

**PACIFIC NORTHWEST AGRICULTURAL SAFETY
AND HEALTH CENTER
1990 – 2006**

Report for National Academy of Sciences Review

Pacific Northwest Agricultural Safety and Health Center
<http://depts.washington.edu/pnash/>

School of Public Health and Community Medicine
University of Washington
Seattle, Washington

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CENTER OVERVIEW

INTRODUCTION

The Pacific Northwest Agricultural Safety and Health (PNASH) Center is one of ten agricultural safety and health centers created by the National Institute for Occupational Safety and Health. We are part of the Department of Environmental and Occupational Health Sciences at the University of Washington, housed within the School of Public Health and Community Medicine. The School was recently ranked by *US News & World Report* as the fourth best in the nation, and is the only school of public health in the four-state region that we serve.

The PNASH Center provides a truly regional focus by addressing the three major agricultural sectors in the Northwest -- farming, forestry, and fishing -- and serving the Northwest states of Alaska, Idaho, Oregon and Washington. We have worked to build a network of health and safety researchers, educators, health care providers, industry and community partners in the field of agricultural safety and health. We have also created opportunities for stakeholder inputs, research partnerships, and research dissemination. The PNASH Center has sponsored a formal Pilot Project Program since 1996 to encourage novel research and education projects.

The PNASH center's focus is primarily on populations not well represented in current research, including hired laborers, migrant/seasonal workers, women and children. The Center's overall aims are to:

- Conduct research related to the prevention of occupational disease and injury among agricultural workers and their families;
- Develop, implement and evaluate educational and outreach programs that promote health and safety for agricultural workers and their families;
- Develop, implement and evaluate model programs for the prevention of illness and injury among agricultural workers and their families; and
- Develop linkages and communication with other organizations involved in agricultural health and safety with special emphasis on communication with other agricultural health and safety programs.

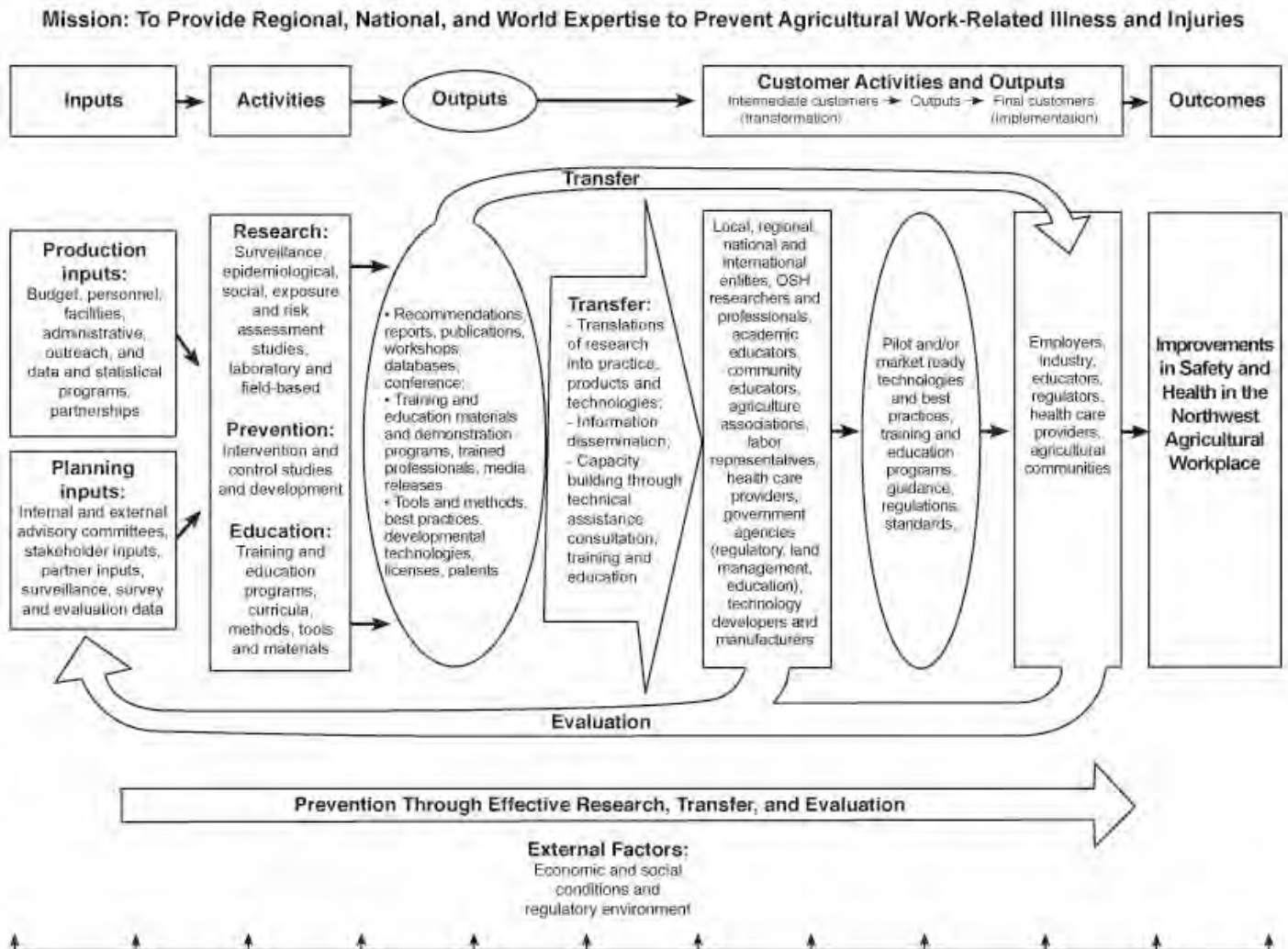
The PNASH Center is part of a vital national infrastructure dedicated to the prevention of illness and injury among agricultural producers, workers and their families. In addition to our regional partnerships, we work collaboratively with other regional centers to formulate national programs and policies in agricultural health and safety. The PNASH Center reflects a cross-disciplinary, multi-institutional, and geographically diverse set of initiatives.

The PNASH Center's principal funding is from the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention under Cooperative Agreement #5U50OH07544 and from the Washington State Medical Aid and Accident Funds. Other significant grant sponsors include the Environmental Protection Agency and the National Institutes of Health.

PNASH CENTER OVERVIEW

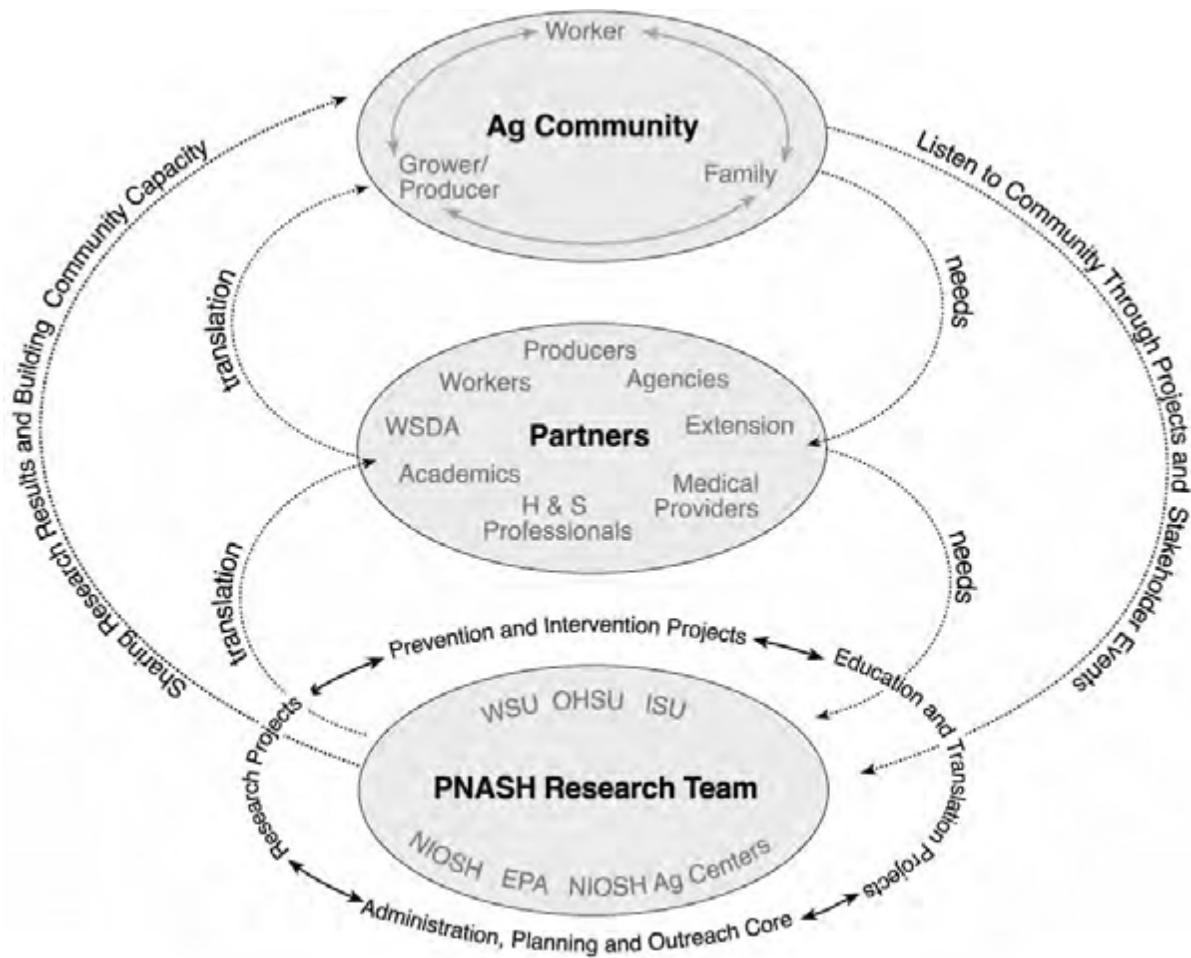
The activities of the PNASH Center can be described within an operational model that charts inputs, activities, outputs, and outcomes, as illustrated in Figure 1. The overall goal of the Center's activities is to produce practical outcomes that prevent or reduce injuries and illnesses in agriculture.

Figure 1. The PNASH Center Operational Model



The PNASH Center's activities can also be seen within the context of a regional model that places an emphasis on interactions with our regional partners, as illustrated in Figure 2. We work to reach the agricultural community – employers, workers, and the rural communities that support agricultural production – through an iterative process. The research products of the center are translated to practical findings that can be implemented within the agricultural community.

Figure 2: The PNASH Center Partnership Model



BACKGROUND AND SIGNIFICANCE

The agricultural industry (production farming, fishing and forestry) consistently ranks among the highest for worker injury and illness. Acute traumatic injury and death are among the most striking outcomes. According to the Bureau of Labor Statistics, approximately 31 deaths per 100,000 workers occurred in the agricultural sector in 2003, compared to an average of 4 deaths for the general working population. Washington and Alaska have seen some of the highest rates of agricultural injuries in the country, and nearly double the national average in the last decade.

Agriculture is a cornerstone of the Northwest's economy and the main source of livelihood for many families. The Northwest is the nation's leading producer of tree fruit, potatoes, certain vegetables (wrinkled seed peas and processing carrots), field and grass seed crops, grapes, hops, aromatic oils (spearmint and peppermint), tulips, raspberries, Christmas trees, lumber, and a variety of fished and farmed sea foods (National Agriculture Statistics Service, 2006).

Washington State agriculture directly employs from 160,000-180,000 workers annually and deciduous fruit tree work employs an estimated 47% of the agricultural workforce. Employment

in agriculture has increased 12.6% between 1990 and 1998 and expansion in the production of tree fruits (apples, cherries, and pears) has been the major source of this expanding workforce.

While agriculture adds about \$5 billion a year to the state's economy, it also adds a measure of injury and illness. The cost averages more than \$8 million a year in workers' compensation claims in just the tree fruit industry in central Washington – plus untold costs to the workers and their families.

The theme of the PNASH center is *Promoting Safe and Sustainable Agricultural Workplaces and Communities*, which frames our aim to integrate the health and safety of workers within the concept of sustainable agriculture and to develop a measuring scale for a sustainable agricultural workplace. Center Director, Richard Fenske, has stated, "In our view, the need for sustainable agricultural workplaces extends beyond the boundaries of the farm, and into the rural communities that are themselves the sustenance of the agricultural economy.... Thus, our theme encompasses a broad, public health view of sustainability and includes the next generation within these communities."

Workers

Management, harvesting, and processing rely on intensive seasonal labor, conducted mostly by Hispanic resident or migrant workers. In Washington state 69% of the agricultural workforce is Hispanic, the majority of whom are employed in tree fruit production (Washington State Employment Security 2005). These workers and their families are at special risk due to the nature of their tasks, as well as language and literacy barriers. A common health issue is musculoskeletal complaints; 40% leave or change jobs because of chronic back or neck pain, and the bulk of worker's compensation claims involve falls from ladders. Through Washington farmworker community surveys and a town meeting, we have heard that their top concerns in 2006 are pesticides and chemicals, work-related injuries and illnesses, and abusive workplace conditions.

Children

Another special population at risk for injury and illness is children who live in farm communities or work on their family farm. Young children are more vulnerable to agricultural chemicals by virtue of their higher metabolic rates, smaller body size, immature biological systems and behaviors. Teenagers working on family farms have higher injury rates than those working in agribusinesses not owned by their family. Hispanic youth working in agriculture report higher injury rates than their non-Hispanic counterparts. The PNASH Center conducts prevention-oriented, research, and intervention development to reduce agricultural injuries and illnesses among children of agricultural workers in the Northwest. Priority issues are identified through research and community surveys.

Setting Priorities

The more than 50 projects undertaken by the PNASH Center span a variety of subjects and research disciplines. As a NIOSH Agricultural Center, the majority of our projects focus on farming. However, recognizing the importance of the fishing and forestry industries to the Northwest, some projects address their needs.

In the development of projects, we select topics that

- Address hazards that are the most serious, affect the greatest number of workers, and where research will make a difference.
- Meet the needs of Northwest employers, workers, and service providers. We have established a process that engages various constituencies familiar with agricultural health and safety throughout our region to help us establish PNASH Research Priorities.

The Center's Agricultural Community, Outreach, and Education Program (ACOEP) is the Center's foundation for building relationships and sharing information with producers, farmworkers, health care providers, extension specialists, government workers, and other researchers and educators. Outreach links the Center to its stakeholders in the agricultural community, forging the partnerships that are essential to the success of all of our activities.

Agricultural Occupational Research Agendas

A key strategic element in our approach has been the development of a stakeholder-based hazard priority ranking process for each of the three major industries. First, in 1998 we gathered producers, labor representatives, health care providers, and key government agency figures to discuss health and safety priorities in Northwest farming. This "Farm Summit" produced an occupational research agenda modeled after the National Occupational Research Agenda (NORA) process pioneered by NIOSH. Second, in the area of forestry, we convened a Technical Advisory Committee of forestry health and safety experts from across the region to help plan a Forestry Safety Workshop. The Workshop was held in February 2000, and included leaders from industry, labor, tribal nations, and government agencies. The research agenda generated from this meeting presents many exciting challenges, and has led to the center's formal inclusion in forestry industry conferences and activities. Third, in the area of commercial fishing we established a Technical Advisory Board of industry leaders to help establish research priorities. The board recommended several directions for our center's activities, but did not believe that a formal priority ranking process was needed for that industry. As a result, no priority-ranking workshop was organized for the fishing industry. In sum, we believe that our center has articulated a new role for health and safety research and education in each of these industries, and has established credibility among industry and labor leaders in the region. The priorities identified by our farming and forestry stakeholders are presented in Table 1.

Additional information regarding the Farm Summit and the Forestry Safety Workshop can be found in the following documents: *Occupational Research Agenda for Northwest Farming* and *Occupational Research Agenda for Northwest Forestlands*. Downloadable PDF reports of these events are available at the PNASH Center website:

http://depts.washington.edu/pnash/research_summaries.php#haz_three

Table 1. Northwest Priority Research Areas – Findings of the PNASH Center’s AgNORA Process

FARMING	FORESTRY
DISEASE AND INJURY	DISEASE AND INJURY
Musculoskeletal Disorders	Hearing Loss
Respiratory Disease	Heat and Cold Stress
Skin Disease	Musculoskeletal Disorders
Traumatic Injuries	Skin Disorders
	Traumatic Injuries
WORK ENVIRONMENT & WORKFORCE	WORK ENVIRONMENT & WORKFORCE
Chemical Exposures	Work Organization
Special Populations at Risk	Environmental Hazards
Social/Economic Foundations of Workplace Safety	Hazardous Operations
Risk Communication Barriers	Training
	Workplace Behaviors
RESEARCH TOOLS & APPROACHES	RESEARCH TOOLS & APPROACHES
Hazard Control Technology	Hazard Control Technology
Intervention Effectiveness	Intervention Effectiveness
Surveillance Research Methods	Surveillance, Data Collection & Reporting
Diagnostic Approaches	Medical Services
	ECONOMIC & POLICY FACTORS
	Government Policy
	Industry Trends
	Top Level Commitment

In 2003 personal interviews with health care providers of farm workers yielded new insight into the needs of this important constituency. The PNASH Center identified the following priorities for health care providers: health effects due to the quality of farm worker housing, skin diseases, depression, and evaluation of programs that enlist community health workers, or *Promotoras*. All of the medical directors of the clinics contacted believed that the main farm worker illnesses were poor nutrition, diabetes, substance abuse, depression, asthma, and domestic violence. The most common noted occupational illnesses were related to musculoskeletal disorders and allergies.

El Proyecto Bienestar Hispanic Agricultural Community Health Concerns

The PNASH Center’s community-based participatory research project (*El Proyecto Bienestar*, the Well Being Project) in the Yakima Valley of Washington State (Dr. Matthew Keifer, Principal Investigator) has conducted key informant interviews and two years of community surveys, culminating in a Town Hall meeting in April 2006. This project has also identified key health concerns in this important agricultural community, as indicated in Table 2.

Table 2. El Proyecto Bienestar Health Priorities

CATEGORY	PRIORITY
Exposures	Pesticides and chemicals Water contamination Extreme workplace temperatures Air contamination
Outcomes	Work-related illnesses and conditions Work-related injuries Cancer Dehydration or heat illness
Contextual Factors	Abusive workplace conditions Low wages or job instability Lack of documentation of immigration status Lack of access to medical care Problems with workers' compensation claims

NIOSH Agricultural Sector Town Hall Meeting

On Jan. 17, 2006, the PNASH Center served as a site-host and planner for NIOSH's agricultural sector NORA Town Hall meeting in Seattle. Through our networking in the region and with the assistance of the other agricultural centers, more than 120 people attended the Town Hall, and 51 speakers presented their ideas for research. We were happy to contribute to the development of the speaker docket, and look forward to the next decade of NORA to refresh our understanding of agricultural research priorities.

SIGNIFICANT FINDINGS

The PNASH Center has succeeded in developing a substantial presence and working relationship with the Northwest farming industry, and in particular, with the tree fruit industry. The Center has had an excellent experience working with a variety of partners, gaining industry support, and in conducting farmworker community-based research.

We summarize six major accomplishments by program area:

- Pesticide Exposure Assessment Methods
- Interventions to Reduce Pesticide Exposures among Agricultural Workers and their Families
- Traumatic Injuries
- Musculoskeletal Disorders
- Noise and Vibration Exposures
- Special Populations – Hired Farmworkers and their Families

TRANSLATION OF FINDINGS

The PNASH Center's activities have made demonstrable impacts in Northwest agricultural safety and health. While we are not able to document that our activities have led to the end goal of reducing injury and illnesses, the following intermediate outcomes are closely linked to our study results and expertise.

Washington State Cholinesterase Monitoring Rule

In 1995, a Technical Advisory Group (TAG) formed by the Washington State Department of Labor and Industries (L&I) found that a cholinesterase monitoring program was technically feasible and necessary to protect worker health. Both PNASH director Richard Fenske and co-director Matthew Keifer served on the TAG. The recommendations outlined in the TAG report, *Cholinesterase Monitoring in Washington State*, were used by the Washington State Supreme Court to decide if a monitoring system was feasible and their recommendations greatly informed the resulting program. The TAG report recommended:

- Medical supervision for workers who mix, load, or handle Class I or II OPs or carbamates
- Testing for workers who handle pesticides more than 3 consecutive days, or more than a total of 6 days in a 30-day period.
- A single pre-exposure baseline measurement taken from workers each year prior to exposure.
- Follow-up testing every three to four weeks (depending on spray cycle) until spray activities are completed for the season.
- Removal of workers whose red blood cell cholinesterase is at or below 70% of baseline levels or plasma cholinesterase is at or below 60% of baseline. Workers would not be exposed to OP or carbamate pesticides until their cholinesterase levels return to 80% or more of their baseline.

In 2000, the Washington State Supreme Court mandated that the L&I develop a Cholinesterase Monitoring Program for workers handling acutely toxic pesticides. The new rule was implemented in February 2004, requiring agricultural employers to provide blood testing to workers who handle organophosphorus and carbamate pesticides. PNASH Center investigators have been instrumental in the development and implementation of the new Washington State rule. Initially, L&I organized an expert committee as it implemented the rule. Dr. Matthew Keifer and Dr. Patricia Boiko, both from the PNASH Center, served on this committee. Subsequently, the PNASH Center developed a training program for clinicians who planned to participate in the monitoring, and published this program as a clinical guide (available through the PNASH Center website). The PNASH Center also contracted with Dr. Karl Weyrauch to develop and test an appropriate informed consent document for pesticide handlers that could be used by clinicians in the testing program (available through the PNASH Center website).

The University of Washington's Department of Environmental and Occupational Health Sciences (DEOHS) has also assisted the state in the evaluation of findings from this mandatory monitoring program. Specifically, several faculty members have been active on the Scientific Advisory Committee formed to oversee data collection and analysis. Dr. David Kalman (the DEOHS department chair) has chaired the program's Scientific Advisory Committee; Dr. Matthew Keifer of the PNASH Center, Professor Gerald van Belle, and Clinical Instructor Dr. David Bonauto have served as members. Dr. Kalman, who for 19 years directed the Environmental Health Laboratory, called this an example of "taking science out of the lab and into the regulatory world." The idea behind the monitoring, he said, is to identify potential poisoning before symptoms develop, providing a margin of safety. Dr. Kalman's committee is reviewing monitoring results to allow the state to determine whether the monitoring program is,

in fact, protecting a significant number of workers. Dr. Keifer described the goals of the monitoring program as preventing poisonings, identifying hazardous conditions and practices, increasing hazard awareness among workers and employers, and helping to determine a safe time frame for returning to work after a poisoning event. The PNASH center is currently conducting follow-up studies to investigate the causes for cholinesterase depression and is also evaluating a field test kit that clinics can use.

Washington State Department of Agriculture Pesticide Applicator Hands-on Training

The PNASH project team, under the leadership of Dr. Fenske, has developed a reciprocal relationship with our partners to enhance the Washington State Department of Agriculture's (WSDA) Hands-on Pesticide Handler Training. This was accomplished by the incorporation of PNASH developed fluorescent tracer demonstrations into the standardized WSDA pesticide-training curriculum. One hundred and fourteen handlers have been trained using this method. Based on the results of this training the WSDA has adopted the use of the FT training on permanent and ongoing basis. The response from educators, orchard managers, and students to the FT hands-on training has been very positive. In addition to the Washington state training program, a FT Manual for educators and others who train pesticide handlers, is being produced. The manual will provide users with specific 'how to' instructions for different training environments, and will be produced in Spanish and English. This manual will be available for distribution locally and nationally.

Washington Tree Fruit Industry Technology Roadmap

The PNASH Center's research on injuries in the tree fruit industry, led by Dr. Matthew Keifer, has found that falls from ladders are the most common injury reported by orchard workers in Washington. The results from these studies have contributed to a plan by the tree fruit industry in the United States to incorporate new technologies in agricultural production. For example, mobile platforms for workers have been introduced into several orchards, obviating the need for ladders. In 2003, the industry developed a "Technology Roadmap" with the goal of improving the sustainability, efficiency, and quality of fruit production in the United States. The Technology Roadmap seeks not only to improve the operational efficiency of tree fruit harvesting, but also seeks to create a more prosperous, skilled year-round work force that works under safer conditions. The tree fruit industry acknowledges that a past practice of merely increasing workload in order to increase productivity is outmoded, yet pure reliance on technology is likely to fail unless it also improves the lives, social conditions, and economics of the industry. PNASH Center investigators are currently working in partnership with the Washington Tree Fruit Research Commission and Washington State University to incorporate sound ergonomic practices into the use of mobile platform technologies in order to prevent musculo-skeletal disorders in the agricultural workplace.

Capacity Building in Farmworker Hispanic Communities

PNASH Center investigators, through the leadership of Dr. Matthew Keifer, have worked to enhance the center's involvement with Northwest farmworker communities. The project, El Proyecto Bienestar, a community-based participatory research project, has been instrumental in capacity-building through various aspects of its work. El Proyecto Bienestar has joined forces with ConneX, a program for economically or educationally disadvantaged students from the Yakima Valley who are interested in pursuing health careers. The University of Washington (UW) accredited curriculum for undergraduates involves classroom work on environmental and occupational health, environmental justice, community-based participatory research, and the scientific method. The course ends with an intensive fieldwork experience, during which students carry out a community survey, complete data analysis and present their findings to the project's Community Advisory Board for inclusion in the project's dataset. Each year, the

ConneX students have received scholarships to present their work at the Western Migrant Stream Forum, where they are exposed to a wide range of academic research and intervention activities. El Proyecto Bienestar has also raised general awareness among farm workers about the scientific process. A recent “Town Hall” meeting in Yakima was a clear example of this effort, and provided a way to share and receive input about environmental and occupational health research. The meeting was one step in a process that has been important in building the capacity of individuals to understand both the potential uses and the limitations of scientific research. Finally, El Proyecto Bienestar has increased the participation of community members in graduate student research. This year, we had an individual from the community act as a committee member for a public health graduate student. This type of partnership increases the knowledge of community members about the processes of academic work, and makes the academic process more transparent for the general community.

Capacity Building of Agricultural Employers

The PNASH Center has focused substantial effort on building partnerships with agricultural employers. We have sponsored numerous short courses that have been attended by farmers. For example, our 2004 “Pesticide Issues” conference, co-sponsored by Washington State University, included special breakout sessions for employers. The PNASH Center director has also given presentations at meetings of employer organizations such as the Washington Growers League.

Most recently, the PNASH Center has played an active role in the development of a new forum for education and outreach, the annual Governor’s Agricultural Health and Safety Conference, or Ag Safety Day. The first Ag Safety Day was held in the late winter of 2004 in Yakima, Washington, and was attended by over 300 agricultural employers and their lead supervisors. PNASH Center investigators served on the Planning Committee. In 2005 we were again active on the Planning Committee, and PNASH Center staff made several of the educational presentations at the conference on such topics as cholinesterase monitoring, heat stress, and reducing children’s exposure to pesticides. Ag Safety Day is an extraordinarily important new development in our region. The conference is held with both English and Spanish language sessions, thereby reaching the primarily Hispanic supervisors who direct the day-to-day activities of workers at the worksite. Ag Safety Day is an ideal venue to transfer PNASH Center research findings to an audience that can implement our educational and prevention strategies.

Capacity Building of Health Care Providers and Occupational Health Professionals

Over the past ten years, the PNASH Center has informed and guided professionals and graduate students engaged in agricultural health and safety. The Center has hosted 14 professional education courses. In our efforts to ensure participation from professions working in rural, agricultural settings, we offered most of the courses in farming communities. We also designed the courses to incorporate breakout and Spanish language sessions to be inclusive of diverse audiences.

The PNASH Center has been pleased to educate and provide research opportunities for graduate and undergraduate students. Students have played an important role in many of the research projects in the Center. We are able to support their research efforts and tuition through funds allocated through the NIOSH-funded Education and Research Center (ERC) and UW departments such as the Department of Environmental and Occupational Health Sciences. Most recently, an EPA grant has allowed PNASH to develop curricula that will be inserted into health care provider higher education for both advanced and mid-level practitioners. PNASH faculty and staff through education and mentoring are improving the capability of future health and safety practitioners.

National Policies and Programs for Agricultural Worker Safety and Health

The work conducted by PNASH Center faculty has led to invitations to participate in national policymaking, particularly in the area of pesticide health risks. In 2002-2003 the U.S. Environmental Protection Agency completed its national evaluation of the federal Worker Protection Standard. Both Dr. Fenske and Dr. Keifer were invited to present their views at the U.S. EPA's "Worker Risk Seminar", a conference that reviewed the strengths and limitations of this important rule that protects agricultural workers from overexposure to pesticides. Fenske and Keifer were the only academic researchers invited to speak at this conference.

Other examples of national service are as follows: Dr. Keifer chaired a national panel to develop diagnostic strategies for pesticide-related illness, and edited a widely cited issue of *Occupational Medicine State of the Art Reviews* on the health effects of pesticides; Dr. Fenske served for eleven years on the advisory panel of the NCI/NIEHS/EPA Agricultural Health Study; Dr. Keifer served on a NAS panel to evaluate the health risks of methyl bromide as a soil fumigant; Dr. Fenske currently serves on the National Academy of Sciences/Institute of Medicine committee that reviews the health effects of Agent Orange and other herbicides used in Vietnam; also, Dr. Fenske is currently a member of the U.S. EPA's Science Advisory Board, the Agency's lead scientific advisory group; he was also appointed recently to the EPA Human Studies Review Board (HSRB), which is responsible for evaluating the scientific and ethical quality of intentional dosing and human exposure studies. The HSRB's activities include the review of scientific protocols for worker exposure studies during pesticide applications and field reentry. Dr. Keifer was recently appointed to the EPA's Pesticide Program Dialogue Committee, a key advisory group to EPA on pesticide policy.

Most recently, Dr. Keifer received a 5-year award from U.S. EPA through a competitive grant process to develop new curricular materials related to pesticides for health care providers ("Pesticide Effects: Integration into Health Care Provider Curricula"). This newly funded project's goal is the only one of its kind in the country. Its purpose is to improve the training of clinicians in the diagnosis, treatment, and prevention of pesticide poisonings. It will develop modules of pesticide related content into pre-med, nursing, mid-level practitioner (physicians' assistants and nurse practitioners) and physician training through the collaborative efforts of faculty from Heritage College, Seattle Pacific University, Medex Northwest, and the UW Schools of Nursing and Medicine. The content in these courses will be tested, and the results disseminated to educational institutions around the nation.

International Programs and Activities

The work of PNASH Center has extended beyond the Northwest region, and has made an impact internationally. Our center works very closely with the University of Washington's NIH-sponsored Fogarty International Center, "International Training in Environmental and Occupational Health". Dr. Matthew Keifer, our co-director, serves as director of this international center. Work conducted through the PNASH Center has informed practices in both

Central America and Southeast Asia. PNASH Center investigators have trained health and safety professionals from Costa Rica, Nicaragua, Vietnam and Thailand. In addition, specific research methods and intervention strategies have been introduced in these and other countries: Dr. Fenske's fluorescent tracer technique for evaluating pesticide exposures has been transferred to scientists and educators in Ecuador, Nicaragua, and Vietnam; our center's work with saliva biomonitoring has been transferred to researchers in Thailand and Nicaragua; and Dr. Keifer's work with cholinesterase monitoring has been transferred to both Vietnam and Thailand.

EMERGING PROBLEMS

Commercial Fishing Emerged Hazards and Barriers to Participation in Research

In the late 1990's, the Center assembled a 13-member Technical Advisory Board to guide our engagement with the Northwest commercial fishing industry. This board informed the development of two projects, each with unexpected impacts on the Center's future work with the fishing industry. These PNASH Center projects were "Respiratory Health in the Seafood Processing Industry" and "The Implications of the Jones Act on Health and Safety in the Commercial Fishing Industry."

The project, "Respiratory Health in the Seafood Processing Industry," focused on potential respiratory illnesses associated with crab processing among commercial fishers in the Northwest. This project developed into an extraordinary network of collaborators during the most recent project period, including NIOSH's HETA group, OSHA Region X, and the Dutch Harbor Clinic in Alaska, whose partnership in the project, "Crab Related Respiratory Illness in Dutch Harbor, Alaska," resulted in an Honorable Mention for the 2001 NORA Partnering Award. Results of this project were published both by NIOSH investigators and PNASH Center investigators.

The project, "The Implications of the Jones Act on Health and Safety in the Commercial Fishing Industry," demonstrated that there are significant policy and liability barriers to fishing industry cooperation in hazard and risk assessment projects. The injury compensation system available to seamen is unique in that it provides guaranteed benefits similar to workers' compensation (i.e., maintenance and cure) and also allows them to sue their employers to obtain a tort recovery for negligence under the Jones Act or for unseaworthiness. A seaman's burden of proof is significantly less than in an ordinary injury case. Moreover, the recoveries a seaman can obtain typically are higher than what would otherwise be received by a shoreside worker who would fall under a workers compensation system. For these reasons, employers are often reluctant to participate in identifying health and safety risks that could form the basis of establishing their liability. This, in turn, has limited our further work in investigating fishing industry hazards.

The National Agricultural Tractor Safety Initiative

While tractor injuries and fatalities present a long-standing problem, this area of research was a new area of work for the PNASH Center. The PNASH Center was brought into this national initiative early in its conception as the developers and writers of the National Agricultural Tractor Safety Initiative publication. The launch of the publication to interested parties took place at the National Symposium on Agricultural Health and Safety in June 2004. This project brought together all the NIOSH Agricultural Centers in their first joint project to address a known problem area. The Centers are now working together to develop an informed solution to the high fatality and injury rates from tractors. PNASH continues to develop communication materials, including a website, for the national initiative and serve as a regional resource.

NEW AND FUTURE DIRECTIONS

Past Redirections

We have recognized our limitations in trying to serve three agricultural sectors in a four-state

region. Many of our resource needs lie in fiscal support, but we also need qualified principal investigators who can address identified stakeholder needs. Over the past 10 years, the Center has been successful in gaining additional project grants in our areas of expertise from Washington State, NIOSH/CDC, US EPA, and NIH. In the past, we broadened our field of research by engaging regional investigators in Northwest priority research through our Pilot Project program. The Pilot Project program also enabled us to respond quickly to emerging problems and stakeholder needs. In the past four years, without the Pilot Project program, we have struggled to respond to needs and bring in new investigators. In the current competitive renewal process, NIOSH reinstated the Pilot Project program, which will greatly aid our ability to respond to regional needs.

Forestry was the main casualty of our scaled-back fiscal and investigator resources. The development of the *Occupational Research Agenda for Northwest Forestlands* offered the Center industry support, partners, and a compelling need, but without an investigator to lead this effort, we have done little more than maintain our relationship with industry leaders and disseminate general safety and health educational information. Unfortunately, in the last cycle of funding, one of the key projects not funded addressed a forestry need investigating noise and vibration exposures. Without a substantial project in forestry, little progress was made. Nonetheless, we continued to embrace the three-industry scope because of the importance of these industries to the Northwest.

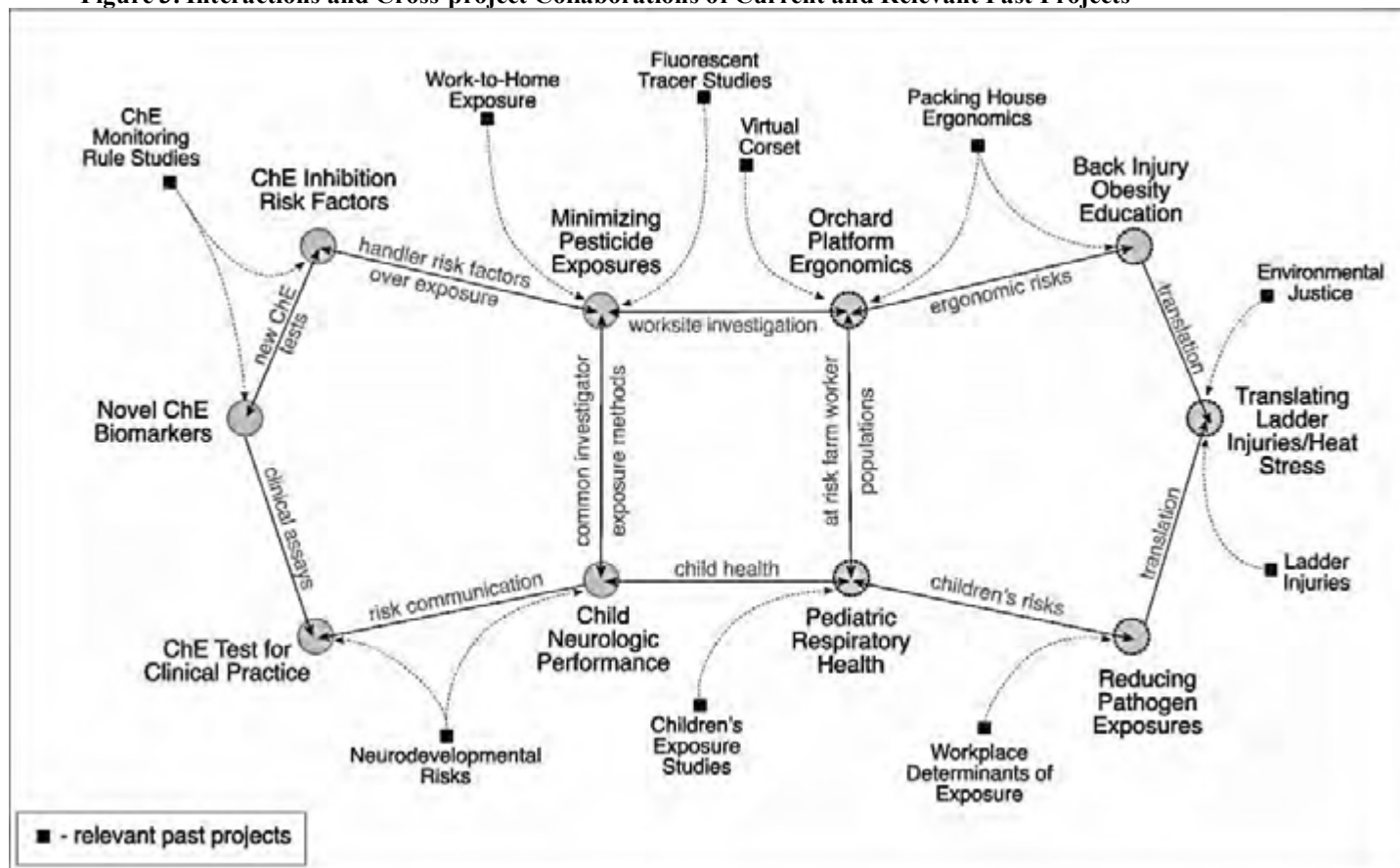
New Directions

For the coming years, the PNASH Center has adopted the theme “***Promoting safe and sustainable agricultural workplaces and communities.***” This theme grew out of our successful September 2004 conference, “Cultivating a Sustainable Agricultural Workplace.” The conference attracted participants from across the nation because it brought occupational health and safety researchers and educators face-to-face with sustainable agriculture practitioners. Our goal was to highlight the need to explicitly recognize the health and safety of workers within the concept of sustainable agriculture, and to develop metrics for a sustainable agricultural workplace. We noted that neither the 1990 farm bill (Food, Agriculture, Conservation, and Trade Act), nor the President’s 1997 Sustainable Agriculture Task Force Report acknowledged the need to include occupational health and safety as a part of sustainable agricultural production processes. In our view, the need for sustainable agricultural workplaces extends beyond the boundaries of the farm, and into the rural communities that are themselves the sustenance of the agricultural economy. Thus, our theme encompasses a broad, public health view of sustainability, and includes the next generation within these communities.

PNASH is also looking to a future assemblage of projects that link multiple institutions within our region, are multi-disciplinary, and result in synergies from information exchanges and interactions. Figure 3 illustrates the multiple connections among the ten proposed Center projects. On the left side of the figure we see five projects with a common thematic focus: **preventing pesticide-related injury and illness**. This issue is a very high priority in our state; the WA State Supreme Court recently mandated cholinesterase (ChE) testing for pesticide handlers, and overexposures have now been documented. The five projects on the right side of Figure 3 also have a common thematic focus: **promoting safe workplaces and communities**.

Another important development for the PNASH Center has been the appointment of Dr. Fenske (Center P.I.) as a Washington State University Visiting Scientist. He will spend a part of each year at the WSU Center for Precision Agriculture in Prosser, WA, working directly with WSU researchers to better integrate health and safety into new agricultural production processes.

Figure 3. Interactions and Cross-project Collaborations of Current and Relevant Past Projects



Trends

In conducting our future work and developing new projects, we are also keeping abreast of trends in Northwest agricultural workforce and practices. Some of these include:

- **Hispanic Workforce Upward Mobility.** The resident Hispanic workforce is increasingly moving into other occupations or taking leadership roles in the agricultural industry as supervisors, managers, and farm owners/employers.
- **Hired Workforce from Central American Indigenous Communities and Thailand.** The hired temporary workers doing hard labor are increasingly indigenous to Mexico and Central America, and recently guest workers from Thailand.
- **Agging Experienced Workforce.** The experienced agriculture workforce is aging; younger workers are not staying in the field.
- **Tree Fruit Industry "Technology Roadmap."** The technology roadmap outlines the industry's goals of improving the sustainability, efficiency, and quality of fruit production in the United States. Major goals of the Technology Roadmap are to use technology to improve the operational efficiency of tree fruit harvesting and to create a more prosperous, skilled year-round work force that works under safer conditions.

PESTICIDE EXPOSURE ASSESSMENT METHODS

INTRODUCTION

The risks faced by agricultural workers and their families through contact with pesticides have not been well characterized. The PNASH Center has conducted a series of field investigations in the Northwest over the past 15 years to better understand pesticide exposure. In so doing, we have developed novel techniques for pesticide exposure assessment that have been adopted by researchers throughout the United States. As a result, the PNASH Center has developed a reputation as a leader in pesticide exposure assessment methodology.

GOALS

The overall objective of this program area has been to develop accurate and practical methods for assessing pesticide exposures in agricultural communities, with particular emphasis on agricultural workers and their children. Specifically, we have worked to:

- develop environmental, personal and biological monitoring techniques, and
- improve methods of exposure assessment (i.e., questionnaires, exposure opportunity models, and spray drift models).

BACKGROUND AND SIGNIFICANCE

The health risks of pesticides remain an area of great scientific uncertainty and public discussion. Recent toxicologic and epidemiologic studies have suggested that relatively low levels of pesticide exposure can have significant impacts on neurologic functioning. Washington state's recent Cholinesterase Monitoring Program requires that pesticide handlers who mix, load, or apply highly toxic pesticides be offered baseline and periodic blood monitoring to evaluate exposure. This program has heightened concerns among employers and workers.

The quality of both epidemiologic studies and human health risk assessments relies on accurate and reproducible exposure assessment methods. When we began our studies of pesticide exposures among children of agricultural families, there were virtually no standard methods available, since this population had never been the subject of systematic study.

Children are considered a vulnerable population in regard to pesticide exposures. The Food Quality and Protection Act of 1996 requires that pesticide risk assessments for children take into account all pathways and routes of exposure, and simultaneous or sequential exposure to compounds with similar toxicologic properties. Children of agricultural workers are a special sub-population for pesticide exposure, since they are exposed not only through diet and residential use, but may also receive exposures due to work-to-home transmission of pesticides and via pesticide drift. The PNASH Center has focused much its work on improving exposure assessment methods for this population, including housedust sampling, urine sampling, and time-location analysis.

The measurement of pesticides in the urine of workers and their children provides an estimate of internal dose and risk. The PNASH Center has developed new methods for such biomonitoring in children. Our group has also explored the novel method of saliva biomonitoring. Saliva biomonitoring permits measurement of the parent compound rather than a metabolite, thus providing a more accurate estimate of internal dose. Finally, the measurement of cholinesterase enzymes found in the blood has been used to monitor occupational exposures to organophosphorus (OP) and carbamate (CB) pesticides for over 50 years. The depression of these blood enzymes is considered to be a surrogate measure of possible depression of a similar enzyme that is vital to function of the nervous system. Pre-exposure (baseline) and post-exposure sampling is required to determine an individual's drop in cholinesterase activity. The PNASH Center has worked actively to improve the methods and protocols involved in cholinesterase monitoring. Our work has provided a foundation for Washington state's Cholinesterase Monitoring Program. Most recently, we have worked to validate a portable test kit -- the EQM™

Test-Mate™kit – for field use. This kit can provide immediate cholinesterase readings, permitting a more rapid response to cases of overexposure, and on-the-spot retesting to check for false positive readings. However, it is not yet clear that the kit can provide ChE measurements with accuracy and precision that has been achieved with laboratory methods.

The primary route of pesticide exposure for most agricultural workers is via skin absorption. Measurement of skin exposure in agricultural workplaces, and quantitative modeling of dermal absorption of pesticides have proven to be complex technical problems. The PNASH Center has worked to improve methods in this area, leading to more accurate estimates of exposure, dose, and risk. In the case of epidemiologic studies, tools are needed to estimate worker exposures over extended periods of time. Traditional work history questionnaires have not demonstrated high reliability or accuracy among agricultural worker populations. The PNASH Center has focused its efforts on the development of icon-based methods that can be effective with low literacy populations.

Agricultural worker exposure to pesticide drift is a major public health concern in the Northwest. Workers may be exposed to drift when adjacent fields are treated. Or they may live in close proximity to farmland that is treated with pesticides on a regular basis. Concern with pesticide drift extends to the families of agricultural workers, and particularly to young children who may be exposed through their normal play activities. The PNASH Center has worked to develop new modeling approaches to pesticide drift that are directly relevant to Northwest agriculture. We have also developed a novel LIDAR method to characterize drift patterns in real time.

ACTIVITIES

Dust Sampling of Pesticide Residues in the Homes of Agricultural Workers

We have conducted house dust sampling for pesticide residues in the homes of agricultural workers since 1992. Our first study involved about 50 worker homes and a reference population. A 1995 study focused on a population of about 100 workers, and a 1999 study involved over 200 workers. We developed a standard procedures for use of a vacuum sampler known as the HVS3, including instructions for sample collection, instrument cleaning between samples, and quality assurance procedures. We also developed an analytical method capable of measuring multiple OP pesticide compounds in dust samples. We validated this method and published it in 2002 (Moate et al. 2002).

Urinary Metabolite Monitoring of Children's Exposure to Pesticides

We adapted existing methods for the measurement of OP pesticide metabolites in workers to the assessment of exposures in children. This work involved improving sensitivity to quantify the relatively low levels of metabolites in children's urine samples. We validated and published this method (Moate et al. 1999). We have used this method in numerous studies of children's exposure (see products section).

Global Positioning System (GPS) Methods for Children's Time-Location Studies

One of our doctoral students, Kai Elgethun, focused his dissertation research on the development and use of a novel global positioning system suitable for research with children. This device was developed in conjunction with a private manufacturer. We have used it in several field studies, including a study that characterized the activities of children of agricultural workers before, during, and after an aerial pesticide application (Elgethun et al. 2003; Weppner et al. 2005). As a result of his work, Dr. Elgethun was invited to meet with federal scientists in Denmark to discuss the application of the method to studies in that country. This method holds tremendous potential for improving the accuracy of children's exposure studies.

Saliva Biomonitoring

PNASH Center researchers, led by Dr. Alex Lu, conducted several years of laboratory studies with animal models in the 1990's to validate the use of saliva as a matrix for pesticide exposure sampling (see Products section). These studies were the first to systematically address this issue, and are the foundation for all of the research that is being done in this field presently. We have also demonstrated the feasibility of saliva biomonitoring in several population studies, including a collaborative study with NIOSH scientists of herbicide applicators (Denovan et al. 2000, Hines et al. 2006), studies of farmers and their children in Nicaragua (Rodriguez et al. 2006), and agricultural workers in Thailand.

Advances in Cholinesterase Monitoring

The PNASH Center has worked directly with the manufacturer of the EQM Test-Mate™ Kit to improve its accuracy and precision. We have tested this kit in both laboratory and field settings, and provided recommendations to the manufacturer that have been incorporated into new models of the instrument. Most recently we have performed rigorous testing of the kit in conjunction with the Washington State Cholinesterase Rule. Phase 1 of this work has involved measurement of ChE levels with the portable test kit, side-by-side with measurements conducted by the Washington State Department of Health Public Health Laboratory. One of our research scientists, Dr. Angela Carden, conducted these analyses in the summer of 2005 at the Public Health Laboratory (PHL) in Shoreline, WA. Dr. Carden ran each of 50 blood samples in triplicate using the test kit. These results were then compared with those generated by PHL for the same samples. We found excellent correspondence between PHL and test kit measurements for both serum (plasma) ChE and RBC ChE. We also conducted a pilot study in the summer of 2005 with a major Yakima Valley clinic that collects blood samples for the state program. Sixteen blood samples were analyzed with the test kit in the clinical setting. The serum ChE results indicated a good correspondence with PHL values; the RBC ChE results were more variable. Phase 2 of this project is ongoing (spring and summer of 2006), and involves a larger study of test kit measurements conducted in the clinical setting. We hope to complete 100 measurements, and compare these with PHL values to determine whether the test kit can be used as a valuable screening tool, and/or as a substitute for samples shipped to a central laboratory.

Farmworker Exposures to Pesticide Residues during Hand Labor Activities

This project examined the mechanisms by which farmworkers are exposed to pesticide residues following orchard applications, and assessed doses and risks associated with such exposures. This work led to an analysis of factors that can reduce skin absorption and dose in these workers. As a result of this project, new funding has been secured to explore novel methods for exposure assessment in agricultural worker populations. This work formed the foundation for the Center's 2002 Awarded Research Project: Workplace Determinants of Take Home Pesticide Exposure.

Icon-Based Exposure History Questionnaires for Low Literacy Populations

PNASH Center investigators, led by Dr. Larry Engel, have developed a novel icon-based exposure history questionnaire (Engel et al. 2001a, 2001b). In their central study, 89 farmworkers and non-farmworkers were interviewed twice, 8-10 months apart, about their lifetime employment. In the first interview, subjects were asked to recount their entire work history, starting from the interview date and moving backwards in time ("traditional questionnaire"). In the second interview, subjects were first asked about important life events, which were recorded with icons on a calendar. They were then asked to recount their work history, which was recorded, job-by-job, on the calendar with icons ("icon-calendar questionnaire"). This study found that the number of jobs and amount of work time accounted for since first employment were significantly greater using the icon-calendar questionnaire than

the traditional questionnaire, the disparity increasing with time from the date of interview. The ratio of number of jobs in the traditional questionnaire to number of jobs in the icon-calendar questionnaire decreased from 100.0% in the most recent time period to 0.0% in the earliest time period. While the percentage of time explained by employment remained relatively constant across time periods in the icon-calendar questionnaire, ranging from 86.3 to 98.9%, it rapidly decreased with time in the traditional questionnaire, from 77.9% in the most recent time period to 0.0% in the earliest time period. The work of the PNASH Center has been included in the efforts of the National Cancer Institute to develop new epidemiologic methods for agricultural worker populations (Zahm et al. 2001). The PNASH Center has since developed a computerized, icon-based instrument for the collection of exposure history information from pesticide handlers in Washington State. This method was pilot-tested in the summer of 2005. A total of 66 pesticide handlers have been recruited to date in 2006, and we will continue to recruit study participants throughout the remainder of the 2006 spray season.

Light detection and ranging (LIDAR) Technology for Pesticide Spray Drift Studies

Optical remote sensing allows one to sample multiple volumes of space remotely using the properties of electromagnetic radiation. In the case of pesticide monitoring, traditional sampling techniques provide only point sample measurements. Furthermore, each sample is collected over a relatively long period of time (minimum 1/2-1 hour), which means that it can only provide a time-averaged concentration measurement. Optical remote sensing measurements can provide near real-time measurements (seconds per sample) over a large area. This rapid measurement feature can provide insight into spray drift movement/evolution over the spray period. LIDAR systems were developed by the military for the purpose of detecting the use of chemical agents in warfare. Since the 1960's they have been increasingly used to study the atmosphere. It is now possible to use such mobile laser systems for environmental monitoring. The PNASH Center, under the leadership of Dr. Michael Yost and doctoral student Ming Tsai, have developed and field-tested a LIDAR instrument appropriate for pesticide drift studies. The LIDAR instrument has now been used in two studies of orchard airblast applications. The results of this work are forthcoming (August 2006) as part of the Ming Tsai's doctoral dissertation.

SIGNIFICANT FINDINGS

Dust Sampling of Pesticide Residues in the Homes of Agricultural Workers

The systematic collection of house dust with state-of-the-art sampling procedures has produced a stable and reproducible metric for children's exposure opportunity in agricultural communities. It has allowed accurate resolution of high and low-exposed populations, and has provided evidence that proximity to pesticide-treated farmland results in home contamination. House dust sampling has thus become a new method for classification of populations for epidemiologic studies, and a useful tool for intervention studies. Our published method for the analysis of OP pesticide in house dust (Moate et al. 2002) provides other laboratories with valuable guidance regarding extraction, detection, and quality assurance procedures. Our initial field study report of house dust levels in farmer and farm worker homes (Simcox et al. 1995) has served as a model for subsequent studies by a variety of research groups (UC Berkeley, Oregon Health & Sciences University, Wake Forest University, Rutgers University, NIOSH).

Urinary Metabolite Monitoring of Children's Exposure to Pesticides

The measurement of the dialkylphosphate (DAP) metabolites in children's urine has proven to be an important tool for both researchers and educators. This method provides an integrated estimate of exposure to the OP pesticides, and permits identification of high risk populations. Our published analytical method for these metabolites (Moate et al. 1999) serves as a valuable guide for other laboratories conducting these analyses. After our initial publication of OP pesticide metabolite levels in children (Loewenherz et al. 1997), the Centers for Disease Control and Prevention elected to include analysis of DAP compounds in the ongoing National Health and Nutrition Examination Survey (NHANES). DAP concentrations for the U.S. population were first reported by CDC in 2001 in the *National Report on Human Exposure to Environmental Chemicals*.

Global Positioning System (GPS) Methods for Children's Time-Location Studies

The PNASH Center has pioneered the use of GPS for children's exposure studies (Elgethun et al. 2003), and for children of agricultural workers in particular (Elgethun 2004; Weppner et al. 2005). Portable GPS instruments have revolutionized the ability of researchers to determine the temporal and spatial patterns of individuals as they related to exposure sources. The specificity of this methodology (5-second time intervals, 3 meter spatial resolution) allows highly accurate characterization of exposure opportunity, and decreases uncertainties in exposure estimates. We are now seeing the rapid adoption of our instruments and methods by other researchers in the field of exposure science.

Saliva Biomonitoring

The PNASH Center has been at the forefront of developing methods for the sampling and analysis of pesticides in saliva. Dr. Alex Lu (now at Emory University) conducted the key laboratory studies in this area as a scientist within the PNASH Center (Lu et al. 1997a, 1997b, 1998, 2003). We have also demonstrated the feasibility of this method through collaborative studies with NIOSH (Denovan et al. 2000, Hines et al. 2006). Most recently we have used saliva biomonitoring in collaborative studies with investigators in Nicaragua (Rodriquez et al. 2006) and Thailand. In so doing we have helped to build research capacity at the National Autonomous University of Nicaragua, Division of Preventive Medicine, and at the Department of Occupational Health, Buripha University, Thailand. Saliva biomonitoring is now being included routinely in epidemiologic investigations (A. Bradman, UC Berkeley, personal communication).

Farmworker Exposures to Pesticide Residues during Hand Labor Activities

The work of the PNASH Center has led to improved methods of dermal exposure assessment for agricultural workers (Lu and Fenske 1994, Fenske et al. 1999), and more accurate models

for dermal absorption of pesticides (Kissel and Fenske 2000, Doran et al. 2003). Our work with the direct-reading ATR-FTIR method (Carden et al. 2005) shows promise as a rapid and inexpensive method for determining pesticide concentrations on the skin and uptake rates.

Advances in Cholinesterase Monitoring

The PNASH Center's validation work with the EQM Test-Mate™ Kit for cholinesterase monitoring has been critical in making this instrument available to clinical providers and researchers both nationally and internationally. The kit is now being used in the clinic of one of the major health care providers in eastern Washington State as a supplementary tool for the Washington Cholinesterase Monitoring Rule. It is also being used with increasing frequency in other parts of the world (Delgado et al. 2004, Thetkathuek et al. 2005).

Icon-Based Exposure History Questionnaires for Low Literacy Populations

Our studies have demonstrated that the icon-calendar questionnaire is more effective than traditional questionnaires for obtaining complex work histories during interviews with agricultural workers. This method produces a more accurate and complete picture of a person's work history.

LIDAR Technology for Pesticide Spray Drift Studies

Our studies with LIDAR technology have demonstrated that pesticide drift occurs for much greater distances than those documented with current sampling methods. We believe this finding will have important ramifications for current drift models, such as AgDrift, the model used by the Environmental Protection Agency for regulatory purposes. LIDAR technology will permit a much more accurate characterization of the temporal and spatial patterns of pesticide drift in agricultural communities.

PRODUCTS/OUTPUTS

Further products are reported in the companion database.

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Questionnaires and Surveys

Worker and Children's Exposure to Pesticides: bi-lingual interview instruments to determine hygienic behaviors of workers, hygienic behavior in worker residences, and residential pesticide use.

Sampling and Analytical Methods

Children's Pesticide Exposure: Improved laboratory methods for the analysis of pesticide metabolites in urine.

Children's Pesticide Exposure: New laboratory methods for the analysis of pesticides in house dust and vehicle dust samples.

Children's Pesticide Exposure: New global positioning system instrument for collection of time-location data of children.

PDA Survey and Field Database: Recording method using PDAs and specialized software to administer health effects and work history questionnaires, and link to exposure data. The PDAs allow us to digitally capture data in the field, to collect data in harsh environments, link exposure data to survey subject, and administer easy to use cascading surveys.

Farmworker Exposure to Pesticide Residues: A new model for assessing dermal absorption of pesticide residues that incorporates information on the time course of dermal uptake.

Saliva Biomonitoring: New field methods for collection of saliva samples; new laboratory methods for analysis of pesticides in saliva.

Methods for Accessing Pesticide/Nitrate Environmental Exposure Databases: Methods to use Global Positioning System (GPS) to obtain coordinates to link to environmental exposure data.

LIDAR: a new technology for characterizing pesticide spray drift in agricultural communities.

Tools for Education and Prevention:

Cholinesterase Field Test Kit: Testing of a field test kit, EQM Testmate Kit™, that shows good performance for measuring cholinesterase depression under field conditions as compared to the laboratory.

OUTCOMES

Our work in the area of children's exposure to pesticides in agricultural communities has spawned numerous studies by other research groups. A recent example is a published report of pesticide exposures among preschool children in an agricultural community in Thailand (Petchuay et al. 2006). This study cites 8 of our publications, and uses the urine sampling and dialkylphosphate analysis approaches that our group documented in the 1990's to characterize children's exposures.

House dust sampling has become a new method for classification of populations for epidemiologic studies, and a useful tool for intervention studies. Our published method for the analysis of OP pesticide in house dust (Moate et al. 2002) provides other laboratories with valuable guidance regarding extraction, detection, and quality assurance procedures. Our initial field study report of house dust levels in farmer and farm worker homes (Simcox et al. 1995) has served as a model for subsequent studies by a variety of research groups (UC Berkeley, Oregon Health & Sciences University, Wake Forest University, Rutgers University, NIOSH).

After our initial publication of OP pesticide metabolite levels in children (Loewenherz et al. 1997), the Centers for Disease Control and Prevention elected to include analysis of DAP compounds in the ongoing National Health and Nutrition Examination Survey (NHANES). DAP concentrations for the U.S. population were first reported by CDC in 2001 in the *National Report on Human Exposure to Environmental Chemicals*.

We are now seeing the rapid adoption of global positioning system instruments by other researchers in the field of exposure, with our methods serving as templates for these investigations.

We have used saliva biomonitoring in collaborative studies with investigators in Nicaragua (Rodriquez et al. 2006) and Thailand. In so doing we have helped to build research capacity at the National Autonomous University of Nicaragua, Division of Preventive Medicine, and at the Department of Occupational Health, Buripha University, Thailand. Saliva biomonitoring is now being included routinely in epidemiologic investigations (A. Bradman, UC Berkeley, personal communication).

The portable cholinesterase test kit is now being used in the clinic of one of the major health care providers in eastern Washington State as a supplementary tool for the Washington Cholinesterase Monitoring Rule. It is also being used with increasing frequency in other parts of the world, such as Costa Rica and Thailand (Delgado et al. 2004, Thetkathuek et al. 2005).

LIDAR technology is now being adapted to the study of airblast applications in Northwest orchards, and is providing new insights into the extent to which pesticide drift results from these applications.

INTERVENTIONS TO REDUCE PESTICIDE EXPOSURES AMONG AGRICULTURAL WORKERS AND THEIR FAMILIES

INTRODUCTION

The PNASH Center has worked with employers and employees to better understand how to reduce exposures among pesticide handlers, and to reduce the transmission of workplace chemicals to the home environment. We have worked primarily with the Washington State Department of Agriculture, the Washington State University Extension Service, and major orchardists in Washington State as a part of this program area. We have also conducted studies in Florida to evaluate the performance of chemical protective clothing and other factors affecting exposures during pesticide applications.

GOALS

The overall objective of this program area is to reduce pesticide exposures among agricultural workers and their families. Specifically, these projects have aimed to reduce exposures through worker education, development of new control technologies, and promotion of safe behaviors.

BACKGROUND AND SIGNIFICANCE

Pesticide handler exposure is an important public health concern nationally, and particularly so in the Northwest region. The U.S. EPA's Worker Protection Standard mandates pesticide handler training, and use of certain forms of personal protective equipment during the mixing, loading, and application of pesticides. The Washington State Department of Agriculture is responsible for the implementation and enforcement of this federal standard in Washington state. In 2004 the Washington Department of Labor & Industries promulgated a new mandatory Cholinesterase Monitoring Rule. This rule requires that pesticide handlers who work with high toxicity pesticides have blood testing for cholinesterase conducted prior to exposure, and then on a periodic basis throughout the spraying season. This monitoring program has demonstrated that a substantial fraction of pesticide handlers in Washington state are exposed at levels that trigger regulatory action. Thus, there is great interest in reducing such exposures.

Our group has used the fluorescent tracer technique in pesticide safety education to demonstrate the possible failure of chemical protective clothing, as well as the importance of applicator training. We have also examined how contamination can inadvertently spread when a contaminated object is handled. The visual experience produced with fluorescent tracer methods – allowing workers to see their own exposures -- has an immediate impact and can increase awareness of how dermal pesticide exposure can occur.

The potential health risks associated with exposure of children to pesticides have received increased attention with passage of the Food Quality Protection Act of 1996 and with new federal emphasis on children's health. Current efforts to characterize such exposures within a risk assessment framework involve the integration of scientific knowledge from several fields. The result is a complex picture of risk, characterized by substantial uncertainty. The current understanding of pesticide health effects is at an early stage of development, and if our experience with childhood lead exposure is viewed as a model, then we can expect new science to deepen the understanding of health risks to children. As the science in this field continues to mature, it seems prudent to reduce children's pesticide exposures where possible. In particular, children of agricultural workers can be exposed to workplace chemicals that are brought home by their parents. The prevention of this work-to-home transmission of chemicals can significantly reduce total pesticide body burden for these children.

ACTIVITIES

Greenhouse Ventilation Studies to Reduce Applicator Exposures

Pesticide handlers in greenhouses commonly use hand-held spray guns to treat ornamentals or other plants on benches. Greenhouses have either natural or forced air ventilation systems to maintain temperature control. We evaluated workers who conducted benchtop hand spraying in commercial greenhouses with the ventilation system either on or off. When operating, the greenhouse ventilation system produced a strong uni-directional air movement. We tested both workers with pesticide application experience, and workers who were new to this task. Applications were conducted for one hour with a fluorescent tracer substituted for pesticides in an aqueous mixture. We used qualitative and quantitative methods to assess the deposition of the fluorescent tracer on the skin and clothing of these workers.

Protective Clothing Performance during Greenhouse Applications

Pesticide handlers in greenhouses employ chemical protective clothing as protection against skin contact with pesticides. CPC is designed to prevent exposure to spills, splashes and spray deposition. However, greenhouse applicators very often are presented with the additional hazard of contact with wet foliage that overhangs the walking spaces between the benches. In this work we evaluated protective clothing performance during handspray applications. A fluorescent tracer compound was added to the applicator's tank prior to work, and served as a surrogate for the pesticides being sprayed. Qualitative and quantitative methods were used to evaluate chemical breakthrough of four garments thought to be protective.

Protective Clothing Performance during Airblast Applications

Chemical protective clothing is often recommended as a method of exposure mitigation among pesticide applicators in orchards and citrus groves. CPC is normally evaluated in the laboratory through permeation studies. That is, the CPC material is challenged with a pesticide formulation, and breakthrough time is measured. Only rarely are follow-up studies conducted to determine if the CPC performs as expected under realistic field conditions. Our work evaluated four CPC regimens (cotton work shirts and work pants, cotton/polyester coveralls, and two non-woven garments) during airblast applications of the organophosphorus insecticide ethion in central Florida citrus groves. The two non-woven garments were provided by the U.S. Environmental Protection Agency as a part of their protective clothing evaluation program. CPC performance was determined by measurement of fluorescent tracer deposition on skin surfaces beneath garments with a video imaging analysis instrument (VITAE system), and by alpha-cellulose patches placed outside and beneath the garments.

Pesticide Safety Classroom Demonstrations of Fluorescent Tracer Exposure

Training is recognized as an effective tool for behavior modification and promoting self-protection. State pesticide applicator training programs promote judicious and safe use of pesticides through outreach education recertification courses that cover a wide range of topics in addition to pesticide safety. These large-audience classes typically are not conducive to interactive learning methods. In addition, applicators may have change-resistant attitudes for a variety of reasons. This study evaluated the impact of different training delivery styles on simulated dermal exposure for pesticide applicators. A fluorescent tracer dye demonstration was incorporated into two of the three delivery styles. The goal was to determine how to conduct more compelling, effective training to motivate applicators to protect their skin from pesticide exposure. A questionnaire was administered at each training site to evaluate training style and impact. Response information was collected from applicator attendees and compared in the context of an intervention effectiveness evaluation. This study was designed to evaluate the educational impact of three different training delivery styles, with and without the demonstration of fluorescent tracers, with all presentations aimed at promoting self-protection from dermal exposure among pesticide applicators. Each of the three delivery styles -- live fluorescent tracer

demonstration, video-tape of the live tracer demonstration, and a conventional instructional video -- was tested at three large-group pesticide license recertification courses in Washington state in 2000 and 2001 for a total of nine locations. Each presentation was a 50-minute segment of a two-day Washington State University Pesticide Education Program recertification training. The nine pesticide applicator courses included 1431 applicators: 80% participated in the questionnaire evaluation of the courses.

Fluorescent Tracer Use in Hands-on Pesticide Handler Training

The Washington State Department of Agriculture (WSDA) and the Washington State University Agricultural Extension Service have developed a novel “hands-on” training method to reach a primarily Hispanic and low-literacy audiences of pesticide handlers. This training course has received favorable reviews from employers and workers alike, but has never been formally evaluated. PNASH Center investigators joined this effort in 2004. Our goals were to introduce the fluorescent tracer (FT) technique into the existing training program, and to conduct an evaluation of the impact of hands-on training program. The PNASH Center has developed an FT training module designed specifically for use in the hands-on training program. Pesticide handlers immediately see potential pesticide contamination by viewing results of proper and improper handling techniques. The effectiveness of the hands-on training and the FT module were evaluated through pre-test and post-test questionnaires, as well as through interviews of a subset of workers.

Workplace Determinants of Take-Home Pesticide Exposure

The PNASH Center has identified and characterized children’s pesticide exposure pathways through a series of studies over the past 10 years. Our early studies in the agricultural region of Washington State demonstrated that agricultural pesticides measured in housedust were elevated in the homes of agricultural workers when compared to other homes in the same community. Follow-up studies collected urine samples from pre-school children, and found that children of pesticide applicators had higher levels of pesticide metabolites than did children of non-agricultural workers. These studies led us to hypothesize a significant para-occupational or “take home” pathway for children of agricultural producers and workers. Our 1999 study of this pathway involved pesticide residue analysis of dust samples collected from the commuter vehicles and residences of more than 200 farm workers. We found a strong association between agricultural pesticide levels in home and vehicle dust, providing further support for the take-home exposure pathway.

Our current efforts have focused on interventions to improve hygienic practices at the workplace to reduce pesticide residue levels in homes. This approach differs from earlier community education efforts to change worker behaviors outside of the workplace (e.g., take shoes off before entering the home), and is based on the industrial hygiene principle of controlling exposures at the source. In this case, we consider the source to be the workplace, and we are working to prevent agricultural chemicals from leaving the workplace. The PNASH Center is partnering with employers and employees to test practical, workplace-based interventions to reduce pesticide levels in the homes of agricultural workers.

We began by sampling vehicle and household dust to determine the extent of take-home pathway contribution to home pesticide residue levels. Three interventions were then developed to reduce this type of pesticide exposure. The first intervention focused on pesticide handlers, and involved a change from a single locker to a double locker system for each worker, so that regular clothing and chemical protective clothing could be kept separate. We also asked the employer to have the pesticide handler locker room cleaned on a regular basis throughout the pesticide spraying season. The second intervention focused on treating work boots used in the field as protective

clothing not suitable for home use. We provided workers with what we have termed a plastic “boot bin” that can be kept in the trunk of the car. Workers were asked to change out of their work boots at the end of the day, and wear different footwear home. The third intervention focused on vacuuming of commuter vehicles before leaving the worksite. We installed a shop-vac style HEPA vacuum at the worksite entrance/exit, and encouraged workers to make use of it at least once a week. We used vehicle and house dust sampling for pesticide residues as our measure of intervention effectiveness. We have now concluded three years of fieldwork, and are currently analyzing the data from these studies to evaluate these interventions.

SIGNIFICANT FINDINGS

Greenhouse Ventilation Studies to Reduce Applicator Exposures

We found that when the ventilation system was in operation experienced applicators had only minimal dermal exposures, while inexperienced applicators had very high exposures. When the ventilation system was turned off the exposures of experienced and inexperienced applicators was similar. These findings indicated that the air movement created by ventilation can present a hazard to workers during application, but can also be used to a worker’s advantage to avoid dermal contact with pesticides. The findings also underscore the importance of greenhouse applicator training. We provided recommendations based on these findings to individual greenhouse owners, and to the industry through the leading greenhouse trade publication, *Greenhouse Manager*.

Protective Clothing Performance during Greenhouse Applications

The four garments tested in these studies all exhibited chemical breakthrough after a 1-hour application period. Follow-up studies indicated that two of these garments had breakthrough times of between 5 and 15 minutes. Interviews with applicators and management indicated that these garments were normally used for a full day (8 hours), and often for multiple days. We ascertained that because these garments caused substantial sweating the workers could not sense that breakthrough had occurred. We concluded that none of these garments could be considered protective under realistic field use conditions, and that contact with treated foliage represented a special hazard during greenhouse applications. As a result of this study, the manager of the greenhouses at the study site discarded the existing clothing, and purchased new clothing based on our recommendations. Our results were disseminated to the industry through the leading greenhouse trade publication, *Greenhouse Manager*.

Protective Clothing Performance during Airblast Applications

We found that the non-woven coveralls tested in these studies allowed significantly greater exposure than did traditional woven garments, primarily because of design factors (e.g., large sleeve and neck openings). The greatest exposure occurred on the forearms beneath the non-woven garments. These exposures were only evident with the fluorescent tracer technique. Many previous studies using the traditional patch technique had failed to measure such exposures. We concluded that the clothing materials tested were not chemically resistant under these field conditions, since fabric penetration was detected for all test garments. As a result of these studies, the U.S. EPA abandoned further testing of the non-woven garments and adopted our recommendations regarding garment design.

Pesticide Safety Classroom Demonstrations of Fluorescent Tracer Exposure

Results from these studies showed that the live demonstration with fluorescent tracer produced significantly more favorable results than the other two treatments for seven of eight outcome measures, including both process and impact evaluation measures. In addition, the videotape of the live skit produced significantly more favorable results than the instructional video for four

out of eight outcome measures. For the four strongly-agree outcomes, the evidence suggests that the interventions produced significantly different responses: that the live tracer demonstration produced significantly more favorable responses than the other treatments, and that the videotape of the live demonstration produced significantly more favorable responses than the instructional video. This work was published in the on-line *Journal of Pesticide Safety Education*, a primary information source for pesticide safety education practitioners.

Fluorescent Tracer Use in Hands-on Pesticide Handler Training

We found that the hands-on training program had a positive impact on knowledge acquisition based on pre- and post-tests. For certain information, the FT module improved knowledge scores, but not in all cases. The dramatic visualization of exposure and contamination provided by the fluorescent tracer method was remarked upon by many of the study participants in the post-training interview, and was strongly endorsed by the trainers. The FT training curriculum (Spanish) has now been incorporated as a standard component of the WSDA Hands-on Pesticide Handler Training program. This program trains approximately 200 Hispanic pesticide handlers each year. In addition, elements of the training (i.e., PPE decontamination) are used in other educational presentations such as at pesticide recertification classes and industry events. We are producing a new FT training manual that will give pesticide safety educators the tools they need to integrate FT training into their own programs. The final print and Web-based model FT training materials will be available in September 2006, and will be distributed nationally and internationally.

Workplace Determinants of Take-Home Pesticide Exposure

Our baseline study in 2003 investigated the concentrations of organophosphorus pesticide residues in the commuter vehicles and homes of three groups of agricultural workers: pesticide handlers, apple thinners, and agricultural workers at an organic orchard (reference group). Pesticide levels in the homes of handlers were the highest among the three groups. Both the handler and thinner groups had significantly more pesticide residues in house dust than the controls. Vehicle dust was found to be a significant predictor of house dust concentrations for all three pesticides studied, and leaving the vehicle window rolled down was found to be a significant predictor of vehicle pesticide concentrations for two of the pesticides.

Our 2004 study pilot-tested two practical interventions: storage bins for work boots, and availability of a high efficiency vacuum at the worksite for cleaning commuter vehicles. We found that work patterns and the use of the interventions were highly variable within this study group. We also learned that a careful analysis of work records would permit a proper assignment to intervention and control groups. Our intervention with pesticide applicators is still under analysis.

In 2005 we implemented a larger-scale intervention study that focused on vehicle vacuuming among agricultural workers who were picking cherries. At the end of the study period, each subject was interviewed and a vehicle and house dust sample was collected. We found that those workers who used the workplace vacuum to clean their vehicles had lower levels of pesticides in both their vehicles and homes than did those workers who did not vacuum. In future studies, we would like to further evaluate this intervention. We plan to develop new strategies to encourage employers to make vacuums available to their workers, and to persuade employers to let workers use the vacuums during work time. We also plan to develop new strategies for motivating workers to vacuum their vehicles on a regular basis.

PRODUCTS/OUTPUTS

Further products are reported in the companion database.

Publications

1. Publications -- Applicator-focused Interventions

Fenske RA. Comparative assessment of protective clothing performance by measurement of dermal exposure during pesticide applications. *Appl Ind Hyg* 3:207-213 (1988).

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Fenske RA. Personal protective equipment. In *Papers and Proceedings of the Surgeon General's Conference on Agricultural Safety and Health*. U.S. Department of Health and Human Services, PHS/CDC/NIOSH, National Technical Information Services, Springfield VA (NTIS No. RB 93-114890), pp. 340-350, 1992.

Methner MM, Fenske RA. Pesticide exposure during greenhouse applications, Part I. Dermal exposure reduction due to directional ventilation and worker training. *Appl Occ Environ Hyg* 9:560-566 (1994).

Methner MM, Fenske RA. Pesticide exposure during greenhouse applications, Part II. Chemical permeation through protective clothing in contact with treated foliage. *Appl Occ Environ Hyg* 9:567-574 (1994).

Methner MM, Fenske RA. Pesticide exposure during greenhouse applications, Part III. Variable exposure due to ventilation conditions and spray pressure. *Appl Occ Environ Hyg* 11:174-180 (1996).

Keifer M [2000]. Effectiveness of interventions in reducing pesticide overexposure and poisonings. *Am J Prev Med* 18(4 Suppl):80-9.

Fenske RA, Birnbaum SG, Methner MM, Lu C, Nigg HN. Fluorescent tracer evaluation of chemical protective clothing during pesticide applications in central Florida citrus groves. *Journal of Agricultural Safety and Health* 8(3):319-331 (2002).

2. Publications -- Pesticide Safety Education

Foss CR, Allen EH, Fenske RA, Ramsey CA. Comparison of live skit and video delivery styles using presentations with and without fluorescent tracer dyes at pesticide applicator training for promotion of self-protection from dermal exposure. *Journal of Pesticide Safety Education* 4:1-9 (2003).

National Train-the-Trainer Workgroup Report [2003]. Agricultural worker protection program. National Assessment and Pesticide Worker Safety Workshop. Arlington, Virginia, March 19-21, 2003.

3. Publications -- Workplace Determinants of Take Home Pesticide Exposure

Simcox NJ, Fenske RA, Wolz S, Lee I-C, Kalman D. Pesticides in housedust and soil: exposure pathways for children of agricultural families. *Environmental Health Perspectives* 103:1126-1134 (1995).

Loewenherz C, Fenske RA, Simcox NJ, Bellamy G, Kalman D. Biological monitoring of organophosphorus pesticide exposure among children of agricultural workers. *Environ Health Persp* 105:1344-1353 (1997). Corrections and Clarifications, *Environ Health Persp* 107(2):A61.

Fenske R [February 2000]. Pesticide exposure and children. Part 1: Why focus on kids? *Agrichemical and Environmental News*. Washington State University Cooperative Extension.

Fenske R [March 2000]. Pesticide exposure and children. Part 2: Children in agricultural communities. *Agrichemical and Environmental News*. Washington State University Cooperative Extension.

Fenske R [June 2000]. Pesticide exposure and children. Part 3: Estimating doses for children. *Agrichemical and Environmental News*. Washington State University Cooperative Extension.

Lu C, Fenske RA, Simcox NJ, Kalman D. Pesticide Exposure of children in an agricultural community: evidence of household proximity to farmland and take home exposure pathways. *Environ Res* 84:290-302 (2000).

Fenske RA, Lu C, Simcox NJ, Loewenherz C, Touchstone J, Moate TF, Allen EH, Kissel JC. Strategies for assessing children's organophosphorus pesticide exposures in agricultural communities. *J Exp Anal Environ Epid* 10: 662-671 (2000).

Curl CL, Fenske RA, Kissel JC, Shirai JH, Moate TF, Griffith W, Coronado G, Thompson B. Evaluation of take-home organophosphorus pesticide exposure among agricultural workers and their children. *Environ Health Perspect* 110:787-792 (2002).

Fenske RA, Lu C, Curl CL, Shirai JH, Kissel JC. Biological monitoring to characterize organophosphorus pesticide exposure among children and workers: an analysis of recent studies in Washington State. *Environ Health Perspect* 113:1651-1657 (2005).

Tools for Education and Prevention

Use of Theater to Introduce Health and Safety Information in Hispanic Communities Play Script Packet (Spanish): Plays which provide health education and farm safety training for Hispanic agricultural workers. Topics covered: Pesticide Safety, Preventing Hepatitis A, Tuberculosis Awareness, Alcohol Education, Pregnancy/Prenatal Concerns, Ergonomics.

Fluorescent Tracer Pesticide Exposure Demonstration: Uses the fluorescent tracer technique to demonstrate to pesticide applicators their potential dermal exposure. Actors are exposed to a fluorescent tracer and water mixture that simulates pesticides under various work conditions. After application of the solution, exposures are demonstrated by standing under a black light. The demonstration is followed by audience discussion of the technique and methods to avoid pesticide exposure at work.

Spanish Language Safety Plays: VHS and DVD format Pesticide Safety (with English subtitles) also streamed on the Farm Center Web page.

Courses and Workshops

- Pesticide Health Risks session at Future of Rural Peoples: Rural Economy, Health People, Environment, Rural Communities conference in Saskatoon, Canada on October 12-23, 2003.

- Pesticide Medicine Short Course. These courses bring together local and national experts on pesticide use, pesticide exposure and pesticide health effects. Washington [2000, 2001, 2003].
- Pesticide Issues Short Course. These courses offered local regulators, employers, health care providers, and workers with the latest pesticide health issues. Washington [2002, 2003].
- Educational Seminars in partnership with Washington Department of Health. Providing education to farmworker health care providers on pesticide education and the use of the mental health diagnostic tool. Washington [2003].
- Train-the-Trainer, 2-day courses taught in Washington (PNASH staff and stakeholders participated). New Jersey, Florida and Puerto Rico [2003].
- Boiko P, Keifer M, Weyrauch K. Onsite Clinic Cholinesterase Monitoring Training Sessions,. Walla Walla, Burlington, Wenatchee, Yakima, Washington [2003].

OUTCOMES

The state of knowledge and transfer of that knowledge on pesticide exposure and health effects is not yet complete. Studies are published regularly, slowly developing the picture of what the problems and solutions to pesticides might be. The uncertainty among scientists and the lack of safer alternative products makes for difficult decisions within the agricultural industry. From a PNASH Center survey of 66 Washington state producers in 2005, we learned that 63% of these wanted further information on pesticides and their health effects. From a farmworker at El Proyecto Bienestar's Town Hall in 2006 it was expressed that what was needed was "Information; about what to do coming home from work. Like after working with pesticides, keep away from the home, like remove the clothes before entering home."

Interventions to Reduce Pesticide Applicator Exposures

Our work to characterize applicator exposures under realistic field conditions remains unique in the scientific literature, and contains numerous recommendations for reducing exposures. These recommendations have been disseminated through state cooperative extension services (e.g., distribution of a fluorescent tracer slide presentation to pesticide safety educators), presentations at meetings of health and safety practitioners (e.g. the American Industrial Hygiene Conference), and trade publications (e.g., *Greenhouse Manager*). Our studies have directly contributed to the protective clothing requirements developed by the U.S. Environmental Protection Agency, and incorporated in the federal Worker Protection Standard.

Pesticide Safety Education

Our work with fluorescent tracers has been a great asset to pesticide safety educators throughout the United States. Our publication in the Journal of Pesticide Safety Education was aimed at practitioners who regularly teach pesticide safety to applicators renewing their applicator licenses. Our more recent work with the WSDA Hands-On Pesticide Handler Training Program has focused on the transfer of the fluorescent tracer (FT) technique to pesticide safety educators. The dramatic visualization of the fluorescent tracer demonstrates 'contamination' during training and gives handlers insight as to where and how pesticide contamination occurs. At the end of FY 2005, a draft of the FT training curricula (Spanish) was in-use with the WSDA program. This program trains approximately 200 Hispanic pesticide handlers each year. In addition, elements of the training (i.e., PPE decontamination) are used in other educational presentations such as at pesticide recertification classes and industry events.

From a masters student project that interviewed pesticide educators who used PNASH's FT training we learned that FT aids pesticide safety educators by:

1. instantly impressing upon participants their messages.
2. providing relevant lessons that trigger participants to instantly connect to real-life exposure situations.
3. creating a fun peer group dynamic to instantly engage participants.

From this same evaluation project, here are a few of many similar testimonials provided by agricultural pesticide safety educators.

"it has been very effective because it tells more (than a) dozen words. Because I can spend hours, two, hours, talking but until the people actually see what I'm talking about, says 'Man, now we know what you are talking about' This is one of the more powerful training tool that I have encountered because the message is clear and it is shocking."

"It makes a big impression on everybody that sees it, it's like 'oh my god, I had no idea... Well, ya, it's an eye opener for everyone."

"The reactions (of participants were) 'How can we do to reduce exposure?' At first, they were a little bit shocked, but then immediate reaction: 'what can we do to reduce exposure?' Ya, it was very, very, very good. They look that they are in risk, they are exposed, 'What will we do to reduce? We use this cloth, or this mask, how can we, what is the doctor recommendations?"

"And it made them think about their, you know, protecting themselves. So it did raise their level of awareness."

Demonstrating the lasting power of the training,

“(The research) was, remember, 7 years ago. But what I remember, remember from participants is some of them were contaminated and said the hands was the most contaminated, and they thought that was the only thing that could be contaminated, or the back of the legs. One month ago, I went to visit two farmers because they were two who were in this study and they still remember that, and they said the guy demonstrated (with FT) to them how difficult it is to escape from the pesticide. So it creates an impact.”

Workplace Determinants of Take Home Pesticide Exposure

Work in this area predated the PNASH Center, but was funded by NIOSH. Center support over the past ten years has allowed this research to proceed at a rapid pace. A series of field studies have been completed that permit assessment of exposure pathways for children of agricultural workers, and allow an estimate of doses received by these children. This work resulted in numerous peer-reviewed journal articles. It received widespread attention in the media, and has informed policy makers at the state and federal levels. This work has also provided a foundation for our current work on interventions to reduce pesticide exposures.

Three interventions have been developed and adopted by a major fruit orchardist over the past two years. Using the results of the baseline study as a starting point, three interventions were evaluated for their ability to reduce work-to-home transmission of agricultural pesticides.

- Thinners were given a work boot storage box (‘boot bin’) and sandals so that they had an alternative to wearing their boots into their home.
- Thinners vacuumed their cars once a week using vacuums (equipped with high efficiency particulate air filters) located at a central location.
- Applicators used a locker room that was cleaned daily and had separate lockers for PPE and work clothes.

We are still in the process of analyzing the results of these studies, but preliminary findings indicate that the vacuuming of commuter vehicles at the workplace decreases pesticide levels in workers’ homes. We plan to publish our work in 2006, and provide a practical guide regarding these interventions for both employers and workers.

PREVENTING TRAUMATIC INJURIES

INTRODUCTION

Traumatic injuries are a known problem for many occupations in the agricultural industry. Over the last eight years PNASH's major effort, under the leadership of Dr. Matthew Keifer, has been a systematic investigation of injuries in the tree fruit industry in Washington state. Overall, PNASH researchers have tackled traumatic injuries through survey, research, prevention and education in four important areas:

- Orchard Injuries
- Tractor Injuries
- Children's Farm Injuries
- Forestry and Fishing Injuries

GOALS

The goal of the PNASH Center's Prevention of Traumatic Injuries program is to reduce occupational injuries among workers in agricultural industries, in particular the tree fruit industry. The sub-goals are to:

- Explore and characterize the array of factors that contribute to injury
- Prioritize the injuries and risk conditions among orchard workers
- Use this information to develop targeted interventions aimed at reducing the frequency of risk conditions that lead to injury
- Evaluate the effectiveness and the cost-benefit ratio of interventions

BACKGROUND AND SIGNIFICANCE

Estimates of agriculturally related deaths from the National Safety Council and statistics from the National Census of Fatal Occupational Injuries converge putting annual agricultural deaths between 780 and 700. The death rate in agriculture of 22.1 per 100,000 is exceeded only by mining and quarrying among major industries in the U.S. U.S. agriculture is not unique in this respect. Canadian data shows that farming there is the fourth most dangerous industry. Nonfatal injuries are also very high in agriculture. The NSC estimated 150,000 disabling agricultural injuries in 1999 and other sources such as the U.S. Department of Labor, the workers' compensation system in California (the largest agricultural producer in the country), and the Department of Labor and Industries of Washington State confirm this high rate of injury. A study of agricultural injuries in Washington state, using Washington workers' compensation data, demonstrated an elevated risk for injuries (2.3 overall) for agricultural workers as compared with the general worker population.

The tree fruit industry, in particular, is a large employer but a dangerous industry. Apples alone employ up to 45,000 workers during peak activity and cherries and pears employ 16,000 and 7000 respectively. The tree fruit industry accounts for some 45-58% of the injuries in agriculture. According to the Washington State Department of Labor and Industry data, the tree fruit industry has the highest rate of injury per full time equivalent of any agricultural sector. Injuries include various musculoskeletal injuries, including back, eye injuries, fractures, amputations, cuts, bruises, and burns. High rates of occupational injury among orchard workers demonstrate a need for further research to study common, preventable risk factors and conditions.

Ladder injuries appear to be a major contributor to these high rates. Based on a PNASH Center review of data from the three-county agricultural area of eastern Washington, ladder injuries account

for 67% of the cost of all fall-related workers' compensation expenditures. Orchard workers are particularly at risk for ladder injuries because of the nature of their work. It seems clear that traditional individualized approaches are not working. The multiple factors and conditions that contribute to ladder injuries demand innovative and creative solutions that emphasize engineering and administrative techniques.

The forest resources industry is also one of the most hazardous in the United States. The fatality rate of loggers in 1997 was approximately 27 times the national average (128 vs. 5 per 100,000). Nationally, nonfatal injuries between 1992 and 1996 declined from 4,537 injuries per year to 2,136 injuries per year, yet rates are still high and injuries severe, resulting in a median number of 11 days away from work. A study of logging fatalities in Washington state indicated that employees of smaller logging firms had a higher risk for mortality. This trend for small businesses is apparent on a national level, with logging in the top five of all small businesses with high risk for injury or death. Based on Washington state workers' compensation claims data, the rate of nonfatal lost time injuries for loggers (13.5 per 100 full time equivalents [FTE]) is more than 3.5 times that of all industries combined (3.8 per 100 FTE). In Oregon, the average fatality rate by industry for 1993 through 1997 finds agriculture, forestry, and fishing as having one of the highest fatality rates (19.0 per 100,000, just below construction at 19.4 per 100,000). In a review of the Alaska Trauma Registry for 1991 through 1995, logging had the highest average annual injury rate (2.5 for every 100 workers) of all occupations in Alaska. The types of injuries sustained by individuals working in forestlands range from frequent minor injuries to very severe incidents. Oregon's disabling claims data indicated loggers most frequently experienced sprains and strains, struck-bys, and back injuries. Likewise, in a review of nonfatal injuries in Alaska, struck-bys and falls led in causes of all severe injuries with fractured bone being the most common injury and most injuries impacting the lower extremities.

ACTIVITIES

Orchard Injuries

To reduce the high rates of occupational injuries among tree fruit industry workers, PNASH conducted a series of projects in the Yakima Valley aimed at identifying and preventing the most common injuries and their causes. This was accomplished through a review of workers' compensation claims data, interviews with key informants and workers, and evaluation of a prevention program. Data revealed a clear problem was ladder injuries. This was reinforced by workers' compensation data review, key informant interviews, and worker interviews. This led to a focus on the development of an engineering intervention: a new ladder with built-in sensors that can, as a training tool, both warn workers and monitor risk conditions. Specific activities included:

1997 Farmworker Survey at community soccer league games. In a first step to characterizing the workforce, injury experience, and use of the workers' compensation system, an interview survey was conducted in the Yakima Valley. The survey used a specific venue for accessing hard-to-reach workers. Among migrant workers, it is common to neither have a fixed address, a permanent phone number, nor a permanent employment location. As a result, this study explored the use of summer soccer tournaments as a location where farm workers, who would otherwise be hard to find and interview, could be found. In a short summer project, a survey conducted by a medical student, netted more than 300 workers during the Yakima Valley summer soccer league games, using the game locations for survey administration.

1999 Community Random Digit Telephone Survey. Seasonal workers, unlike migrant workers, generally have permanent residences and permanent telephone lines. This project used a random digit dialing approach to access workers in the Sunnyside, Washington area where, according to the 1990 census, 57% of residents were Hispanic and the vast majority of economic activity is agricultural. A 66% participation rate among 2363 households found 514 households with at least one adult agricultural worker. 440 workers participated in the survey.

2001 Review of Washington State Workers Compensation Data. All workers' compensation claims data for deciduous tree fruit workers in Region 5 of Washington state between 1996 and 2001 were reviewed and categorized according to cause of injury. Claims data were analyzed by cause of injury in terms of frequency, severity, and cost. While the worker compensation database is an administrative database aimed primarily for addressing billing issues, it can be used to a limited degree for epidemiological purposes. The weakness is that data fields on injury mechanism are filled in by non-epidemiologically trained workers. Its clear advantage is its reach. Almost all hired agricultural workers in the state are covered by the system.

2002 Key Informant Interviews. Aware of the limitations of data collected by an administrative database, we also sought information from persons who would be familiar with the health and safety issues in orchard agriculture. These 25 individuals included government workplace inspectors, worker representatives, private health and safety consultants and medical personnel in the region.

2002 Evaluation of Labor and Industries Eyes and Fall Prevention Program.

Responding to a request from the Washington Department of Labor and Industries, the PNASH researchers attempted to determine if a safety consultation program offered by L&I was effective in reducing injuries from ladders and eye injuries. The program in its early stages, did not have sufficient reach to statistically detect an effect on the injury rate in the covered area. Based on this information, the program switched to focus on the effectiveness of the consultation program from the perspective of the growers who participated. A project was undertaken to evaluate the experience of growers who had received consultation vs. growers who had not in terms of changes in behavior and attitudes about safety on the farm.

2002 Ladder Injury Interviews. In order to delve more deeply into the mechanism of ladder injuries, we conducted interviews with workers who had sustained injuries in orchards on ladders. Cases were identified by collecting data on all ladder-related injuries reported to the workers' compensation system. We sought to identify cases within two weeks of the index injury. Workers who could be located were interviewed using an open-ended interview format to determine the mechanism of ladder injury.

2003 Worker Interviews / 2004 Worker Survey. The purpose of this study was to gather information about Hispanic orchard workers' perceptions and experiences related to the risks and hazards related to their work. The study consisted of two phases of data collection: 1) open-ended, personal interviews of 25 Hispanic workers from two agricultural communities in central Washington, and 2) a written survey based on the interviews of 184 orchard workers.

The primary goal of the first phase of the study was to gain insight into the workers' perceptions about occupational health and safety of orchard work. Areas of inquiry included participants' day-to-day experiences as orchard workers, injury experiences, and perceptions of factors contributing to injury

2005 Sensing Ladders as a Training and Hazard Assessment Tool. These studies provided the impetus to develop a tool that could reduce the injury rate for orchard ladders. Specifics about mechanisms of injury by ladder users were derived principally from interviews with injured workers and workers who had witnessed injuries of others. The “smart ladder” was designed to both monitor the occurrence of risk conditions and to warn workers of the conditions that are associated with a high risk of injury. The ladder is equipped with sensors that can detect the workers’ position on the ladder, determine his or her center of gravity, and alert the worker when the stability of the ladder is threatened. A single prototype has been developed, equipped with accelerometers and load cells; its reliability has been tested and verified.

Tractor Injuries

This project brought together all the NIOSH Agricultural Centers in their first joint project to address a known problem area. The Centers worked together to develop an informed solution to the high fatality and injury rates from tractors. Specific activities to date include the production of a joint report to outline the problem and recommended solutions. A launching meeting with stakeholders was held during June in 2004. Currently, a two-year grant from NIOSH is allowing us to build partnerships, finalize the evidence package, and conduct audience research. While this initiative is still underway, the development and launching of the initiative with national partners is a first step to implementing a strategic social marketing campaign that will reduce farmer injuries and deaths.

Children’s Farm Injuries

A number of projects characterized children’s farm injuries and evaluated prevention programs. A community phone survey in Sunnyside, Washington, characterized problem areas, injury rates, and patterns of work and treatment outcomes for teenaged hired farm workers. One pilot study investigated family supervision of farm children. Two existing educational prevention programs were evaluated: one teen tractor safety program in Washington and one children’s farm safety day camp in Idaho. Currently, PNASH is engaged in evaluating and disseminating an agricultural safety curriculum to Washington state Ag-in-the-Classroom programs.

Forestry Injuries

Like farming, forestry occupations face high rates of fatal and disabling injuries. While PNASH lacks the resources to pursue a thorough investigation into these areas of work, some pilot studies have addressed aspects of these industries. The Forestry Summit pointed out many concerns in logging and forestry work. In 2002, two small projects characterized injuries in wildland firefighters.

SIGNIFICANT FINDINGS

Orchard Injuries

1997 Farmworker Survey at community soccer league games. We found that among 316 subjects interviewed, 97.7% identified Spanish as their preferred language and 85% worked in agriculture. Respondents earned an average of \$12,222 per year, of which an average of \$9974 was earned in 8.7 months of agricultural work. Among the workers interviewed, 46 reported having sustained work-related injuries, 44 occurring in agricultural work. Of these, 40 received medical attention. Half (22) reported that their employers paid their medical expenses and 12 of the injured workers paid these expenses themselves. When asked about their knowledge of the worker's compensation (WC) system in Washington state, only 26.5% had knowledge of such a system. When asked how they would cover the expenses of a workplace injury, the majority of workers (51.3%) said that they would themselves pay. Only 12.3% reported that they would file a WC claim for a work related injury. This study demonstrated that work related injuries were common, that workers appeared to know little about the WC system (which covers all workers in Washington state), and that the use of what we termed the "soccer survey" was an effective means to contact workers inexpensively and with good cooperation.

1999 Community Random Digit Telephone Survey. This study also demonstrated that injuries are common among agricultural workers (47 total and 39 medically treated injuries among 440 workers; 10.6% and 9% per year respectively). It also demonstrates that workers often do not use the worker's compensation system and that incidence rates based on WC data may underestimate the injury rate in this population. Only 29 of 39 medically treated injuries resulted in the filing of claims by this population. The relative lack of ladder injuries in this population may reflect the manner in which a subject could report injuries or the fact that many of these workers also spent large percentages of their time in non-orchard industries.

2001 Review of Washington State Workers Compensation Data. Claims related to ladders were not only the most frequent, but were also the most expensive as a group in terms of medical aid, time loss, and other costs. On a per claim basis, ladder-related injuries were among the most severe and costly reported injuries. Other common causes of injury among claims were branches and vegetation, structure and material, and ground-related injuries.

We found that when we focused on deciduous tree fruit as an industry, of the 13,068 claims that were classifiable by us in the dataset, 4,020 (30.8%) were determined to have been ladder-related. Ladder-related claims accounted for nearly half (48%) of all compensable claims (claims involving time loss, disability, or loss of earning power in addition to medical expenses). Ladder related injuries represented the single most important cause of injuries both in numbers and in cost within the workers' compensation system. On a per-claim basis, ladder-related injuries were among the most severe and costly reported injuries as well.

2002 Key informant interviews. Key informant interviews highlighted musculoskeletal and eye injuries, ladders, and the following risk factors: worker responsibility, employer obligations, priorities and responsibilities, governmental oversight, and the difficult nature of the work. The 25 qualitative, open-ended interviews revealed themes that indicate that knowledge and experience, physical and psychological aspects, and external influences all affect the occurrence of injuries in orchards. Reports from these informants again strongly endorsed ladders as being the primary source of injuries in the orchard environment.

2002 Evaluation of Labor and Industries Eyes and Fall Prevention Program.

Program participants (PP) versus employers not participating (NP) in the program were much more likely to report the implementation of safety changes: OR=16.87 (95% CI 6.96-40.9)). The difference remained significant after controlling for hours and business years, with OR=15.47, (CI 3.57-67.0). The changes most commonly reported by PP included the use of site-specific hazard communication and accident prevention programs. Among the changes most commonly reported by NP were the distribution of glasses to workers, the use of an accident prevention program, and ladder safety instruction. Of the 19 PP who implemented only some of the recommendations, 47% reported that the other change(s) were already in place before the consultation. Of the 52 NP who made no safety changes in the last three years, 90% believed that there was no need for it. Implementation difficulties were experienced by 32 (44%) of PP and 20 (59%) of NP. When only partial implementation was achieved by program participants, it was mostly (63%) because the grower believed that there was no need for more to be done, or because he/she considered the remaining suggestions unworkable. A fourth of the 23 PP reported difficulties with the installation of eye wash and shower facilities in the field; time constraints were a barrier to implementation in 19% of the cases and expense was mentioned by 16%.

Among the interviewed program participants 35 (41%) reported not having received recommendations to minimize the risk and cost of injuries. Fourteen could not tell whether they have received such risk management consultation. All the 34 PP who received risk management (RM) consultation reported partial (44%) or full (53%) implementation. Management of workers' claims was the most common change mentioned (20%), followed by the addition of policies for corrective action (16%) and changes in hiring practices (14%). Unlike the implementation of safety changes, no difficulty was reported by 69% of the participants who implemented RM changes.

Most (77%) of the interviewees did not have any program modification suggestions. More (36) of the interviewed growers made suggestions regarding ways that L&I could help them maintain the safety changes. Specifically, 16% expressed an interest in being informed about rules and 14% would like to receive safety material. The wish to be left alone was expressed several times by 4-10 participants in response to both of these open-ended questions. Fewer than 50% of the interviewed program participants provided feedback about the program and L&I staff. The feedback regarding the L&I staff was generally positive.

2002 Ladder Injury Interviews Over a nine-month study period, 37 injured workers were interviewed. These workers provided insight into how workers are hurt on ladders. This information helped formulate approaches to enhancing ladder safety. The study found that 25% of the injured workers had less than a year's experience working in orchards; 44% of cases took place on the upper third of ladder; ladder movement was the main cause in 47% of cases; the worker slipped in 27%. Back injuries and ankle sprains were the most common injuries. Several injuries occurred when a picker missed the last rung while coming down the ladder with a full bag of apples. The heavy bag can obscure vision and throw the worker off-balance. Missing the last step on descent, loss of balance while reaching, sliding of the third (mobile) leg, slipping on slippery ladder rungs, rolling on branches trapped between the foot and the rung all were scenarios identified by workers as mechanisms of ladder injury.

2003 Worker Interviews/ Worker Survey. The most common injury event, reported by nearly 60 percent of the injured workers, was a fall from a ladder; and the most common types of injury were sprains and strains, broken bones, and eye injuries. Factors contributing to injury fell into three major categories: personal attributes: (limited occupational choices, experience, risk-

taking behavior, carelessness), work-related issues: (relationship with ‘boss,’ workplace treatment, employer demands, communication styles, training, resource availability, equipment and external factors: (weather, terrain, regulations, economic conditions).

A major goal of the second phase was to determine the importance of factors identified in phase one. A written survey was developed that included the factors identified in the first phase. Subjects were asked to indicate the importance of these factors using a five-point Likert scale. More than a quarter of these 184 subjects (n=49) reported having had an injury while working in the orchards, and nearly 75% reported that this injury involved a ladder. The factors that subjects identified as most likely to contribute to an injury included limited experience, being older, being female, (lack of) permission to make decisions, and employer demands. When data were compared using these factors, it was determined that, inconsistent with the workers’ perceptions, experienced workers were more likely to be injured than less experienced workers (p=.012). However, gender did not affect injury rate and contrary to workers’ perceptions, older workers were more likely to be injured than were younger workers (p=.017). Subjects also commented that regulations were not enforced and that weather and the terrain affected safety. About half of the workers (n=98) indicated that they had some training; about half of these were trained by their co-workers or through the use of written materials. Thus, only about one quarter of these subjects had any type of ‘formal’ training. Other contributing factors included ‘poor equipment’ (such as ladders), careless behavior, and lack of skills.

This study provided an interesting glimpse into the world of Hispanic orchard workers. While personal attributes (i.e., age, gender) were ranked as the most important contributors to injury, factors in the work organization (i.e., employer demands, workers’ decision latitude, poor equipment) may be major contributors to workplace safety; and these work-related factors are most amenable to interventions. Further studies are needed to determine the extent of worker training, to learn about the contribution of other factors such as piece rate payment, workplace climate, use of personal protective equipment and the enforcement of rules and regulations. In order to be most effective, interventions should be aimed at workplace modifications; the development of effective, appropriate training methods; and the development of methods to promote compliance with rules and regulations.

2005 Sensor Ladders as a Training and Hazard Assessment Tool. The next steps in the development of the smart ladder are to develop a protocol for using sensor input to identify the risk conditions that warrant warning a worker. Further engineering needs to be done to simplify the sensor array and field harden the sensor package.

Once fully developed, the smart ladder will be a useful training tool for providing real-time feedback, through sensor triggered alarms, to workers being trained on orchard ladders. The smart ladder will also be usable for monitoring the effectiveness of training. By silencing the alarms and allowing workers to use the smart ladders in the fields under true work conditions, data on the frequency of the occurrence of worker induced risk conditions among trained ladder users can be collected. This can assist in evaluating the effectiveness of training and can provide feedback to instructors on improving training.

Tractor Injuries

The Agricultural Centers’ years of study of tractor related injuries and deaths have led to several conclusions on the problems and solutions. Research has demonstrated that the following key recommendations would drastically reduce tractor injuries and deaths:

- Establishing a range of incentives to retire older tractors or retrofit them with ROPS
- Increasing the use and maintenance of preventative and protective technologies
- Mounting a social marketing campaign aimed at safe tractor use
- Building private and public sector (especially legislative) support for the initiative

Children's Farm Injuries

Injuries in teens working in agriculture. A study that used random digit dialing of the Sunnyside Washington area identified and interviewed parents or guardians of teens in order to assess the teen's agricultural injury experience. The study found 439 households with a teenager in the house. Two hundred were identified as doing agricultural work. Among these, 8 teenagers were identified as having suffered an injury while at work. A total of ten injuries were reported in the survey among teens. Three of the injuries were reported to the WC system. Only two of ten injuries were cared for in a hospital. The study found an injury rate among surveyed teens of 5.0 % or 19.2/100 full time equivalents (FTE). The rate was higher for Hispanic teens at 7.2 % and 27.2/100 FTE respectively. However, this rate did not reach statistical significance.

Forestry Injuries

Through our stakeholder engagement of the forestry industry we learned that traumatic injuries are a major concern in logging and forestry work. Project participants identified traumatic injuries as one of the top priorities for research. Concerns included both fatal and nonfatal injuries, with an emphasis on eye injuries. Traumatic incidents were attributed to struck-by injuries, slips, trips, and falls. Overexertion and fatigue were also noted as predispositions to forestry-related incidents.

In wildland firefighting we found an elevated injury frequency rate for the T-1 "Hotshot" crews assigned to the Clear Creek fire. There were a significant number of injuries in the fire camp setting, which offer opportunities to reduce injuries on future fires. The report includes recommendations to improve firefighter safety and reduce injuries, both on the fireline and among fire support personnel in the fire camp setting. It also proposes future research needs to better define the types of injuries, the resources affected, and the need to look at fire illnesses as another component of the wildland fire health and safety program.

PRODUCTS/OUTPUTS

Further products are reported in the companion database.

Publications

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Swenson E [2005]. Improving the health and safety of northwest orchard workers and their families. SPHCM’s Spotlight on Research, Issue 19: Winter 2005.

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Questionnaires and Surveys

Agricultural Work and Injuries in Teenagers Survey (English/Spanish): A Community-based telephone survey to estimate the one-year cumulative incidence of work-related injuries and characterize work patterns.

Tractor Safety for Teens Questionnaire: Includes a self-assessment behavioral checklist, teen knowledge and attitude assessment tool, and parent attitude assessment tool.

Questionnaire on Ladder Injury Experience (English/Spanish): A questionnaire to be delivered in a personal interview to determine the characteristics of orchard ladder injuries.

Farm Families and the Employment, Training, and Supervision of Children Survey: A personal interview survey using open-ended questions to assess the types of farmwork done by children; the conditions under which children perform tasks, and the extent and nature of parental training and supervision of children.

Older Farmers: Factors Influencing their Retirement Decisions Survey: A personal interview survey using open-ended questions to assess circumstances that affect older farmer’s retirement decisions and potential risk factors for injuries.

Tools for Education and Prevention

Orchard Injury Project’s “Smart Ladder.” The Orchard Injury project has developed an engineering intervention to prevent the most common causes of injuries in the orchard, ladders. The “smart ladder,” senses the position, weight, center of gravity and weight shift of the worker.

PNASH is applying to license a working model of the invention. Patenting the ladder will open it to commercial development, which could facilitate its use in other industries, beyond its primary purpose for orchard worker training.

Design for Sensor-based Devices and Modifications to the Ladders. To facilitate training methodologies for improved ladder safety in orchards.

Safety and Health Research Agenda for Northwest Wildland Firefighting. Describes health and safety research priorities for wildland firefighting, as identified through literature review and key informant interviews.

OUTCOMES

Orchard Injuries

Improving the practice of the Washington State Department of Labor and Industries.

Reuel Paradis, a regional administrator for the Washington Department of Labor and Industries sums up the impact of PNASH with:

“our frequent interface with PNASH researchers and their feedback added great value to our understanding of the relationship of regulatory authority and the regulated community and assisted in our developing insight to methods for improving work place safety. In addition, PNASH provided us with two unpublished papers that, in my opinion, are illuminating.

A short list of insights I’ve gained, and I believe staff involved with the implementation of ‘eyes and falls’ gained, from the ‘eyes and falls’ project and from our association with PNASH researchers.

- *The department of labor and industries administrates public policy for the government of Washington state. The government of Washington state is the registered voters of the state. The department of labor and industries can not compel compliance with safety and health public policies or with the principles of loss control management.*
- *Industries, employers and workers, need to own their safety and health issues.*
- *The department of labor and industries needs to develop meaningful partnerships with everyone – other public sector entities, higher education entities and private sector entities – who can impact (add value) work place safety and health problem resolution.”*

Model of a “Smart” Tripod Orchard Ladder

To date, the Smart ladder is still in prototype. The promise of this device is that it will be both an excellent training and training assessment tool. As the device can monitor a worker’s status with respect to position, movement and balance and either warn or just record this information, it can be used both to teach workers to stay within the confines of the ladder stability envelope and can later be used to silently monitor the change in behavior brought about by that training. The smart ladder can also identify the benefits of changes in worker equipment or behavior designed to increase ladder safety. The outcomes brought about by this device have not as yet been realized. Further development will be needed.

Technology Roadmap

As a result of the now acknowledged impact and cost of orchard worker injuries and in particular, ladder injury, the United States tree fruit industry is turning to technology to reduce labor and the burden of that labor. In 2003, the US tree fruit industry developed a Technology

Roadmap to improve the sustainability, efficiency, and quality of fruit production in the United States. The Technology Roadmap seeks not only to improve the operational efficiency of tree fruit harvesting, but also to create a more prosperous, skilled, year-round work force that works under safer conditions (Warner, 2004). The tree fruit industry acknowledges that a past practice of merely increasing workload in order to increase productivity is outmoded, yet pure reliance on technology is likely to fail unless it also improves the lives, social conditions, and economics of the industry.

A first and critical component in the Technology Roadmap is to semi-automate labor-intensive aspects of fruit orchard work, including harvesting, pruning, and fruit thinning, in order to increase productivity, with the ultimate goal to fully-automate harvesting and other labor-demanding activities in 10-15 years. The aim is to produce improved quality fruit at lower production costs. These industry changes will result in fewer, but more highly trained workers working in technologically advanced orchard management systems. As part of the transition to automated orchard activities, a near-term and central goal of the Technology Roadmap is to transition from performing orchard work on ladders to performing orchard work on mobile, raised platforms. Given the aggressive goals of the Technology Roadmap, mobile platforms are moving from an experimental tool to an actual product that will be used in orchard activities.

Tractor Injuries

Launching of National Tractor Safety Initiative.

This project brought together all the NIOSH Agricultural Centers in their first joint project to address a known problem area. The Centers worked together to develop an informed solution to the high fatality and injury rates from tractors. Through a two-year grant from NIOSH, we are building partnerships, finalizing the evidence package, and conducting audience research. While this initiative is still in an early phase, we are preparing for a national social marketing campaign to reduce farmer injuries and deaths.

Research has demonstrated that the following key recommendations would drastically reduce tractor injuries and deaths:

- Establishing a range of incentives to retire older tractors or retrofit them with ROPS
- Increasing the use and maintenance of preventative and protective technologies
- Mounting a social marketing campaign aimed at safety tractor use
- Building private and public sector (especially legislative) support for the initiative

Children's Farm Injuries

PNASH's educational intervention evaluation projects have improved the effectiveness of two ongoing children's safety programs: Magic Valley Safe Kids Coalition's Safety Day Camp in Idaho, and Washington State University Extension's Teen Tractor Safety program in Skagit County. In addition, PNASH has continued our commitment to children's safety and educational interventions by initiating an evaluation of the new Washington State Safety and Health for Agricultural Teens, a curriculum that will be implemented in Washington state through Ag-in-the-Classroom in 2006.

Forestry Injuries

Improving injury record keeping for wildland firefighters.

This study reviewed injuries that were documented on two large fires, to determine if individual characteristics, environmental factors, fatigue and/or fitness levels affected the numbers and types of injuries. The report back to the USDA Forest Service identified areas to improve firefighter safety and reduce injuries, both on the fireline and among fire support personnel in the fire camp. It also proposes future record keeping and research needs to better define the types of injuries, the resources affected, and suggests looking at fire illnesses as another component of the wildland fire health and safety program. Improvements in record keeping and further investigation could lead to improved safety and health for wildland firefighters.

MUSCULOSKELETAL DISORDERS

INTRODUCTION

There is a growing awareness in the industry and among occupational safety professionals on the burden of work related musculoskeletal disorders. In response to industry concerns, PNASH investigators have approached this problem both in packinghouses and in the field. In conducting these investigations, PNASH has worked with affiliated programs at the University of Washington: The Field Research and Consultation Group and the Ergonomics Program.

GOALS

The goal of the PNASH Center's Musculoskeletal Disorders program is to reduce occupational injuries among workers in agricultural industries. The sub-goals are to:

- Assess the hazards of musculoskeletal disorders in high-risk occupations
- Develop targeted interventions aimed at reducing the frequency of risk conditions that lead to injury
- Evaluate the effectiveness and the cost-benefit of interventions

BACKGROUND AND SIGNIFICANCE

The U.S. tree fruit industry is struggling to survive in the increasingly competitive global agricultural economy. Growers in China, New Zealand, Chile, Italy, Turkey, and Mexico are producing greater portions of the global apple market share. According to the US Apple Association, between 2000 and 2003, apple imports to the U.S. rose by 30% while exports simultaneously declined by 8%. Increasing labor costs and declining labor availability contribute to U.S. growers' challenge to compete with foreign suppliers. Labor is the greatest expense in orchard activities involving hand-picking, pruning, and thinning fruit. Good labor supply and low wages in foreign countries increase the competitive pressures on U.S. growers. The supply of workers available for hand harvesting in the U.S. has steadily decreased as agricultural workers go to better paying, year-round jobs in other industries. The end result is that orchard owners and growers have to respond to the changing demographics of the agricultural workforce, relying less on migrant and temporary workers and developing the ability to offer competitive, higher-paying year round jobs.

Agriculture has historically been one of the most hazardous and physically demanding workplaces in the U.S. From previous PNASH research we know that falls from ladders are the most common injury reported by orchard workers in Washington, and thus they result in the highest number of workers' compensation claims filed by agricultural workers. To compound these safety problems, the agricultural workforce and the U.S. work force is aging. Ladder work cannot be safely and efficiently performed by individuals who are not in good physical condition, who have had injuries limiting physical capacity or mobility, or are at an age where their physical capacity has decreased. In the case of these individuals, redesigning the worksite to reduce the physical demands would open up new avenues of employment.

The tree fruit industry also employs thousands of workers throughout the year in packing houses, warehouses, packing sheds and canneries. The U.S. Bureau of Labor Statistics lists more than 45,000 employed in the 45-2041, Graders and Sorters, Agricultural Products category (Bureau of Labor Statistics, 2004). However, many if not most fresh food packing and sorting workers are part-time and temporary, interspersing warehouse work with field work or other agricultural work throughout the year. Thus, the actual number of people working in fresh fruit or vegetable packing houses, processing warehouses, or canneries is much higher.

Some research has been reported on health and safety conditions in the packing houses. Fruit and vegetable packing was among the top 5 industries for gradual onset upper extremity disorders in Washington state workers compensation claims between 1989 and 1996. In the period from July 1994 to July 1995, three occupational groupings accounted for 57 percent of the unemployment insurance claims filed in Yakima County. They were agriculture (32 percent), processing jobs (12 percent), and packing and material handling (14 percent), all of which are based in the agricultural economy (Labor Market and Economic Analysis Branch, 1997).

ACTIVITIES

Packinghouse Hazard Assessment

Between 1997 and 1999, PNASH investigators conducted two studies in Washington packinghouses, a musculoskeletal hazard assessment and a study of the perceptions of workplace health and safety risks among the primarily female Hispanic workforce that conducts this work. Sixty-nine workers were interviewed using a combination of quantitative and qualitative research methods. The hazard assessment was led by the PNASH-affiliated University of Washington Field Research and Consultation Group.

Packinghouse Training Intervention

The “Hispanic Farm Workers One-Act Plays” was a multiphase project conducted by PNASH satellite Center for Farm Safety and Health. In Phase I, four one-act Spanish plays presented health information and farm safety training to agricultural workers. The plays are delivered live by a troupe of community-based actors and evaluated for effectiveness in imparting knowledge and also developed into videos for sustained use. Play #4 “Dora Evelia” provides training on bending, lifting, and ladder safety. In Phase II, an educational intervention program was developed for migrant and seasonal packinghouse workers in eastern Washington. This training program was largely based on the ergonomic play, “Dora Evelia.” This project is still active, with data analysis and dissemination of the study results due in fall 2006.

The Virtual Corset: An Objective Tool for Measuring Postural and Vibration Exposures

This pilot project led by PNASH investigator Dr. Peter Johnson developed a new device, which allows ergonomic researchers to continuously collect simultaneous data on back, side, and limb dynamics of agricultural workers over the course of their day or multiple days. This “Virtual Corset” was developed in conjunction with Microstrain, Inc., and will further our understanding of the relationship between cumulative exposure to vibration, posture, and musculoskeletal disorders.

The Virtual Corset activities included the development of a pager-sized logger with 2mb of built-in memory called the Virtual Corset which non-invasively, and continuously collects data on postural exposures in two dimensions. The pager sized Virtual Corset can be mounted on the upper arms, sternum, or upper back and continuously records a worker’s postural exposures, in two dimensions, relative to gravity. With programmable sampling rates, the Virtual Corset can collect continuous data over a whole work shift or over multiple days (up to 80 hours). This measuring capability has not been practical previously due to memory and battery power limitations. We have also explored the utility of using a different continuous, inexpensive, non-invasive exposure assessment device called a Ballistic Actigraph to characterize repetitive exposures to the hand.

Ergonomic Evaluation of New Tree Fruit Harvesting Technologies

Most recently we have successfully pilot tested the proposed suite of direct measurement tools to measure and characterize postural exposure for assessing musculoskeletal risks to workers using

new tree fruit harvesting mobile platforms. Data is obtainable from the low back (Virtual Corsets), postural exposure data from the upper arms (Virtual Corsets), hand activity exposures (Actigraphs), and metabolic loading (Heart Rate Monitors) during orchard work. Using a repeated measures design, we collected and analyzed exposure data from four workers while they performed 30 minutes of pruning work on a mobile platform, as well as during 30 minutes of pruning on ladders.

In order to measure back flexion/extension and lateral bending, one Virtual Corset was attached to the upper torso of each worker in the thoracic region of the spine between the shoulder blades using an adjustable, cross-shaped Velcro strap. To measure upper arm abduction/adduction and flexion/extension, two Virtual Corsets were attached to the lateral aspects of the upper arm midway between the shoulder and elbow using Velcro straps. To measure hand activity, two Ballistic Actigraphs were attached to each wrist, in the same manner as wrist watches.

SIGNIFICANT FINDINGS

Packinghouse Hazard Assessment

Between 1997 and 1999, PNASH investigators conducted two studies in Washington packinghouses, a musculoskeletal hazard assessment and a study of the perceptions of workplace health and safety risks among the primarily female Hispanic workforce that conducts this work. Sixty-nine workers were interviewed using a combination of quantitative and qualitative research methods. The hazard assessment was led by the PNASH affiliated University of Washington Field Research and Consultation Group.

Most of the problems of apple warehouse work relate to the physical labor involved in sorting and packing fresh apples. Repetitive motions, heavy lifting and awkward positions are examples of the problems identified by the Field Group. The Field Group survey of musculoskeletal injuries among male and female workers in three Yakima area warehouses found a prevalence of 70% for any problem that occurred in the current job (Simcox et. al. 2001). The Field Group defined a work-related musculoskeletal injury as one that occurred at least once a week, or lasted one week or more, was not an accident, occurred on the current job, and had affected the worker within the previous year. Based on these criteria, 52% of the Field Group sample had experienced an injury. Sixty-two percent of all women surveyed in the Field Group study met these criteria, including 55% of all Hispanic women. In the study of risk perceptions, 54 percent of the participants reported a workplace injury or illness (37 out of 69). Some participants viewed accidents as an inevitable hazard of apple warehouse work. And in fact, 45 pound boxes do fall, packing carts tip over, and fingers get caught in machinery. More insidious are the acute injuries that result when well-meaning workers try to prevent boxes of apples from falling and wrench their backs by reaching or grabbing heavy objects with sudden movements. In these cases, workers feel particularly wronged when the employers try to downplay the injury or refuse to pay for treatment. These workers feel that their injury was caused when they were specifically doing something to help the employer, and the consequences should be compensated. Some worker comments included,

“For me, it is a very fast and hard job. I am not used to it. I don’t know how dangerous it is, but when you see people getting hurt, you just wish it does not happen to you.”

“But still, people are very pressured, and have a lot of work. They get way too many injuries because of what happens. They try to do 10 days of work in one week. They force the people to do a lot of work. It is difficult.”

“I don’t think there is much they can do [to prevent risks] because the risks are there. All they can do about it is let you know, and talk to you about it. And let you know where are the most risks. Other than that, preventing someone from getting hurt, no, anyone can get hurt.”

Development and Evaluation of Training Interventions

The “Hispanic Farm Workers One-Act Plays” Phase I project developed four one-act Spanish plays, including Play #4 “Dora Evelia” for training on bending, lifting and ladder safety.

With funding from NIOSH and a Washington State Department of Labor and Industries Safe@Work grant, performances were presented across a three-county region of Eastern Washington. To date, more than 700 individuals have viewed the safety play performances in a variety of community settings with positive results. A video of the live play has been disseminated to regional producer associations and educators.

In Phase II, an educational intervention program was developed for migrant and seasonal packinghouse workers in eastern Washington. This training program was largely based on the ergonomic play, “Dora Evelia.” Three large fruit packing houses participated in training sessions for a total of 275 participants. Of these, 220 participants completed the follow-up observation post-test sessions and received the certificate of completion. This project is still active, with data analysis and dissemination of the study results due in fall 2006.

The Virtual Corset: An Objective Tool for Measuring Postural and Vibration Exposures (Figure 2)

We have been involved in a collaborative study with the University of British Columbia where over 200 full-day low back postural exposure measurements have been collected in five heavy industries. In addition, we have successfully developed and implemented a software platform to evaluate the full-day low back postural and movement velocity exposures.

We have also explored the utility of using a different continuous, inexpensive, non-invasive exposure assessment device called a Ballistic Actigraph to characterize repetitive exposures to the hand. Orchard work is hand intensive, and we would like a way to characterize and measure difference in hand exposures across different mobile platform designs and measure differences across the various proposed work methods.

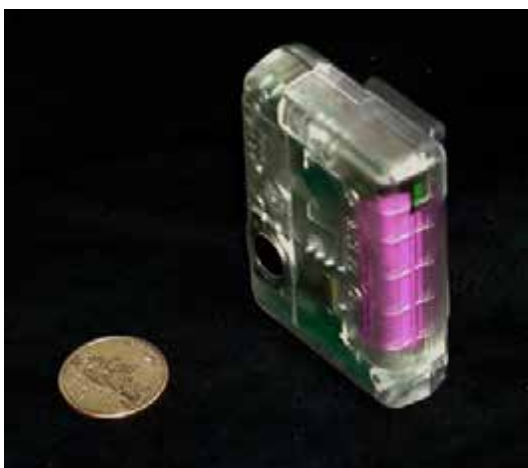


Figure 2 –The Virtual Corset (left) and Ballistic Actigraph (right).

Ergonomic Evaluation of New Tree Fruit Harvesting Technologies

The recent 2005 pilot of an assessment of tree fruit harvester musculoskeletal risks has demonstrated the field utility of the Virtual Corset and Actigraph and promise for a future comprehensive field study.

PRODUCTS/OUTPUTS

Further products are reported in the companion database.

Publications

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Snyder, K [2004]. Risk perception and resource security for female agricultural workers, In: Michael Alvard (ed). *Socioeconomic Aspects of Human Behavioral Ecology*, Research in Economic Anthropology, Volume 23: 271-292, 2004.

Questionnaires and Surveys

Perception of Risk among Female Workers in the Fruit Packing Industry Survey (English/Spanish): Personal and detailed interviews to test whether reproductive status, household resources, personal and general working conditions, and socioeconomic and cultural context predict differences in perceptions of health and safety risks and a greater tolerance for workplace hazards.

Yakima Farmworker Community Surveys [2004 and 2005].

Sampling and Analytical Methods

The Virtual Corset – miniature, two-axis posture measurement system with 2 Mb of memory.

Tools for Education and Prevention

Musculoskeletal Risks in Washington State Apple Packing Companies: An ergonomic evaluation of job tasks in Washington apple warehouses that led to the development of a publication that includes ergonomic risk factor reduction recommendations.

Spanish Language Safety Play and Curriculum: VHS and DVD format Reducing Musculoskeletal Injuries (with English subtitles) also streamed on the Farm Center Web page.

OUTCOMES

Influencing Work Practices in Packinghouses

To date, more than 700 individuals have viewed the Hispanic live play “Dora Evelia,” which teaches safe bending, lifting and ladder safety through performances in a variety of community settings with positive results. The human resources manager of a large employer commented that “*we are finding that the use of theater is a very effective way of impressing the safety message on our workers.*” The video of the play has been purchased for use by 20 producer associations and educators. One producer is using the play scripts as a training tool. The recent training program largely based on the ergonomic play, “Dora Evelia” has been delivered to three large fruit packinghouses for a total of 255 participants. Of these, 220 participants completed the follow-up observation post-test sessions and received a certificate of completion. Observed behavior change data are currently under analysis.

Researchers using Virtual Corset to Measure Ergonomic Exposures

PNASH investigator Dr. Peter Johnson has developed and introduced a new tool to assess postural and vibrational exposures to agricultural workers. This tool is currently being used in Washington state in a pilot investigation of the ergonomic risks posed to workers using a new platform harvesting technology.

This tool has been disseminated to researchers to use in field investigations. While PNASH proceeds to use this tool to study risks to agricultural populations, we are also offering the tool and methods to other researchers to adopt. We have been involved in a collaborative study with the University of British Columbia where more than 200 full-day low back postural exposure measurements have been collected in five heavy industries. The Virtual Corset is an important research tool that has been highlighted in the NIOSH e-news and the UW Department of Environmental and Occupational Health Sciences 2003-2005 Biennial Report.

Serving the Health and Safety Needs of a Modernizing Industry

The critical component in the Technology Roadmap is to semi-automate labor intensive aspects of fruit orchard work, including harvesting, pruning and fruit thinning, in order to increase productivity, with the ultimate goal to fully automate harvesting and other labor demanding activities in 10-15 years. The aim is to produce improved quality fruit at lower production costs. These industry changes will result in fewer, but more highly trained, workers employed in technologically advanced orchard management systems. As part of the transition to automated orchard activities, a near-term and central goal of the Technology Roadmap is to transition from performing orchard work on ladders to performing orchard work on mobile, raised platforms. Given the aggressive goals of the Technology Roadmap, mobile platforms are moving from an experimental tool to an actual product that will be used in year-round orchard activities. The pilot and proposed work of the PNASH Center

to assess and control the musculoskeletal hazards will impact the developing technology that will be promoted by the tree fruit industry.

Karen Lewis, WSU Extension, in the Good Fruit December 2005 issue was reported as saying *“it’s a benefit to the tree fruit industry to have the University of Washington researchers bring their ergonomics skills to help address the problem.”*

NOISE AND VIBRATION EXPOSURE

INTRODUCTION

Vibration and noise represent a major occupational hazard to agricultural workers. Data collected from a small PNASH project in forestry has demonstrated that workers employed in these common Northwest occupations experience substantial over-exposure to vibration and noise.

GOALS

The goals of the PNASH Center's program area in noise and vibration were to conduct a task-based assessment of the relevant hazards that would allow:

- Identification of specific activities that contribute to hazardous exposures.
- A focus on the combined aspects of such exposures that contribute to higher risk.

BACKGROUND AND SIGNIFICANCE

Work in the forestry industry traditionally has involved exposure to a wide variety of safety and health hazards. The multibillion-dollar forestry industry, which includes the most dangerous occupation in the United States, logging, employed approximately 122,000 workers nationwide in 1996. The fatality rate for loggers at the time of this work was 128 deaths per 100,000 workers, compared to the overall U.S. rate for all occupations of 5/100,000. Washington and Oregon, in the U.S. Pacific Northwest together represented 16.7% of total U.S. logging employment, and accounted for 73 logging deaths annually, or 9.5% of the annual U.S. logging fatalities.

As a result of these alarming fatality statistics, most health and safety efforts in the Northwest have focused on the prevention of traumatic injuries. However, forestry workers are at risk for a variety of other occupational diseases. In particular, exposure to occupational hand-arm vibration (HAV) has been associated with a variety of adverse health effects, collectively known as hand-arm vibration syndrome (HAVS), since the early 1900s. Additionally, long-term whole-body vibration (WBV) exposure to seated persons has been associated with an increased risk of degenerative lumbar spine injuries, central nervous system disturbances, and possible damage to the digestive and genital/urinary systems.

Occupational noise exposure is common in both forestry work and in many other agricultural occupations. The Washington State Department of Labor and Industries has seen compensation claims for noise-induced hearing loss increase ten-fold in recent years. Occupational noise exposure is recognized as a causal factor for permanent, irreversible hearing loss.

ACTIVITIES

Noise and Vibration Exposure in Forestry Workers

This project conducted in 1998 to 2002 used a novel task assessment instrument developed for forestry workers. Task-based assessment offers an important departure from traditional exposure assessments in forestry that focus on job titles or single tools. Information on tools as exposure sources is embedded within task assessments, along with other factors such as posture, force repetition, and temperature. The assessment methods used NIOSH and OSHA exposure metrics.

A total of 58 workers operating 17 types of equipment were assessed for noise and vibration exposure, health status, and work history in Northwest logging sites: 32 in Washington, 10 in Alaska, and 16 in Idaho. Thirty office worker control subjects were recruited from the UW

School of Public Health and Community Medicine, and 3 forestry technician control subjects were recruited from the Washington Department of Natural Resources. Three-hundred seventy four vibration measurements (115 WBV and 259 HAV) and 57 full-shift noise exposure measurements were collected, as well as 89 health effects questionnaires and 65 work history questionnaires.

SIGNIFICANT FINDINGS

Noise and Vibration Exposure in Forestry Workers

The results gained through the use of the task-based assessment suggested that exposure reduction strategies should move beyond the traditional HAV and noise control targets. In addition to chainsaws, heavy equipment controls such as joysticks, operating levers, and other handle-type controls, were found to produce HAV levels well above the ACGIH TLV. The highest HAV exposure sources also are associated with significant noise sources: chainsaws, falling operations, and yarding and landing operations in particular. A similar picture emerges from task assessment of whole body vibration (WBV) exposures. The greatest WBV sources were log processing, road construction, front-end loaders, and excavators. The task and tool associated with the highest noise exposure levels were unbelting chokers on landings and chainsaws, while the task and tool associated with the highest vibration exposure levels were log processing and front-end loaders (WBV), and notching stumps and chainsaws (HAV). Thus, using task-based assessment, specific exposure sources are not treated in isolation but contribute to a constellation of factors in a high-risk task.

PRODUCTS/OUTPUTS

Publications

Robert Leo, Master of Science [2001] UW Department of Environmental Health. Systematic Observation of Noise Exposure and Hearing Protector Use in Worksites in Two Noisy Industries.

Neitzel R, Yost M [2002]. Task-based assessment of occupational vibration and noise exposures in forestry workers. *AIHA Journal* 63:617-627.

Websites/Listserve

[Occupational Noise and Vibration Exposures in Forestry Workers](http://staff.washington.edu/rneitzel/forestry.htm). Developed and maintained by investigator, Rick Neitzel, this site provides an overview of the Center's research in noise and vibration in forestry and offers educational materials in links and downloadable documents. <http://staff.washington.edu/rneitzel/forestry.htm>

OUTCOMES

Noise and Vibration Exposure in Forestry Workers

This study has impacted the Northwest logging industry in many ways. In 2003, at the state agency level, Jim Sedore of the Washington Department of Natural Resources said he was *“using the results of the report on noise and vibration to assess whether timber cruisers and other woodland DNR employees need to be included in a hearing conservation program, and whether any administrative controls need to be put into place for their employees that operate chainsaws.”*

From an industry standpoint; Alaska Pacific Logging in Craig, AK stated in 2003 that they were going to start making hearing protection available to their workers based on the results of our noise monitoring, as well as replace a broken window in one of their log yarders to reduce the noise levels in the cab. Allen Cutting Company in Shelton, WA was contacted in May 2003 were they then reported that they were going to start encouraging use of anti-vibration gloves among the fellers they employ.

SPECIAL POPULATIONS – THE HIRED FARMWORKER AND THEIR FAMILY

INTRODUCTION

The PNASH Center's emphasis is primarily on populations not well represented in current research, such as hired laborers, migrant/seasonal workers, and their families. This focus is seen across the great majority of our projects and program areas. In this section, we shall share our major efforts and outcomes that are not already addressed through the program areas of pesticide interventions, pesticide exposure methods, traumatic injuries, and musculoskeletal risks.

Our work with and for the Northwest farmworker community is possible through our partnerships with the Washington State Department of Agriculture; Washington State University; Northwest Regional Primary Care Association; and a number of community organization, farmworker health clinics, and producers. Furthering our reach to the farmworker is our Center's field office in the Yakima Valley and the recent development of a community health worker (CHW) network.

GOALS

The goal of the PNASH Center's emphasis on hired farmworkers and their families is to address health disparities of this vulnerable population. The subgoals are to develop:

- Health care capacity to serve farmworkers and their families
- Farmworker community capacity to identify and address health disparities
- Communication tools for low literate Hispanic farmworkers

BACKGROUND AND SIGNIFICANCE

Agricultural workers, and orchard workers in particular, are exposed to a variety of hazards that contribute to injury, disability, and death. Their work life and work activities vary by season and by the specific needs of the growers. Although picking fruit is often viewed as the primary role of the orchard workers, they are involved in a multitude of other tasks over the farming seasons. All of these activities are accompanied by hazards that may result in injuries and illnesses. Examples of commonly reported events are back injuries, eye injuries, sprains and strains, amputations, fractures, cuts, lacerations, burns and electrocutions, and poisonings (from chemicals and pesticides). Traumatic occurrences were related to improper operation of machinery as well as to livestock, ladders, and electricity. In addition to multiple physical hazards, orchard workers are often exposed to working conditions that increase their susceptibility to injury. For example, they may be required to work long hours under severe time constraints and their work may be hampered by weather conditions.

Agricultural communities are a great place to raise kids. However, the farm is a complex workplace that contains a broad spectrum of hazards, and that the boundary between workplace and home is often hard to draw. In the past decade, new insights into more subtle mechanisms of toxicity, and concerns regarding the special vulnerability of children to environmental pollutants have led to a new focus on children's environmental health. An important wake-up call was a 1996 Executive Order directing all federal agencies to develop an explicit strategy for including children's health in their evaluations. Passage of the Food Quality Protection Act of 1996 pointed the spotlight directly at pesticide health risks and children. This law, approved by a unanimous vote of Congress, requires the Environmental Protection Agency to review the toxicity of every pesticide, and to determine both the acute and chronic health risks these chemicals pose to children. This increased scrutiny has led to new questions about children and

pesticides. Thus, the hired farmworker may inadvertently bring pesticides home to his or her family through the take-home pathway.

ACTIVITIES

Health Care Providers

The rural primary health care provider is an excellent channel for PNASH's work to reach agricultural communities. Yet, there are significant barriers to working with this target audience. The nature of clinician's work is highly scheduled with little free time, and the work sites are remote, scattered, and most often without the technical infrastructure to use distance learning technologies.

In the last program cycle PNASH began in-person interviews at Northwest clinics. Interviews took place with leadership and staff, from which PNASH learned strategies for health care provider outreach and research needs. Following up on this information, a new project was developed - a farmworker mental health diagnostic tool in an audiotape format to address language and literacy barriers. For professional education, PNASH trained clinicians on pesticide health effects and how to serve as medical monitors under the new Washington state cholinesterase monitoring rule. Training took place through the PNASH and WSU sponsored Pesticide Issues Conference, PNASH Pesticide Medicine course, clinic on-site training, the Western Migrant Stream conference, and distribution of a PNASH-produced manual.

More recently we helped establish a statewide Community Health Worker (CHW) network, which we have come to recognize as the best way to contact farmworkers outside of their workplace. In May 2006, PNASH co-hosted an intensive teacher training program in which 26 CHWs participated from Washington, Oregon, and Idaho. The curriculum covered pesticides, specifically organophosphates (OPs), routes of exposure, the behavioral aspects of children and adults that lead to children's encounters with OPs, the biologic factors that make children more susceptible to the adverse effects of pesticide exposure, and the short and long-term effects of exposure.

This last year we have also developed an informal network with physicians and midlevel practitioners who see farmworker clients. This was a by-product of key informant interviews conducted as part of a risk communication project on the neurodevelopmental effects of organophosphate exposure in children. During a heat wave last summer that resulted in the death of a farmworker, we were able to alert our healthcare providers and provide them with a literature summary of the most efficacious means to lower body core temperature in cases of heat shock. A new four-year cooperative agreement between PNASH and the EPA provides health care providers with training in their higher education curriculum. Together with UW medical school, two nurse practitioner schools, one physician assistant (PA) program, two schools of nursing, and a rural premedical program, we are integrating pesticide issues into their curricula. We have a close partnership with the Northwest Primary Care Health Association, with which we partner on activities such as the Western Migrant Stream Forum, CHW Network and continuing education for health care providers.

Farmworker Community

To develop a relationship with and serve the farmworker community, PNASH, under Dr. Matthew Keifer, developed and secured support for two large community-based participatory research projects. The following projects focus on the development of strategies to enable local Hispanic communities to better respond to the health risks faced by workers in regional fields and orchards.

El Proyecto Bienestar (Well Being Project)

At the heart of this project are the Yakima Valley agricultural workers and their families. A community advisory board that includes 13 different constituencies guides the project. Along with the University of Washington, three partners serve as catalysts, educators, and resources for the community: Northwest Communities Education Center/Radio KDNA, Heritage College, and Yakima Valley Farm Workers Clinic/Northwest Community Action Center. As a part of *El Proyecto Bienestar*, a community-based participatory research project (CBRP) in the Yakima Valley, two community surveys were done in 2004 and 2005 to understand the environmental and occupational health concerns of Yakima Valley farmworkers and their families. A total of 445 surveys were completed and their results are now informing 2006 research activities.

Idaho Partnership for Hispanic Health. This partnership, newly formed in collaboration with the Idaho Mountain States Group, will address health disparities among Idaho Hispanics. PNASH is advising on community-based participatory research methodologies and will provide research and health care expertise to help communities address safety and health interests.

In addition to our CBRP projects, our joint enterprise with farmworker clinics to form a regional CHW Network is expanding our understanding of and outreach to other farmworker communities throughout the Northwest.

Low Literate Communication Tools

In the course of conducting our work, novel communication tools have been developed to survey and reach out to the often low-literate Hispanic farmworker. These tools include:

Community Theater Troupe: Health and Farm Safety Training for Hispanic Agricultural Workers. Development of four one-act plays for farmworkers in the state of Washington.

Narrative Based Model for Presenting Safety Information

This project defined and contrasted two narrative genres that communicate safety information to agricultural workers. It documented the appeal of informal stories and formalized narratives based on the responses of farmers with varying agricultural experience and knowledge

Self-administered Audiotape

This study developed and tested a mental illness diagnostic tool for use among farmworkers with varying literacy skills. It found that a self-administered audiotape is effective. The diagnostic audiotape has been distributed to Western farmworker clinics and copies continue to be available on request.

Icon Based History Questionnaire

This early PNASH project validated an icon based occupational history questionnaire for use among Hispanic migrant and seasonal farmworkers. The questionnaire is specially designed to obtain lifetime work histories from illiterate or semiliterate subjects for use in long-term exposure studies. More recently, the icon format has been used in a computer-based exposure history questionnaire. Currently, the touch-screen exposure/medical history questionnaire is being used in clinics as an efficient tool for use with low-literacy Hispanic pesticide handlers being monitored under the new Washington state cholinesterase monitoring rule.

SIGNIFICANT FINDINGS

Health Care Providers

From PNASH's 2002 interviews with Northwest farmworker clinics we learned strategies for meeting the outreach and research needs of health care providers, which include farmworker housing and health effects, skin diseases, depression, and *Promotora* program evaluation. The

major health issues for the farmworker population were considered to be poor nutrition, diabetes, substance abuse, depression, asthma, and domestic violence. The most common occupational illnesses were described as musculoskeletal and allergic related.

Presently, in order to develop appropriate risk communication materials for health care providers who serve agricultural workers, we conducted an informational needs assessment. Key informant interviews were conducted in 2005 with 23 physicians (52% Family Practitioners and 39% Pediatricians), 14 mid-level practitioners (MLP) (9 Physicians Assistants and 5 Nurse Practitioners), and 12 Community Health Workers (CHW), 4 of which were program supervisors. The key preliminary findings were as follows:

- 51% of the providers had no previous training on pesticides, and the largest group without previous training were mid-levels (64%).
- Only 2 physicians reported that pesticides were covered in their medical or residency training.
- 61% do not feel comfortable handling patient's questions about pesticides.
- The majority of providers in all three disciplines had an interest in receiving more information on the effects of pesticide exposure in children (73%) and the neurodevelopmental problems of OP exposure (71%).
- More CHWs reported using pesticide information in their work (83%) compared to MLPs (64%) and physicians (35%).
- More MLPs are asked ("frequently" or "sometimes") pesticide related questions by their agriculture working patient population (43%) compared to MDs (17%) and CHWs (33%). But in contrast, physicians were mentioned most frequently as the provider who would most likely discuss pesticide issues with their patients.
- Physicians and mid-level's turn first to the Poison Control Centers for pesticide information. The next best source for physicians in order of preference was the Internet, then a colleague or expert in the community. An expert was chosen before the Internet by mid-levels as well as community health workers. All groups mentioned that they would use Internet sites and written summary materials.
- Conferences or workshops were mentioned as a preferred source of information by both Mid-level practitioners (conferences) and CHWs (popular education workshops).
- Oral presentations and radio were considered the best means to reach farmworkers with pesticide information according to community health workers with the best ties within the community.

These results will inform our development of appropriate training materials.

Farmworker Community

From *El Proyecto Bienestar* (Well Being Project), Dr. Mathew Keifer's community-based participatory research project in the Yakima Valley, PNASH learned about the major health concerns in this important agricultural community through key informant interviews, two years of community surveys, and a town hall meeting in April 2006. More than 100 community members attended the event where they learned about the previous study activities and were invited to speak about risks they did not feel were represented on the list from our previous data collection.

El Proyecto Bienestar Hispanic Agricultural Community Health Concerns

EXPOSURES

Pesticides and Chemicals
Water Contamination

Extreme Workplace Temperatures
Air Contamination

OUTCOMES

Work-related Illnesses and Conditions
Work-related Injuries
Cancer
Dehydration or Heat Illness

CONTEXTUAL FACTORS

Abusive Workplace Conditions
Low Wages or Job Instability
Lack of Documentation
Lack of Access to Medical Care
Problems with L&I Claims

Low Literate Communication Tools

Community Theater Troupe

The use of Spanish-language live theater has been proven an effective means to provide farmworkers with information on health hazards and illness prevention strategies. The difficulty we experienced with live theater is securing the fiscal and management support necessary to sustain the theater troupe.

Narrative Based Model for Presenting Safety Information

This project investigated the appeal of informal stories versus formalized narratives based on the responses of farmers with varying agricultural experience and knowledge. Results indicated the highly generative quality of informal stories; they usually stimulated further storytelling or higher level thinking about safety. When safety information was packaged in informal, unscripted narrative, receivers of the information added their own comments and evaluation to match or build upon the previous story. In contrast, pre-planned formal safety narratives may have given the impression of being official, complete, and beyond questioning. The informal stories, by their very nature, invited participation and engagement. Based on these findings, we suggest three hypotheses for future research:

- Informal stories are an effective tool in safety training.
- Stories need to have sensory impact.
- Stories must accommodate differences among learners, taking into account such factors as age, experience, type of farm, interests, and cognitive styles.

Self-administered Audiotape Questionnaire

As a component of the mental illness diagnostic tool study, a self-administered audiotape questionnaire was developed for use among farmworkers with varying literacy skills. It found that a self-administered audiotape is effective and PNASH investigators have used the tool in a number of subsequent studies with a high degree of success.

Icon Based History Questionnaire

This early PNASH project validated an icon based occupational history questionnaire for use in Hispanic migrant and seasonal farmworkers. The questionnaire is specially designed to obtain lifetime work histories from illiterate or semiliterate subjects for use in long-term exposure studies. More recently, the icon format has been used in a computer-based exposure history questionnaire. Currently, the touch-screen exposure/medical history questionnaire is being used

in clinics as an efficient tool for use with low-literacy Hispanic pesticide handlers being monitored under the new Washington state cholinesterase monitoring rule.

PRODUCTS/OUTPUTS

Further products are reported in the companion database.

Publications

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Questionnaires and Surveys

Icon Based Occupational History Questionnaire: A questionnaire designed to obtain lifetime work histories for illiterate or semiliterate subjects for use in long term exposure studies.

Asthma Questionnaire in Spanish: For the detection of asthma in community-based studies of Spanish-speaking Mexican populations.

Poison Oak Intervention Questionnaire (English/Spanish): A questionnaire to measure farmworkers' ability to recognize a poison oak plant.

Farmworker Mental Health Questionnaire: A mental illness diagnostic tool for use among farmworkers with varying literacy skills. This survey is reliable for diagnosis of depression and mental illness in farmworkers who cannot read well enough to answer the standard self-administered diagnostic tool.

Sampling and Analytical Methods

Diagnosis of Mental Illness among Farmworkers Audio Tool: Spanish language tape for use in the identification of depression and other mental health disorders, distributed free at conferences, meetings, and by request [2003].

Tools for Education and Prevention

Literacy and Safety: Safety Materials for Migrant Farmworkers: Guide for educators to develop materials for farmworkers that are efficacious/readable as well as culturally and socially sensitive.

Mental Illness Audio Survey (Spanish). Developed in consultation with psychiatric and literacy experts. The audio survey included questions about depression, substance abuse, panic and generalized anxiety, domestic violence, economic and family stressors, and firearm availability.

Play Videos and Play Script Production Packet.

Poison Oak Intervention Poster and Pamphlet: Developed in a joint effort between L&I and the PNASH Center, the poison oak intervention uses a combination of a warning poster targeting farmworkers (Spanish) and an information pamphlet directed towards the owners and managers. In addition, the project utilizes a Spanish-language questionnaire to measure participants' ability to recognize a poison oak plant.

Courses and Workshops

Farm Summit [1998], March 5-6, 1998, Portland Oregon.

Cultivating Collaborations [2003]. September 16-18, 2002, Coeur d'Alene, Idaho.

Cultivating a Sustainable Agricultural Workplace Conference [2004], September 12-14, Troutdale, Oregon.

El Proyecto Bienestar (The Well-Being Project) Town Hall Meeting [2006], April 7, 2006, Sunnyside, Washington

Northwest *Promotora* Pesticide Training Workshop [May 2006], May1-2, 2006, Leavenworth, Washington.

Continuing Education Courses. PNASH annual continuing education courses are usually full-day courses and are accompanied by a course manual. Courses are designed to train health care and safety professionals and are conducted in collaboration with other academic partners.

Websites/Listserves

Pacific Northwest Agricultural Safety and Health Center, <http://depts.washington.edu/envhlth/>.

Environmental Justice, <http://depts.washington.edu/envhlth/>.

OUTCOMES

The intermediate impacts of PNASH's hired worker program area have included:

- The engagement of the Hispanic farmworker community through two community based participatory research projects: Washington and Idaho.
- The establishment of the Northwest Community Health Worker Network and Listserv.
- Training of clinicians in the diagnosis, treatment, and prevention of pesticide poisonings through training of community health workers and professional education such as short courses and the insertion of pesticide related content into higher education for premed, nursing, and mid-level practitioner students.

From the farmworker community at *El Proyecto Bienestar's* Town Hall in 2006 we heard the encouraging words from community members, "*That is good to have persons like you to help the farmworkers. I have worked in the fields and in the warehouses and it's an injustice the treatment they get.*" And direction to "have more meetings for the people, because we need lots of information about health and safety of the people."

From the community students who learned about occupational safety and health and conducted research on their own community we heard, "*the only way to find out what a problem may be in the community is to go out and find out people's opinions,*" and "*I also learned that environmental health can be practical and applicable to all groups of people, rather than*

ignorantly, idealistic, and filled with unattainable goals, as I thought before.” One of the same community member/students offered to PNASH researchers, “Thank you for trying to help the community.”

While these are inspiring sentiments, evidence of actual use of information is the type of transfer outcome we’re looking for. After PNASH’s May 2006 Promotora Pesticide Training Workshop, follow-up comments from farmworker health clinic outreach directors included:

“What an excellent and worthwhile class! (name omitted) began using materials and knowledge from the class during a home visit to a family in White Swan on Wednesday... I have no doubt (names omitted) will use materials in the near future. Thank you for such a fine training. We’ll be providing the message to our high risk (from pesticide exposure) asthma clients.”

“It is amazing to know that there are people as you. The training had all components to achieve a behavior change. You let us develop our skills not only in the cognitive area, but also in the psychomotor, and particularly in the affective areas. Thanks so much for letting me participate. I enjoyed it. This morning I had the opportunity to talk on my radio program about pesticides. This show was terrific, I received several calls from people who work in Skagit Valley as farmers.”

From El Proyecto Bienstar’s project partners who are leaders and practitioners of farmworker community education and health care, we heard:

"Farmworkers are a vulnerable work force to health and safety hazards at the work site, be it the harvest fields or warehouses. They are also subjected to humiliations, wage abuses, and sexual harassment because of their educational and economical disadvantaged status. The Proyecto Bienestar research findings will be the leverage to initiate solutions to these health and safety issues."

- Ricardo R. Garcia, Executive Director, Northwest Community Education Center

“One of the early accomplishments of El Proyecto Bienestar was to establish a structure for communications and decision-making that is fully inclusive and participatory. Through this process, local Hispanic populations--frequently disenfranchised, though disproportionately exposed to occupational and environmental risks--are genuinely engaged and have a voice both in assessing the type and extent of risks and also in determining the steps to mitigate those risks.”

- Eric Leber, Professor, Heritage University

"For Yakima Valley Farmworkers Clinic, El Proyecto Bienestar has been a powerful example of a genuine community-based participatory research partnership. It has enriched the community particularly through the training and education opportunities it has provided to local youth who are pursuing health professions education. In this way it has operationalized our belief that in addition to the immediate issue of interest, the university's presence in the community should provide long term benefit and enrichment."

-Vickie Ybarra, YVFWC, Director, Planning & Development