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Review Article

Occupational Health Outcomes for Workers in the Agriculture, Forestry and Fishing Sector: Implications for Immigrant Workers in the Southeastern US

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Background *Workers in the Agriculture, Forestry, and Fisheries (AgFF) sector experience exposures directly related to the work itself, as well as the physical environment in which the work occurs. Health outcomes vary from immediate to delayed, and from acute to chronic.*

Methods *We reviewed existing literature on the health outcomes of work in the AgFF sector and identified areas where further research is needed to understand the impact of these exposures on immigrant Latino workers in the southeastern US.*

Results *Outcomes related to specific body systems (e.g., musculoskeletal, respiratory) as well as particular exposure sources (e.g., pesticides, noise) were reviewed. The most extensive evidence exists for agriculture, with a particular focus on chemical exposures. Little research in the southeastern US has examined health outcomes of exposures of immigrant workers in forestry or fisheries.*

Conclusion *As the AgFF labor force includes a growing number of Latino immigrants, more research is needed to characterize a broad range of exposures and health outcomes experienced by this population, particularly in forestry and fisheries.* Am. J. Ind. Med. 56:940–959, 2013. *© 2013 Wiley Periodicals, Inc.*

KEY WORDS: immigrant; agriculture

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INTRODUCTION

The southeastern United States (US) has a long tradition of production in the Agriculture, Forestry, and Fishing (AgFF) sector, which is among the largest industrial sectors and employed over 1.2 million workers in 2010 [BLS, 2012a]. Immigrant labor accounts for about 37% of the AgFF workforce [AFL-CIO, 2005]. In 2010, this sector reported the highest rate of fatal work injuries [27.9/100,000 workers], and an incidence rate for nonfatal injury of 4.5 per 100 workers, compared to 2.2 in mining and 3.9 in construction [BLS, 2011, 2012b].

The last several decades have seen a substantial increase in the proportion of immigrant Latino labor in this sector in the Southeast. Over the five years preceding the 2000 census, the southern US received more domestic Latino migrants and international Latino immigrants than any other region in the country [US Census Bureau, 2003]. This new labor force includes immigrants who have established permanent residence in the US and work either year-round or seasonally in AgFF jobs, as well as migrants who move from place to place for their jobs. The latter include immigrants who move within the US and those who move back and forth across international borders for work. Within all these categories, only some of the workers have appropriate documents to be in the US (e.g., proof of citizenship, permanent resident alien work permits, or H-2A or H-2B temporary worker visas). This results in difficulty in accurately determining the number of immigrant Latino workers in the southeastern US, as discussed by Arcury et al. [2013].

The health outcomes from work in the AgFF sector arise from a complex set of exposures created in the workplace. These include: exposures related to the work environment that are generated by the industries themselves, including the machinery, tools, and chemicals used; conditions produced by these exposures, such as noise or airborne particulates; and industry products, including crops, livestock, fish, and timber. Such exposures occur within the context of the natural environment, which itself creates exposures relevant to health outcomes, such as weather, soil, water, plants, animals, and insects. How workers experience these exposures depends on contextual factors of the industry and the worksites [Grzywacz et al., 2013], with examples that range from external contextual factors (e.g., market prices and laws) to employer-specific factors (e.g., pace of work, provision of safety gear) to task-specific factors (e.g., repetition, worker control). Health outcomes from this range of exposures can vary in the time of occurrence from immediate to delayed, and in duration from acute to chronic.

This article addresses each of three industries–agriculture, forestry, and fisheries. For each industry, eight specific types of outcomes are addressed, including those related to specific body systems and others related to particular exposure sources (e.g., animals, noise). Each section presents a review of what is known about the particular health outcome or exposure source for the three industries in the US in the *general worker population* and then for *immigrant workers within the southeastern US* in particular. Where evidence is lacking, we extrapolate from research in other populations. Finally, we summarize findings and highlight major areas for future research.

AGRICULTURE

General Worker Population

Acute trauma

Major mechanisms of traumatic injury and death in agriculture include falls, being struck by falling or rolling objects, crush injuries, assault by animals, and being run over or otherwise injured by machinery such as tractors, combines, and augers [Coury et al., 1999; Hard et al., 2002; Myers and Hendricks, 2010]. Commonly reported traumatic injuries on US farms are broken bones, cuts, and lacerations [Mariger et al., 2009; Goldcamp, 2010], with the most often injured body parts being hands, shoulders, back, and chest [Goldcamp, 2010]. Eye injuries account for 8.2% of all injuries in the agriculture sector [Gerberich et al., 1993]. These range from blunt trauma to perforation to complete enucleation and have been caused by debris from sharpening or using tools, chemical burns, and butting with an animal horn [Saari and Aine, 1984; CDC, 1995; Mackiewicz et al., 2005; Sprince et al., 2008]. Burns, dislocations, and spinal damage are less frequent but important farming-related injuries [Mariger et al., 2009].

Work involving livestock is the second-leading cause of nonfatal injuries on farms. In 1995, the greatest number of agriculture-related injuries (43.3%) occurred in beef, hog, or sheep operations [Myers, 2001a]. Contact with livestock is more likely to result in fractures and crushing injuries than other sources of injuries on farms. Risk factors for animal-related injuries include age (both young and old), hearing loss, arthritis, male sex, working with older farm equipment, living on beef farms, and taking prescription medications [Stallones, 1990; Brison and Lawrence, 1992; Zhou and Roseman, 1994; Layde et al., 1996; Sprince et al., 2003].

Aquaculture has trauma risks unique to the aquatic environment [Myers, 2010]. Aquaculture workers are at risk for stings, bites, and pinching injuries [Erondu and Anyanwu, 2005]. Wet or icy surfaces pose the risk of slips and falls [Moreau and Neis, 2009], and operating a skiff, maintaining cages, or feeding animals place workers at risk of falling into water where hypothermia or drowning

may occur [MacGregor, 2004]. Operating heavy machinery poses other risks such as entanglement, tripping, and being struck by snapping cables. Collisions of forklifts with pedestrians and falling materials [Moreau and Neis, 2009] and tractor rollovers have also been reported [Cole et al., 2009]. Use of heavy equipment (trucks and ATVs) on sea ice during harvesting presents additional drowning risk if the vehicles fall through the ice [Moreau and Neis, 2009]. Electrocution is a risk when using power tools near water [Cole et al., 2009; Moreau and Neis, 2009]. Additionally, replacing the nets around aquaculture pens requires workers to use SCUBA equipment and risk becoming entangled under the water [MacGregor, 2004].

Musculoskeletal disorders

Low back disorders are common musculoskeletal injuries, particularly due to working in stooped postures [Fathallah et al., 2008] and repeated exposures to vibrations and jarring motions while operating mechanical equipment [Hostens and Ramon, 2003; Mayton et al., 2008]. Crop harvesting imposes prolonged and repetitive stooping and often results in low back, hand, and wrist pain [Fathallah, 2010], sprains and strains [Amshoff and Reed, 2005], and ligament tears [Goldcamp, 2010]. Farmworkers' exposure to repetition, high forces and loads, and sustained postures [Fathallah, 2010] can lead to chronic low back pain, degeneration of the spine, and deficits in postural stability [Mayton et al., 2008].

Dairy farm work entails routine and strenuous tasks [Innes and Walsh, 2010] associated with arthritis of the hips and knees [Kirkhorn and Schenker, 2002], increased risk for knee osteoarthritis in women [Holmberg et al., 2004], and musculoskeletal discomfort in the back, torso, shoulders, neck, and head [Innes and Walsh, 2010]. In aquaculture, musculoskeletal injuries occur due to repetitive lifting or hand feeding, lifting of heavy cages or bags of feed, prolonged non-neutral postures at workstations, and tractor use [Moreau and Neis, 2009; Cole et al., 2009; Nonnenmann et al., 2010]. These general risks can be exacerbated by exposure to extremely cold work environments [Cole et al., 2009; Moreau and Neis, 2009].

Chemicals

Potential sources of hazardous chemicals in agriculture include pesticides, fertilizers, organic solvents, metals, sterilization compounds, gasses from confined animal wastes and silos, and plant residues [Keifer et al., 2010]. Farmworkers face routine pesticide exposures from: planting; harvesting; food and water contamination; mixing, loading, and applying pesticides; maintenance of mixing and application equipment; spills, spray drift, and runoff; and casual contact through drift and surface residues [Das et al., 2001; Kasner et al., 2012].

Pesticide exposure can cause dizziness, confusion, abnormal skin sensations, contact dermatitis, irritation of the eyes, blurred vision, muscle twitching, increased bronchial and salivary secretions, chest tightness, diarrhea and other gastrointestinal problems, vomiting, convulsions, and even death in cases of acute exposure [Krieger, 2001; Frank et al., 2004; Costa et al., 2008]. The EPA estimates 10,000–20,000 pesticide poisonings occur among hired US agricultural workers yearly [NIOSH, 2010]. While poisonings comprise a relatively small portion of total agricultural worker occupational illness [Litchfield, 1999; Kasner et al., 2012], this is likely underestimated due to inadequate state surveillance programs, lack of physician training to recognize poisonings, lack of health insurance among farmworkers, and worker reluctance to report poisonings [Das et al., 2001; McCauley et al., 2006].

Agrochemical exposure also has been linked to diverse chronic conditions, including: dermatological sensitivity; respiratory disease including lung fibrosis and chronic bronchitis [Eduard et al., 2009]; asthma-like syndromes [Koksal et al., 2003]; non-Hodgkins lymphoma [Chiu and Blair, 2009]; neurological symptoms [Kamel et al., 2005, 2007a]; neurobehavioral dysfunction [Alavanja et al., 2004; Keifer and Firestone, 2007; Costa et al., 2008; Colosio et al., 2009]; and chronic nervous system effects such as neurodegenerative disease [Frank et al., 2004; Sharp et al., 1986; Dreiher and Kordysh, 2006], including Parkinson's disease [Dick et al., 2007; Kamel et al., 2007b; Bronstein et al., 2009; Costello et al., 2009; Tanner et al., 2011]. Further, chronic exposure to agrochemicals has been linked to cancers, including leukemia, prostate cancer, multiple myeloma, soft tissue sarcoma, prostate cancer, gastric cancer, and lung and cervical cancer [Dreiher and Kordysh, 2006; Mahajan et al., 2006; Andreotti et al., 2009; Blair and Freeman, 2009; Chiu and Blair, 2009; Delancey et al., 2009; Koutros et al., 2009; Lynch et al., 2009; Bonner et al., 2010]. Diesel exhaust and solvent-related activities are associated with ''wheeze'' [Hoppin et al., 2004] and prostate cancer [Richardson et al., 2008; Parent et al., 2009]. Farmworkers also can be exposed to heavy metals such as arsenic and lead from several agrochemicals and from grinding or welding metal [Quandt et al., 2010b]. Such exposures have been linked in other populations with cancer, reproductive problems, and neuropsychological and cognitive effects [Tsai et al., 2003; Mahata et al., 2004; Wright et al., 2006; Shih et al., 2007; Weuve et al., 2009]. Occupational pesticide exposure is associated with adverse reproductive outcomes [Hanke and Jurewicz, 2004; Farr et al., 2006; Perry, 2008; Rosas and Eskenazi, 2008; Jurewicz et al., 2009; Van Maele-Fabry et al., 2010; Sathyanarayana et al., 2010].

Aquaculture chemicals include pesticides, spawning hormones, and anesthetics, some of which are listed as hazards by NIOSH [2005]. Concern over the health effects of aquaculture chemicals has focused more on the food consumer than on the producers [Erondu and Anyanwu, 2005; Cole et al., 2009]. Very limited epidemiological evidence exists regarding aquaculture workers' exposure or health outcomes resulting from such exposures.

Dust and particulates

Dust and particulate matter contribute to pulmonary conditions. Dust and particulate matter can carry contaminants such as allergens (e.g., animal dander, antigenic proteins from crops), organic (e.g., animal feces particles, crop and insect fragments), and inorganic (e.g., earth from tilling) matter [Schenker, 2000]. Agricultural workers in animal confinement facilities are particularly at risk for dust and particulate exposure [Iversen et al., 2000; Von Essen et al., 2010]. Workers in swine confinement facilities have a two- to three-fold increased risk of developing respiratory symptoms [Radon et al., 2000]. More generally, farmworkers face higher rates of rhinitis [Siracusa et al., 2000], acute and chronic bronchitis [Zejda et al., 1993], asthma-like syndrome [Bongers et al., 1987; Haglind and Rylander, 1987], and organic dust toxic syndrome [Vogelzang et al., 1999]. Symptoms appear to be linked to task and time of the growing season [Mirabelli et al., 2010a].

Weather

Farm work involves prolonged exposure to weather-related risks. From 1995 to 2002, 129 work-related deaths in the US were due to lightning strikes. Agriculture had the highest number of fatalities and the second highest fatality rate [Adekoya and Nolte, 2005]. Sun exposure increases risks for sunburn and skin/lip cancer [Blair and Freeman, 2009]. From 1992 to 2006, AgFF workers, especially crop workers, had heat-related death rates substantially higher than other US workers [Luginbuhl et al., 2008].

Infections and envenomations due to animals

Agricultural workers are at risk of acquiring zoonotic infections from disturbing the soil or working with animals. Zoonotic infections account for 61% of infections in humans [Taylor et al., 2001] and may be acquired from aerosols, direct contact with an infected animal, or through infection transmitted by substances such as bedding. Infections associated with livestock and wild mammals are caused by bacteria (e.g., *E. colibacillosis* and lyme disease), viruses (e.g., foot and mouth disease and influenza), parasites (e.g., giardiasis, mange, and trichinosis), fungi (e.g. ringworm), and prions (e.g., bovine spongiform encephalopathy). A recently recognized fish pathogen, *Streptococcus iniae*, can cause skin infections and even endocarditis among fresh fish aquaculture workers [CDC, 1996; Weinstein et al., 1997]. Envenomation can occur when agricultural workers encounter venomous animals; and farmworkers have relatively high rates of nonfatal insect and spider injuries and illnesses [Drudi, 2000].

Noise

Agricultural crops are often planted and harvested using heavy machinery, which can involve substantial noise exposure. While OSHA has mandated exposure limits and requirements for hearing conservation programs in several industry sectors, agriculture is not included among these. Roughly 10% of US farmers are exposed to noise that exceeds OSHA thresholds, and it is estimated that 25% and 50% of farmers at age 30 and 50, respectively, have noise-induced hearing loss [Karlovich et al., 1988; Rein, 1992]. Only 30% of farmers report using hearing protection more than half the time [Carpenter et al., 2002; Schenker et al., 2002].

Immigrant Workers

Acute trauma

AgFF is among the top four industrial sectors in the US in terms of reported work-related deaths for Hispanic workers; and between 2003 and 2006, foreign-born Hispanic workers experienced 2.4 more fatalities per 100,000 workers compared to native-born Hispanic workers [Cierpich et al., 2008]. Limited data exist on traumatic injuries among immigrants in the southeastern US, and these data may be underestimates. North Carolina and Georgia experienced a large increase in the numbers of immigrant workers between 1990 and 2000 [AFL-CIO, 2005], the majority of whom were Latinos in North Carolina [Arcury and Marin, 2009]. From 1992 to 2006, three southeastern states were among those indicated as having the highest number of fatalities (Florida) or the highest fatality rates (South Carolina and Georgia) for Hispanic workers [Cierpich et al., 2008].

Traumatic eye injuries among Latino farmworkers occur at rates exceeding those for overall US crop production [Quandt et al., 2012]. Specifically, eye injuries may result from hydraulic fluid from ruptured hydraulic lines in old machinery; airborne and loose soil; contact with plants when harvesting; chemical exposure; and being sprayed in the face by automated irrigation systems in the field [Lacey et al., 2007; Quandt et al., 2012]. Many of these workers (70–81%) have not been properly trained to

use eye protection and underestimate risks of eye injury [Verma et al., 2011].

Musculoskeletal disorders

Sprains and strains are frequently reported among Hispanic orchard workers [Salazar et al., 2005]. A majority of immigrant nursery (55%) and vineyard (48%) workers in the western US reported musculoskeletal pain, with back pain being the most common symptom [Brumitt et al., 2011; Faucett et al., 2001]. It is likely that such injuries are underreported [Dembe, 1999; Cooper et al., 2006; Castaneda, 2009]. At least five southeastern states (Florida, Georgia, North Carolina, South Carolina, and Virginia) are involved heavily in fruit and vegetable production [Arcury and Marin, 2009], so back, neck, and upper and lower extremity pain, as well as sprains and broken bones may occur at similar rates.

Chemical exposures

In North Carolina, urinary metabolites of immigrant Latino farmworkers indicate exposure to multiple agrochemicals as well as elevated levels of lead and arsenic [Arcury et al., 2009a, b; Quandt et al., 2010a, b]. Many farmworkers had repeated detections in subsequent sampling. Children also are exposed to multiple pesticides due to chemical contamination of farmworker residences [Quandt et al., 2004; Arcury et al., 2005, 2007].

Because agencies do not commonly assess immigration status [Calvert, 2010], characterization of acute pesticide poisoning in Latino immigrant farmworkers often relies on retrospective interview data from workers recruited near the worksite or at farmworker aid organizations. Among California Hispanic farmworkers, 7% reported previous chemical poisoning, 7–12% of workers had been sprayed or experienced drift, and 6–10% were told to taste unwashed grapes, which was significantly associated with gastrointestinal pain and diarrhea [Villarejo and McCurdy, 2008]. Pesticide contact among Latino farmworkers is associated with irritated eyes and skin, blurry vision, and headaches [McCurdy et al., 2003; Villarejo et al., 2010]. Specific crops and pesticides have been associated with particular cancers among Latino farmworkers in California [Mills et al., 2009]. Agrochemical exposure also has been linked with adverse neurobehavioral outcomes among Latino farmworkers and their children [Reidy et al., 1992; Kamel et al., 2003; Rohlman et al., 2005, 2007]. Among Latino women, maternal exposures to pesticides are associated with adverse reproductive outcomes including decreased fecundability, increased rate of autism spectrum disorders, neurodevelopmental delays, decreased child IQ, and abnormal perinatal reflexes [Young et al., 2005; Eskenazi et al., 2006; Roberts et al., 2007; Harley et al., 2008; Bouchard et al., 2011].

Dust and particulates

No data could be found for health effects of dust or particulates among immigrant agricultural workers in the US.

Weather

From 1995 to 2000, 41 out of 129 occupational fatalities from lightning strikes occurred to Latino workers, with a fatality rate among these workers four times higher than among non-Hispanic Whites [Adekoya and Nolte, 2005]. Of the 28 reported heat-related fatalities among US crop workers in 2003–2006, 20 were foreign-born workers [Luginbuhl et al., 2008]. In a 2009 survey of Latino farmworkers in North Carolina, 94% reported they had worked in extreme heat in US agriculture, and 40% of those reported having experienced symptoms consistent with heat-related illness [Mirabelli et al., 2010b]. Among immigrant farmworkers in North Carolina, changes in work activities and work hours during hot weather are associated with a lower prevalence of heat-related illness in H-2A but not non-H-2A workers [Mirabelli et al., 2010b]. Latino farmworkers in California reported common personal sun protection behaviors such as always wearing a hat, a long-sleeved shirt, or a collared shirt [Salas et al., 2005]. Use of sunglasses or sunscreen or limiting sun exposure are much less common protective measures [Quandt et al., 2001; Salas et al., 2005; Luque et al., 2007].

Infections and envenomations due to animals

Latino farmworkers in North Carolina report a high prevalence of superficial fungal skin infections [Krejci-Manwaring et al., 2006; Arcury et al., 2007]. No data could be found on envenomation among immigrant agricultural workers in the US.

Noise exposure

In a cross-sectional survey of migrant and seasonal farmworkers, more than half reported some hearing loss; and few reported using hearing protection [Rabinowitz et al., 2005].

FORESTRY

General Worker Population

Acute trauma

In the logging process, falls and being struck by or against an object are the primary causes of injury [Wang et al., 2003; Mujuru et al., 2006]. Falls and crush injuries

can occur when body parts are pinned between logs or equipment [Wolf and Dempsey, 1978], while struck by injuries can result from falling trees or kickback from power saws, branches, or rolling logs. Logging injuries include traumatic brain injuries; fractures of the spine, skull, and legs; and eye injuries [Vayrynen, 1983; Saari and Aine, 1984; Johnson et al., 2002]. Mechanized operations, overall, seem to result in a lower injury risk than for comparable manual tasks [Laflamme and Cloutier, 1988]. Smaller, less mechanized forestry operations are likely to sustain more crush injuries from splitting tools and cuts from blades and chain saws [Lindroos et al., 2008].

Musculoskeletal disorders

Forestry workers' risk factors are related to trade-specific tool use. Manual tree planting requires prolonged and repetitive non-neutral postures. Planters in Ontario reported feeling the greatest pain in their wrists and feet; back pain was the most consistently reported symptom, and pain scores for almost all areas of the body increased significantly over the course of a single planting season [Slot and Dumas, 2010]. Chain saw operators experience greater nerve damage compared with forestry workers who primarily do heavy lifting tasks [Bovenzi et al., 2000], and the severity of nerve damage is related to cumulative vibration exposure. Exposure to cold conditions can further increase the risk of conditions such as vibration-induced white finger [Bovenzi et al., 1998; Bovenzi, 2010].

Chemicals

Forestry workers are exposed to chemicals including fertilizers, pesticides, lubricants, diesel and gasoline fuels, and their emissions [Athanassiadis, 2000; USNLM, 2010]. Fewer types of pesticides are used in forestry than in agriculture, with herbicides being predominant [Michael, 2000; Oregon Department of Forestry, 2009].

Pesticide exposure is reported among Canadian tree planters; more limited evidence of herbicide exposure is reported among Swedish and US seedling handlers [Lavy et al., 1992; Robinson et al., 1993; Elfman et al., 2009]. Although forest herbicide sprayers demonstrate less effect of exposure than agricultural sprayers [Frank et al., 1985; Knopp and Glass, 1991], pine foresters have greater exposure than potato harvesters working with the same fungicide (dithiocarbamate) [Kurttio and Savolainen, 1990]. In forestry, chemical hazards do not appear to be a significant source of acute injury [Helmkamp and Derk, 1999; Navarro et al., 2004; Elfman et al., 2009].

Compared to agriculture, less attention has been paid to the effects of long-term low-level exposure to forestry chemicals. An increased risk of non-Hodgkins lymphoma was found in Swedish forest care workers [Wiklund and Holm, 1986; Wiklund et al., 1988]. Evidence is mixed for an increased risk of non-Hodgkins lymphoma associated with phenoxy herbicides in North American forestry workers [Green, 1991].

Dust and particulates

Most studies on respiratory effects in the forestry industry have been conducted in Europe and Canada. Approximately 2.0% of European workers are exposed to inhalable wood dust [Blot et al., 1997]. Most of these workers are in the construction and furniture industries, with a much smaller percentage (9%) in the combined sawmilling and forestry industries [Kauppinen et al., 2006]. Such exposure increases cancer, primarily nasal, risk [Blot et al., 1997].

Weather

Forestry involves high levels of physical exertion. Heavy protective equipment, along with exposure to heat and sun, can lead to dehydration and increased risk of heat illness [Wästerlund, 1998]. Among Japanese forestry workers, fewer years of experience and heat were among factors associated with increased risk of heat stroke symptoms [Maeda et al., 2006]. However, compared to other causes, deaths attributable to heat in this industry are relatively low (<1%), with 14 deaths from environmental heat in the US from 1992 to 2001 [Buckley et al., 2008].

Although forestry is often conducted in regions where exposure to cold and severe weather is also common, the physical nature of forestry/logging work may provide some protection from cold-related injury and hypothermia [Conway and Husberg, 1999]. Lightning strike also is a hazard for forestry workers. From 1992 to 2001, of 200 deaths in the industry attributed to ''Exposure to Harmful Substances and Environments'', 7 were attributed to lightning [Buckley et al., 2008].

Infections and envenomations due to animals

As in agriculture, forestry workers are at risk of acquiring zoonotic infections from disturbing the soil or from contact with animals. Forestry workers are at risk of stings from sawflies, wasps, bees, and ants, especially when nests or mounds are disturbed [Copertaro et al., 2006]. Up to 3–4% of people stung are at risk of developing an anaphylactic reaction [Giannandrea et al., 2003; Incorvaia et al., 2004]. This can be fatal if not treated immediately, and is a challenge for forestry workers in remote locations. Encounters with snakes in forests are not unusual. In the US, copperheads, cottonmouths, coral

snakes, and rattlesnakes are venomous species of concern. While rarely fatal, bites can lead to prolonged disability.

Forestry workers are at increased risk of infection from several tick-borne diseases. In some countries, 20–30% of forestry workers are seropositive for Lyme disease [Buczek et al., 2009]. Other such diseases reported in forestry workers include tick-borne relapsing fever, Colorado tick fever, Rocky Mountain spotted fever, erhlichiosis, babesiosis, and tularemia [Covert and Langley, 2002; Cisak et al., 2005]. Workers also may be at risk of viruses transmitted by mosquitoes such as eastern equine encephalitis, western equine encephalitis, and St Louis encephalitis [APHA, 2008]. Finally, workers may face exposure to rabies or other infections if approached by wild animals.

Noise exposure

During 1997–1998, the logging industry in Washington State had the highest rate of hearing loss claims reported to workers' compensation at 70 claims per 1,000 worker years, twice as high as the rate for road construction [Daniell et al., 2002]. Logging tasks associated with excessive noise levels include the use of chokers and chain saws [Neitzel and Yost, 2002].

Immigrant Workers

The immigrant worker population in forestry is large and expanding [McDaniel and Casanova, 2003]. Between 1996 and 2001, the southeastern US led the country in the number of H-2B visas requested [McDaniel and Casanova, 2003]. With over 100,000 H-2B visas issued, this is a fairly well-documented immigrant worker population. Smaller contractors, however, are more likely to employ undocumented immigrants. H-2B workers in the US move among contract sites as dictated by their employer. This presents a challenge for reporting immigrant worker population or injury rates in specific states because employers do not necessarily employ workers in the state in which their H-2B visas were issued [Sarathy and Casanova, 2008].

Acute trauma

No evidence could be found documenting traumatic injuries among immigrant workers specifically in the forestry sector. However, some data exist for the overall forestry industry in the southeastern US. In Alabama, where forestry operations are largely mechanized, struck by and crush/run over injuries were responsible for the vast majority of fatalities during 1988–1997 [Bordas et al., 2001].

Musculoskeletal disorders

Although no data were found on immigrant forestry workers specifically, there is reason to believe that musculoskeletal injury is a significant health problem. H-2B guest workers make up 100% of work crews for the three largest tree-planting contractors in the southeastern US [McDaniel and Casanova, 2005]. Tree planting is a highly repetitive process requiring long hours in stooped postures and repeated use of small hand tools [McDaniel and Casanova, 2003].

Other health outcomes

No data could be found regarding the effects of chemicals, dust and particulates, weather, infections or envenomations due to animals, or noise exposures on immigrant workers in forestry.

FISHERIES

General Worker Population

Acute trauma

Some exposures differ by region, but particular risks exist for all fish industry workers. Vessel casualties resulting from sinking, capsizing, fires, explosions, or collisions are substantial [Drudi, 1998; Jensen et al., 2005; Perez-Labajos et al., 2009; Lincoln and Lucas, 2010]. Between 2000 and 2009, over half of commercial fishing fatalities were a result of vessel disasters [Lincoln and Lucas, 2010]. Common hazards include falling overboard after becoming entangled in gear, slipping or tripping on deck, losing balance, or being washed overboard by large waves [Drudi, 1998; Thomas et al., 2001; Lucas and Lincoln, 2007; Lincoln and Lucas, 2010]. A majority of deaths after falling overboard occur when a crew member is working alone on deck [Lucas and Lincoln, 2007].

Fishing gear use and maintenance cause the greatest number of injuries and the most severe injuries such as broken bones and joint dislocations [Torner et al., 1995; Jensen et al., 2005, 2006; Chauvin and Le Bouar, 2007]. More specific causes of injury include entrapment of upper limbs in ropes, cables, or chains; lacerations, bruises, and fractures from breaking or snapping of cables; fractures and other injuries subsequent to falls on the deck or between deck levels; crush or head injuries caused by loaded nets or boxes falling onto the worker; entanglement in the winch drum, tripping over the winch cable, or the sudden snapping of the winch cable [Norrish and Cryer, 1990; MacGregor, 2004]; ocular and facial penetration due to fishing hooks, lures, and weights [Erisen et al., 2001; Alfaro et al., 2005]; cervical spine injury from harpoons [Mouzopoulos and Tzurbakis, 2009]; and forcible amputation due to entanglement in nets and lines [Nagesh and Rastogi, 2007].

Trawl doors used in trawl fishing are large and heavy and pose considerable crush risk if a limb or body becomes pinched between a trawl door and the vessel [MacGregor, 2004]. Seine fishing involves the use of large booms and a skiff, increasing the chances of a ''struck by'' injury or falling into the water. Seining also carries the additional risk of being performed mostly at night under low lighting conditions [MacGregor, 2004]. Long lining, salmon trolling, and crab fishing present a high risk for eye injuries from flying hooks on gear, the use of metal flashers with hooks, and the frequency of tossing the catch into storage, respectively [AMSEA, 1999]. Eye injuries can result from fish spitting out hooks or by workers touching their face after handling the catch [AMSEA, 1999].

The fish catch itself also exposes crew members to pricks, pinches, cuts, bites, and stings from various species of aquatic animals [MacGregor, 2004]. Although rare, fish can bite or stab with their spines, which can lead to severe injuries such as lacerations, amputations, and puncture wounds. These penetrating wounds can also become infected [Marshall et al., 2004]. Once the catch is on the boat, injuries can occur from large fish ''flopping'' on deck. Among commercial workers in the southeastern US, 20% of hand injuries were due to contact with finfish, shellfish, or other sea animals [Kucera et al., 2008].

Musculoskeletal disorders

Fishing exposes workers to heavy loads, forceful exertions, non-neutral postures, repetitive tasks, and working in moving environments [Fulmer and Buchholz, 2002; Duncan et al., 2010]. Common musculoskeletal injuries include strains to muscles and injured tendons [Torner et al., 1995; Chauvin and Le Bouar, 2007]. In lobstering, as an example, where multiple traps are continuously set out rather than a single large net, the speed and high frequency of work poses a risk for strain injury [Fulmer and Buchholz, 2002].

Chemicals

Principal acute chemical hazards in fisheries are exposure to toxic gases and asphyxiation from catch decomposition. Studies of Danish fishing vessels have found high concentrations of several potentially poisonous gases (hydrogen sulfide, carbon dioxide, ammonia, and methylamines), as well as low oxygen concentrations. Exposure to toxic gases accounts for 1 in 25 fishing deaths among Danish workers and 1.7% of fatalities among Alaskan workers [Dalgaard et al., 1972; Thomas et al., 2001; Laursen et al., 2008]. Chemical exposure can also result in burns [Lawrie et al., 2003] and allergic and respiratory reactions [Atkinson et al., 1993; Madsen et al., 2004]. Fishing industry workers also have extensive exposure to diesel and gasoline powered engines and exhaust [Kirrane et al., 2007]. The use of diesel fuel in pesticide dips for traps may also place workers at risk of long-term exposure to unburned diesel fume vapors [Barre and Van Vleet, 1994].

Dust and particulates

Fishery workers are exposed to aeroallergens produced during processing and canning, which places them at risk of pulmonary disease. The primary pulmonary condition observed is termed ''occupational asthma'' [Lucas et al., 2010]. Risk factors include exposure to aerosols from arthropods, such as shrimp, crab, and lobster, during fishing or processing [Malo and Cartier, 1993; Ortega et al., 2001]. Predisposition toward developing allergic reactions (atopy) is a risk factor for the development of occupational asthma in fishery workers [Gautrin et al., 2010]. There is considerable variation in the prevalence estimates of asthma (2–36%), due largely to varying definitions of the condition [Jeebhay and Cartier, 2010].

Weather

Natural environment hazards for fishing industry workers are similar to those in agriculture and forestry, but with the added factor of performing work on a moving vessel. Severe weather compounds the effects of physical demands due to boat motions [Petersen et al., 1989; Torner et al., 1988, 1994] and increases the risk of falls on deck or overboard. Working in cold waters places laborers at risk for cold-related mortality [Drudi, 1998] and morbidity [Conway and Husberg, 1999]. The combination of wet and windy environments with cold weather contributes to conditions such as frostbite, trench foot, and hypothermia. In a person-overboard situation, workers are at risk of drowning as well as hypothermia. From 1990 to 1999, 186 out of 217 fishing industry worker deaths were due to drowning or death from hypothermia as a result of vessel-related events and falls overboard [Conway et al., 2002].

Infections and envenomations due to animals

Workers in the fishing industry are at risk of envenomations, infections, and allergic reactions due to marine life [Burke, 1997; Ortega et al., 2001]. Venomous aquatic animals include catfish, zebra fish, scorpion fish, stingrays, jellyfish, and the Portuguese man of war [Burke, 1997], with jellyfish being the most common source of injury [Brown, 2005]. Fishing industry workers risk envenomation when handling fish or when removing jellyfish that

have become entangled in fishing nets. Although serious injury and death can occur, most stings in US waters cause only minor injury [Brown, 2005].

Fishing industry workers with open wounds from punctures or stings are subsequently at risk of acquiring a number of infections from the aquatic environment, usually by the bacteria *Staphylococcus* and *Streptococcus* [Lehane and Rawlin, 2000]. The widespread bacterium *Erysipelothrix rhusiopathiae* causes skin dermatitis (also referred to as fish poison, crab poison, or shrimp pickers disease) and can, rarely, cause endocarditis [APHA, 2008]. The bacterium *Edwardsiella tarda* can cause skin abscesses and serious life threatening infections [Hargreaves and Lucey, 1990; Slaven et al., 2001]. *Mycobacterium marinum* enters open skin and slowly grows into a warty-like lesion that can spread along the lymph channels and invade tendons, bones, and joints [Burke, 1997]. Gastroenteritis as well as serious wound infections may result from the bacterium *Aeromonas hydrophila*. Resulting wound infections can lead to muscle destruction and a particularly deadly form of gangrene, gas gangrene [Fulghum and Linton, 1978]. Various species of halophilic Vibrio organisms can also cause gastroenteritis, wound infections, and septicemia [Blake et al., 1979; Burke, 1997; APHA, 2008]. The bacteria *Vibrio parahaemolyticus*, *Vibrio damsela*, and *Vibrio vulnificus* can cause tissue inflammation and gas gangrene, which can lead to septic shock. Contact with certain algae, dinoflagellate organisms (red tides), bryozoans, and even fish slime can cause allergic reactions such as contact dermatitis in workers [Burke, 1997].

Noise exposure

Fishing industry workers often work on vessels with diesel engines and other equipment used to pull in gear and remove and process the catch. Workers often spend several consecutive days on a boat and can thus be exposed to excessive noise both during and outside of their work shifts. In a case study of Massachusetts fishing vessels, two of three vessels had noise levels close to US Coast Guard threshold values [Fulmer and Buchholz, 2002]. Catch processing vessels have high work-shift and 24-hr exposure levels.

Immigrant Workers

Acute trauma

Little information could be found on immigrant workers in the fishing industry. It is likely that immigrant workers would experience similar types of traumatic injuries as native-born workers, but the extent to which cultural or language barriers create additional occupational risks for immigrant workers remains unclear. Previous research with Texas Gulf Coast commercial fishermen noted over half (52%) spoke little or no English, highlighting the importance of delivering safety training in their native language [Carruth et al., 2010; Levin et al., 2010]. Although the immigrant worker population in fishing is poorly documented, there is some evidence regarding injuries specific to the types of fishing done in the southeastern US. In North Carolina, between 1977 and 1991, the fishing industry reported the highest rate of fatalities due to environmental working conditions compared to other industries [Loomis et al., 1997]. Also in North Carolina, a high prevalence of penetrating wounds occurs among small scale fin-fishing and crabbing crews, affecting primarily the hands, wrists, and fingers, and mainly attributable to contact with fish or marine animals [Marshall et al., 2004]. Hand injuries among commercial fishing industry workers in the southeastern US are related to maintenance work on the vessel and to using more than one type of fishing gear [Kucera et al., 2008].

Musculoskeletal disorders

Evidence of risks specific to the immigrant worker population in fishing could not be found. However, some studies have assessed the musculoskeletal impact of commercial fishing in North Carolina, and these are likely representative of risks for fishing industry workers in the southeastern US. Low back symptoms are the most commonly reported among commercial fishers in North Carolina, followed by symptoms in the hands, wrists, and shoulders; and rates of musculoskeletal symptom onset among workers with no prior symptoms are highest for the lower back and shoulders [Lipscomb et al., 2004]. The rate of onset varies with hours spent fishing daily [Lipscomb et al., 2004; Kucera et al., 2009]. Among North Carolina fin-fishing and crabbing crews, 25% of injuries are strains and sprains, especially of the back and shoulders, and caused mostly by hauling gear and vessel loading or unloading [Marshall et al., 2004].

Chemicals

In an Alaskan study of injury aboard fishing vessels, toxicity from chemical, liquid, or gas was noted in 0.74% of non-fatal incidents, and burns comprised 5.3% of non-fatal injuries. Immigrant workers made up 5% of the non-fatal injury group [Thomas et al., 2001].

Dust and particulates

In the southern US, Latinos are a large part of the workforce in the crab processing industry [Selby et al., 2001]. However, no studies could be found on rates of

occupational asthma, as seen elsewhere from aerosolized proteins from these crustaceans [Ortega et al., 2001].

Weather

No previous studies could be found documenting weather-related events among immigrant workers in the fishing industry. A review of medical examiner death certificates in North Carolina from 1977 to 1991 found that 41 out of 2,524 work-related deaths were due to natural environmental conditions; relative to all industries, fishing, agriculture, agricultural services, and logging occupied four out of the top five highest rates in this cause of death category [Loomis et al., 1997]. Though cold-related mortality and morbidity for this industry is highest among northern states such as Alaska [CDC, 1993; Conway and Husberg, 1999], risks may also be elevated in milder climates having rapid temperature changes, such as North Carolina [Fallico et al., 2005], where poor or extreme weather conditions often are combined with inadequate protective clothing and exposure to water and wind [Butts, 1994; Beaman et al., 2000].

Other health outcomes

No data were found on animal-related infections and envenomations or noise among immigrant fishery workers.

PSYCHOSOCIAL EXPOSURES AND OUTCOMES

AgFF industries share characteristics that can lead to distress and subsequent adverse mental health effects on workers in these industries. Forestry and fishing can involve separation from family and social supports. For agriculture, this condition exists for immigrant workers, but not for resident farming populations. All are industries where uncontrollable environmental conditions regularly affect the ability of workers to make a living. These include natural conditions such as storms, droughts, and crop and livestock disease, as well as human-caused disasters such as fires or chemical contamination. Existing literature suggests that workers in these industries respond to such stressors with increased levels of distress, including depression, anxiety, and symptoms of post-traumatic stress syndrome [Picou, 1992; Palinkas et al., 1993; Freeman et al., 2008; Sartore et al., 2008; Taylor et al., 2008; Caldwell and Boyd, 2009].

Immigrant workers in the AgFF sector experience work conditions that are frequently dangerous, monotonous, and unpleasant. Many live in poor and unsanitary conditions [Arcury et al., 2012a, b]. They are socially marginalized, and subject to discrimination and threats due to their immigrant status. Many are separated from kin and both socially and physically isolated from the larger US society [Grzywacz et al., 2006]. These conditions are potent threats to mental health. Studies of immigrant workers in the southeastern US have found that categories of stressors experienced include legality and logistics, social isolation, work conditions, family, and substance abuse by others [Grzywacz et al., 2007, 2010; Hiott et al., 2008].

The largest body of research on workers in the AgFF sector in the southeastern US has focused on farmworkers. The farmworker population in this region has become predominantly Latino in only the last few decades. In contrast to the farmworker population elsewhere in the country, which consists largely of family groups, in the southeastern US agricultural workers include many single men or men unaccompanied by their families. Evidence from studies on farmworkers throughout the US suggests that poor mental health among farmworkers is relatively common [e.g., Magaña and Hovey, 2003]. A psychiatric survey among California workers found that one in five met lifetime criteria for at least one psychiatric disorder, with anxiety disorder, substance abuse, and mood disorder being the most common [Alderete et al., 2000]. Mexican folk illnesses such as *nervios* [nerves] and *susto* [fright] also have been reported at high frequencies [Mines et al., 2001; Weigel et al., 2007].

In the southeastern US, a substantial number of male farmworkers show indications of alcohol abuse [Kim-Godwin and Fox, 2009]. Binge drinking has been reported by 27% of farmworkers, with 38% showing signs of alcohol dependence. Anxiety and depression at levels resulting in impairment affect farmworkers at rates of 18% and 42%, respectively [Grzywacz et al., 2007; Hiott et al., 2008]. These levels are substantially higher than those reported among farmworkers in California [Alderete et al., 2000]. Depressive symptoms in North Carolina tend to be highest early and late in the agricultural season [Grzywacz et al., 2010]. Few data exist for the southeastern US on folk illnesses, though Baer and Penzell [1993] found that 20% of workers reported *susto* after exposure to pesticides.

FUTURE RESEARCH NEEDS FOR IMMIGRANT AgFF WORKERS IN THE SOUTHEASTERN US

The AgFF sector is among the largest employers in the US as a whole, and the southeastern US specifically. Work in this sector involves exposure to a broad range of risk factors for a broad range of adverse health outcomes. This sector also employs a large, and in some cases increasing, number of minority immigrant workers. Though evidence to date is quite limited, these workers appear to have a disproportionate burden of occupational morbidity and mortality. This review demonstrates the uneven nature

TABLE I. Summary of Existing Literature on Occupational Health and Safety in the Agriculture, Forestry, and Fisheries Sector, for Workers in the US in General, Immigrant Workers Anywhere in the US, and Immigrant Workers in the Southeastern US, by Industry

	Agriculture			Forestry			Fisheries		
Outcomes or exposures	US[a]	US immigrant	SE US immigrant	US[a]	US immigrant	SE US immigrant	US[a]	US immigrant	SE US immigrant
Acute trauma	***	***	**	***	–	–	***	–	–
Musculoskeletal disorders	***	***	**	***	–	–	***	–	–
Chemicals	***	***	**	***	–	–	***	**	–
Dust and particulates	***	–	–	***	–	–	***	–	–
Weather	***	***	**	***	–	–	***	–	–
Infections and envenomations due to animals	***	–	–	***	–	–	***	–	–
Noise	***	**	–	***	–	–	***	–	–
Psychosocial	***	***	**	***	–	–	***	–	–

–, No studies available; ***, multiple studies available; **, limited studies available.
[a]Includes studies in any worker population in the US or from comparable industries in other countries.

of occupational health research in this sector. In general, the literature is most extensive for agriculture, covering all the outcomes or exposures included in this review (Table I). The literature for forestry and fisheries is, overall, much sparser. Some topics have little or no research; and risk factors presented are speculative, based on the nature of exposures. The literature for immigrant workers in the US is most robust for agriculture, though several exposures have not been studied among immigrants. Almost no research has been conducted on occupational health of immigrant labor in forestry and fisheries in the US. Research on occupational health among immigrant workers in the southeastern US is limited to agriculture. Much of this has been conducted in North Carolina and focuses on chemical exposures, heat, and psychosocial factors. The uneven nature of the research suggests several areas where further study of health and safety of immigrant workers in the US as a whole and the southeastern US, in particular, is needed.

Acute Trauma and Musculoskeletal Disorders

Due to the prevalence of documented H-2B guest workers, the forestry industry arguably has the greatest potential for in-depth injury risk analysis for immigrant workers in the southeastern US. Musculoskeletal injury analysis may be the most relevant given the high number of immigrants performing highly repetitive tree-planting work. However, because of the difficulty of obtaining H-2B visas, there may still be a fairly large population of undocumented workers, especially among smaller forestry contractors that need to be accounted for when determining injury risk.

The need for more research on immigrant workers is most evident in the fishing industry. The literature is lacking regarding the number of immigrant workers employed in fishing in any region of the US, and no data could be found that are specific to the southeastern region. An immediate research need is to identify the proportion of immigrant fishermen in the US, their distribution among the various types of fishing, their occupational roles, and their injury rates. As with prior research in agriculture, such evidence will help identify how immigrant workers are contributing to overall occupational injuries reported in the fishing industry and may distinguish injury risks that are disproportionately high for immigrant workers.

Determining injury rates of immigrant workers with disabilities may also be of interest. Xiang et al. [2010] reported that, for forms of disability, immigrants are more likely to be employed than US-born adults with an equivalent disability. Additionally, AgFF, along with most other industries, employs a similar percentage of immigrants with and without disabilities.

Chemicals

More work should be directed at quantitative assessment of chemical exposures to pesticides for immigrant workers in the southeastern US region, other than North Carolina, to determine if there are geographic differences. More work should be devoted to analyses of health outcomes (e.g., psychiatric disorders, neurodegenerative disease) and to identifying common combinations of pesticide exposures. Genetic variants for susceptibility to pesticide-induced pathology in workers should be further explored. The consequences of long-term exposure to hazardous non-pesticide chemicals, and their interaction with

pesticides, should not be ignored in farmworkers or forestry workers.

Weather

Recent US deaths during heat waves in 2005, 2007, and 2008 have brought attention to the safety of agricultural workers. Weather-related injuries, such as heat illness, hypothermia, and struck-by-lightning are amenable to intervention in this industry given appropriate information and work practices (e.g., appropriate clothing, work organization). California and Washington have enacted state legislation requiring employers to take steps to prevent heat illness among outdoor employees [Washington Department of Labor and Industries, 2008; California Department of Industrial Relations, 2010]. Despite regulation, it is unclear whether employers abide by the regulations or whether they are enforceable [Burke, 2008; Rural Migration News, 2009]. Studies of intervention diffusion and effectiveness are an area for future research.

Immigrants present a particular challenge and emphasize the importance of safety messages being provided in both English and Spanish native languages and in a format that will reach the most workers (e.g., lay providers, tailgate talks). Heat safety interventions currently being implemented include programs such as Project Fresco, a bilingual educational program delivered to Texas farmworkers door-to-door by lay health workers [Gonzales, 2010]. Future studies can provide needed information about immigrant workers in forestry and fishing.

Noise

Given the difficulty of monitoring and enforcing noise levels in traditional industrial settings, and the fact that employees reported wearing hearing protection only 62% of the time when exposed to noise [Daniell et al., 2006], the AgFF sector presents a particular challenge for intervening where oversight is more limited. Intervention effectiveness and compliance present areas for fruitful research. Future studies among immigrant populations are needed in forestry and fishing.

Infections and Envenomations Due to Animals

Updated national surveys of animal-related injuries on farms are needed. Rates of injuries from farm animals differ by race and region of country, and studies are needed to determine factors responsible for these differences. National serosurveys of zoonotic diseases that are not currently reportable need to be undertaken to determine the prevalence in various populations. The frequency of domestic and wild animals kept in migrant camps needs to be assessed and the use of rabies vaccination in dogs and cats in these camps determined. Work is needed to determine factors that influence the use of insect repellants in agriculture and forestry workers. The frequency of contact with wild animals has not been well studied in forestry workers.

The frequency of occupational allergy to shellfish needs to be determined in fishing industry workers and shellfish processing workers in the southeastern US. Surveys of health care providers among coastal communities on the risks of unusual infections that can result from marine water or fish contact need to be implemented and educational programs designed.

Psychosocial Exposures

The dearth of mental health research in forestry and fishing in the southeastern US calls for future research. Both are sectors where the risk factors created by immigrant status and social and physical isolation are likely to be substantial. The sectors include exceedingly dangerous jobs that can be made more dangerous by inattention due to mental illness. Although farmworker research exists, it is largely limited to North Carolina, with a focus on men. Broader foci including other areas in the southeastern US and on women is needed. In addition, research on interactions with specific exposures (e.g., organophosphorus pesticides) known to be associated with mental illness [Stallones and Beseler, 2002] is needed. Finally, studies of mental health issues such as suicide that have been demonstrated to occur at higher than expected rates among farmworkers [Hovey and Magaña, 2003] should be conducted in the southeastern US.

RECOMMENDATIONS

Addressing the burden of occupational health and safety among immigrant workers in the southeastern US will require new efforts on several fronts. Based on the current review, the following are recommended as near-term research needs and directions.

- Obtain improved estimates of the population and distribution of immigrant workers in the diverse jobs comprising the AgFF sector.
- Compile improved estimates of morbidity and mortality rates among immigrant workers in the AgFF sector.
- Identify specific jobs and/or work tasks that involve substantial exposures of immigrant workers to diverse categories of risk factors.
- Continue to identify the relationships between exposures and health outcomes among immigrant workers.
- Document and describe specific challenges involved in controlling risk factor exposures among immigrant workers.

- Develop and test intervention methods tailored to immigrant workers in AgFF.

Progress on these can be anticipated to contribute to substantial improvements in the occupational health of immigrant workers.

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