in this project due to budget restrains), the "average" flow number had to be interpreted very carefully. Likewise, the constituent concentration was only valid for the runoff at the sampling time and should not be applied to subsequent irrigation events. This affects the accuracy of any load calculations made for agricultural tailwater flows in this study.

The average pesticide loads (Table 6) at BASIC sites were one and a half to almost five times higher for diuron, glyphosate, chlorpyrifos, and prometryn compared to conventional sites but the average calculated flow was also approximately three times higher at BASIC sites during the time of sample collection.

Table 6. Pesticide load averages at BASIC and conventional sites. Only one flow measurement and one pesticide analysis were conducted for each sampling event. The daily load calculations can only represent a snapshot in time (a small part of the entire cotton field irrigation and growing season).

Parameters	**Average Flow (f^3/sec)**	**Diuron (g/day)**	**Glyphosate (g/day)**	**Chlorpyrifos (g/day)**	**Prometryn (g/day)**
BASIC	0.23	74	1.79	0.00322	0.44
Conventional	0.08	25	1.23	0.00060	0.10

The amount of water used per acre during an irrigation period was approximately the same for the enrolled BASIC fields and the conventional fields. Possibly due to better communication with BASIC farmers as part of the SCP and advanced notice for SFEI staff before irrigation, the BASIC cotton fields were predominantly sampled during high flows in the tail ditch while the conventional fields were sampled later in the irrigation (sometimes on the second day of the irrigation). This resulted in the average flow at the conventional sites only being one third of the flow measured during sampling at the BASIC sites. Due to this bias, it could be assumed that the observed pesticide concentrations at the BASIC sites would be lower if the flow was similar to the flow at the conventional sites but no relationship between flow or SSC and detected pesticides was found to verify this assumption. All calculated relationships for SSC vs pesticide and flow vs. pesticide were too weak to adjust the pesticide data (diuron <10% with SSC, 20% with flow; glyphosate 2% with SSC, 3% with flow; prometryn 10% with SSC, <10% with flow).

The average nutrient loads (Table 7) showed a similar pattern as the pesticides. At BASIC sites the average daily loads were two to three times higher for TKN, ortho-P, and TP compared to the conventional sites. The exception is nitrate + nitrite, for which the calculated daily load was approximately three times lower at the BASIC sites compared to the conventional sites despite the higher flow.

Table 7. Nutrient load averages at BASIC and conventional sites. Only one flow measurement and one nutrient analysis were conducted for each sampling event. The daily load calculations can only represent a snapshot in time over the course of an entire cotton field irrigation.

Parameters	**Average Flow (f^3/sec)**	**Nitrate+Nitrite (g/day)**	**TKN (g/day)**	**Ortho-P (g/day)**	**TP (g/day)**
BASIC	0.23	840	1,302	207	498
Conventional	0.08	2,353	626	67	172

Nitrogen is an essential nutritional element for the cotton plant. To achieve desired yields, the adequate amount of nitrogen is very important. Cotton removes 50 to 55 lbs. of nitrogen from the soil per bale of cotton (Mullins and Burmester 1990, Unruh and Silvertooth 1996). BASIC farmers regularly test their soil to determine the nitrogen base level and to determine the additional amount of nitrogen needed. Other sources of nitrogen are considered for this calculation to minimize the amount of nitrogen added. In the San Joaquin Valley, the extensive use of synthetic fertilizers, the concentration of industrial dairies and feedlots, the new urban developments, and the rising fossil fuel combustion have increased the supply of reactive nitrogen in the environment (Galloway and Cowling 2002). At least 20 lbs. of nitrogen per acre are deposited through rainfall each year during the wet season (Cowling et. al. 2001) and do not have to be added in form of fertilizers. The consideration of these facts helped reduce the amount of nitrogen added to the fields enrolled in the BASIC program since regular soil monitoring is part of the BASIC program. This was an important achievement since the contamination of water resources by nitrate from agricultural sources is a major health and environmental quality issue confronting California today.

5.7 Ancillary Measurements

Dissolved oxygen (DO) is a very important indicator of a water body's ability to support aquatic life. Oxygen concentrations greater than 5 mg/L are generally considered safe for aquatic biota. Dissolved oxygen concentrations varied from 2.3 mg/L at BASIC 5 to 9.3 mg/L at a Conventional 2. Within this range, concentrations fluctuated without exhibiting any significant patterns at the seven sites. A change in dissolved oxygen concentrations due to the different farming practices is therefore unlikely. A total of four measurements were below 5 mg/L during the study period, two at BASIC sites, two at conventional sites.

Electrical Conductivity (EC) is a measure of how well water can conduct an electrical current. Conductivity increases with increasing amount of mobility of ions. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively and positively charged when dissolved in water. Therefore, EC is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution. The EC varied from 0.41 mS/cm at BASIC 5 to 2.95 mS/cm at Conventional 3. Measurements throughout the sampling period were fairly consistent and did not exhibit any significant changes associated with framing practices. Salinity, a related parameter ranged from 0.00 ppt at BASIC 5 to 1.4 ppt at Conventional 3 with no particular pattern exhibited for the different farming practices.

pH is a general indicator for the acidity of a water body as measured by the proton (H+) concentration: pH=-log [H+]. A measurement of pH<7 is considered acidic, pH=7 is neutral, and pH>7 is basic. pH represents the effective activity of hydrogen ions (H+) in water. Changes in pH can also affect aquatic biota indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream that could potentially cause toxicity. In this study pH values ranged from 6.5 to 9.1, both measured at BASIC 1.

Temperature of water is an important factor for aquatic life. It controls the rate of metabolic and reproductive activities, and determines which aquatic biota can survive. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. Water temperatures ranged from 16.4°C at BASIC 4 to 35.5°C at Conventional 2.

Turbidity is a measure of the cloudiness of water. It is caused by suspended matter, such as clay, silt, organic matter, plankton, and other microscopic organisms that interfere with the passage of light through water. Turbidity is closely related to total suspended sediment concentration, but also includes plankton and other organisms. Turbidity in this study varied widely from 6.0 NTU at BASIC 1 to 1,000 NTU at Conventional 2, while the flow during these turbidity measurements was four times higher at the conventional site. The turbidity fluctuation exhibited no consistent change related to different farming practices over the course of this study. The recommended turbidity according to EPA's reference conditions for rivers and streams is 5.2 NTU (US EPA 2001).

Hardness is a measurement of the concentration of divalent metal ions. In this study, hardness was measured as a concentration of calcium salt $CaCO_3$. Water hardness concentrations varied from 111 mg $CaCO_3$/L at BASIC 5 to 1,070 mg $CaCO_3$/L at BASIC 4. Water hardness describes the presence of certain minerals in the water column, and studies have shown that high calcium and magnesium concentrations in water can reduce the effectiveness of pesticides when hardness is above 150-300 mg/L in source water for pesticide mixtures (Boerboom 2001). This suggests that during 25% of the sampling events (at BASIC and conventional sites) bioavailablity of pesticides was likely reduced in the ambient water. Herbicides, especially glyphosate, are also known to be very susceptible to inactivation by silt and organic matter. Silt was not measured in this study but measured organic carbon concentrations suggested that this may have occurred.

Dissolved Organic Carbon (DOC) is a broad classification for organic molecules of varied origin and composition within aquatic systems. DOC concentrations ranged from 1.8 mg/L at Conventional 3 to 23.4 mg /L at BASIC 1 with a slightly higher average DOC concentration for all BASIC sites compared to the conventional sites.

6. Conclusion

Even though the SCP put a tremendous effort into the education of farmers and the improvement of BMPs in cotton, we could not show a statistically significant reduction in pesticide loads running off the BASIC cotton fields during irrigation in comparison to the conventionally grown cotton. Almost all sampling events in this study indicated that it was not very likely that the enrolled BASIC cotton fields that were monitored were treated differently than the conventional fields.

One of the problems that may have lead to the BASIC growers applying more chemicals could be that 2007 and 2008 were two below normal rainfall years. Farmers had to struggle with extreme water shortages because of the dry winters and the temporary shut down of the Delta pumps for Delta smelt protection. The Federal Water District had only 50% of its normal water supplies and water was predominantly assigned to higher priority permanent crops, like almonds and grapes. This additional stressor may have made growers less willing to further reduce pesticide use and risk cotton plant loss. Since mostly smaller fields were enrolled in the BASIC program (Table 1) the incentive for a slightly higher price for the sustainable cotton may not be worth taking the risk of reduced yield due to pest damage.

Another reason for the higher pesticide use the amounts that were anticipated by the BASIC program could be that several enrolled BASIC fields were next to safflower which resulted in a greater pest pressure. Safflower is a food-oil crop and generally not sprayed for its own benefit since the yield is not affected by insect damage. But it is a pest attractor and will increase pest pressures on neighboring crops. It may be sprayed for the benefit of those neighboring crops, which must be done aerially to be most efficient. The most commonly pesticides sprayed on safflower are chemicals that control insects that damage cotton and alfalfa, e.g., chlorpyrifos. Hence, chlorpyrifos concentrations could be higher at enrolled BASIC sites either due to spray drift (very common with aerial applications), potential source water contamination, or because of a high pest pressure and the need to spray the enrolled cotton field directly. In 2007 and 2008, even more safflower was grown than in previous years. Often the pest pressure got so high that cotton farmers paid the neighboring safflower farmer to spray early and regularly.

6.1 Recommendations

A reduction in the application of pesticides at the BASIC sites has an obvious and direct benefit to the watershed. However, it takes time until these benefits will result in measurable improvements in waters of the state. A two-year Project with a limited sampling budget can only point out trends observed for the duration of the study but continued monitoring would be needed to evaluate water quality improvements with more certainty.

The concentrations and total amounts of pesticides in runoff water are dependent upon the characteristics of the pesticides, methods and rate of chemical application, and timing of post-application irrigation. Previous studies reported the percentage of applied pesticides being carried off the field in cotton runoff as very low (0.1 –1%) (Spencer and Cliath 1991). The percentage for soil-applied herbicides is usually 1 – 2%. Most OP-pesticides and pyrethroids were previously reported at concentrations less than 0.1% of the application rate. Reductions in pesticide loads can be achieved with good timing of the pesticide application and the following irrigation event. Even though it may be difficult for the farmers at times to extend the time period before irrigation, a great benefit for water quality would be accomplished after approximately 23 - 31 days post pesticide application. Spencer and Cliath (1991) reported the time between the pesticide application and the irrigation event as inversely related to the log concentration of the pesticide found in runoff water.

Spencer et al. (1985) showed that during the first irrigation, most pesticide concentrations were highest within the first two to three hours of the start of irrigation runoff. Concentrations were much lower after that even though the hydrograph peaked later on during the irrigation. Pesticide runoff and water flow did not seem to be correlated in any of the monitored fields that Spencer et al. studied.

In this study there was also no apparent relationship detected between the pesticide concentrations and flow so that the main focus for additional improvements of water quality should be on elapsed time. Prolonged time periods between chemical application and cotton irrigation will contribute to the decrease in pesticide concentrations in runoff. Even if schedules have to be adjusted during the growing season due to unforeseen pest outbreaks, an attempt for pesticide reduction through elapsed time as a BMP will likely show an improvement for water quality.

Additionally, filter strips or vegetated ponds (Hunt et al. 2008) at the end of the tail ditch could reduced pesticide and nutrient loads to receiving water bodies substantially by storing runoff water from approximately the first four hours of runoff, the time period for which the concentrations seemed to be highest. After that critical time period, runoff water could bypass or overflow the pond or filter strip, leaving the more contaminated particles to settle in the retaining structure. Both recommended BMPs would be low-cost, low maintenance practices with a high probability for pesticide mitigation effectiveness.

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