AIHA Journal

ISSN: 1542-8117 (Print) (Online) Journal homepage: http://www.tandfonline.com/loi/uaih20

Crab Allergen Exposures Aboard Five Crab-Processing Vessels

Nancy Beaudet , C. Andrew Brodkin , Bert Stover , Feroza Daroowalla , Joy Flack & Dan Doherty

To cite this article: Nancy Beaudet , C. Andrew Brodkin , Bert Stover , Feroza Daroowalla , Joy Flack & Dan Doherty (2002) Crab Allergen Exposures Aboard Five Crab-Processing Vessels, AIHA Journal, 63:5, 605-609, DOI: 10.1080/15428110208984746

To link to this article: https://doi.org/10.1080/15428110208984746

AIHA Journal 63:605–609 (2002) Ms. #316

Crab Allergen Exposures Aboard Five Crab-Processing Vessels

AUTHORS
Nancy Beaudet[a]
C. Andrew Brodkin[a]
Bert Stover[a]
Feroza Daroowalla[a]
Joy Flack[b]
Dan Doherty[b]

[a]Occupational and Environmental Medicine Program, Departments of Medicine and Environmental Health, University of Washington, Box 359739, 325 Ninth Ave., Seattle, WA 98104; [b]Region X Occupational Safety and Health Administration, Seattle, WA

This project was supported by National Institute of Occupational Safety and Health Pacific Northwest Agriculture Safety and Health Center grant U07/CCU012926-04.

Aerosolized crab allergens are suspected etiologic agents for asthma among crab-processing workers. The objectives of this study were to characterize crab allergen concentrations and respiratory symptom prevalence among processing workers aboard crab-processing vessels. A cross-sectional survey of five crab-processing vessels was conducted near Dutch Harbor, Alaska. Crab allergen concentrations were quantified during specific work activities with 25 personal air samples collected on polytetrafluoroethylene filters and analyzed by a competitive IgE immunoassay technique. Two standardized respiratory questionnaires were used to assess respiratory symptoms suggestive of bronchitis or asthma in 82 workers. Aerosolized crab allergen concentrations ranged from 79 ng/m^3 to 21,093 ng/m^3 (mean = 2797 ng/m^3, SD = 4576 ng/m^3). The highest concentrations were measured at butchering/degilling work stations, which were combined on the smallest vessel. A significant percentage of workers reported development of respiratory symptoms during the crab-processing season. Cough developed in 28% of workers, phlegm in 11% of workers, and wheeze and other asthma-like symptoms developed in 4% of workers. Despite variations in crab allergen levels, respiratory symptom prevalence was similar across all job categories. Substantial concentrations of crab allergen exposure were measured, as well as the potential for wide variability in exposure during crab processing aboard vessels. The high prevalence of reported respiratory symptoms across all job categories suggests potential adverse respiratory effects that should be further characterized by prospective studies using pulmonary function and serology testing, and rigorous exposure characterization.

Keywords: allergen, asthma, crab, exposure, occupational, respiratory

Respiratory illness in the crab-processing industry has been reported in several studies of land-based processing facilities. Illnesses have variably been described as asthma, hypersensitivity pneumonitis, or bronchitis.[1–5] Aerosolized allergen concentration characterization in the fish-processing industry has been limited to land-based facilities, with published reports of estimated levels ranging from 179–5,061 ng/m^3.[4]

In addition to land-based facilities, many processing workers are exposed aboard vessel processors where work occurs in more confined, less-ventilated areas. Although investigation into vessel safety and fatalities-at-sea have been performed, few studies have addressed respiratory illness in this population due to limited access to a seasonal work force employed in remote areas. The present study was designed to estimate aeroallergen exposures and respiratory symptoms among workers aboard crab-processing vessels. The authors conducted a cross-sectional survey of five crab-processing vessels, measuring airborne crab allergen levels by sampling the breathing zone of 25 processing workers, and assessing reported respiratory symptom prevalence among a group of 82 processing workers.

METHODS

Setting

The survey of five crab-processing vessels was conducted near Dutch Harbor, Alaska (Bering Sea Fishery). Temperatures in the holds of processing vessels are often low with constant exposure to water and ice. The limited space aboard, as well as the short harvesting season (6

TABLE I. Exposure Assessment Participants and Questionnaire Respondents by Job Title and Vessel

	Exposure Assessment Participants (Questionnaire Respondents)					
Job Title	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Totals
Butcher/Degiller	N/A (n/a)	3 (2)	3 (1)	N/A (n/a)	N/A (n/a)	6 (3)
Butcher	2 (8)	N/A (n/a)	N/A (n/a)	0 (2)	1 (0)	3 (10)
Degiller	2 (8)	N/A (n/a)	N/A (n/a)	2 (6)	2 (20)	6 (34)
Cooker/Chiller	2 (0)	2 (2)	2 (2)	2 (2)	2 (3)	10 (9)
Sorter	0 (10)	0 (0)	0 (0)	0 (7)	0 (8)	0 (25)
Boxmaker	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (1)
Totals	6 (26)	5 (4)	5 (3)	4 (18)	5 (31)	25 (82)

to 10 weeks), results in long workshifts up to 18 hours.[6] Crab-processing workers are exposed directly to aerosolized particulate of flesh, shells, and endolymph of live crabs during butchering and degilling. Additional exposures occur from steam contaminated with crab allergens, which is generated during crab cooking procedures. Specific sensitizers have not been identified; however, Leung has postulated that the protein tropomyosin, found in shrimp, crab, and other shellfish, is involved in some allergic, seafood-related reactions.[7]

Crab-Processing Operation

The predominant species of crab harvested in the Pacific Northwest are Dungeness (*Cancer magister*), King (*Paralithodes*), snow (*Chionoecetes opilis* [or opilio]), and Tanner (*Chionoecetes bairdi*). The Alaskan crab fishing season typically extends from January to early March, with the exception of the King crab season, which typically occurs for a few days in November. Commercially harvested crabs are brought to processing plants on shore, or factory vessels, where they are prepared and packaged for transport and marketing. Factory vessels are located near the crab harvesting grounds in the waters off the coast of Alaska.

Crabs are taken from a live state to a cooked, frozen, and packaged product by workers at sequential stations. Live crabs are split into halves and gutted by ''butchers,'' then cleaned of gills with revolving brushes by ''degillers.'' On some vessels crab butchering and degilling occurs at one job station (''butcher-degillers''). Degilled crab halves are then forwarded to ''graders'' and ''sorters,'' who grade and sort the crab meat based on size and quality and pack the crab into metal boxes for cooking. Crabs are then cooked in fresh water at more than 200°F by ''cookers.'' The cooking process takes 15–20 min and produces steam. Next, crabs are rinsed, and preservatives such as sulfites may be added. The shellfish are chilled in cold tanks by ''chillers.'' Finally, crabs are transferred from metal to cardboard shipping containers by ''packers'' and are placed into freezers for storage.

Personal protection equipment generally worn by crab-processing workers aboard these vessels included rubber bib overalls, insulated rubber gloves and boots, and ear plugs.

Crab-Processing Vessel and Worker Selection

During the 1998 fishing season, the Occupational Safety and Health Administration (OSHA) assessed crab-processing vessels for health and safety compliance activity. Prior to that effort, OSHA personnel met informally with occupational and environmental medicine representatives to review clinical experience and develop specific respiratory illness questions that would provide information on the development of illness during the processing season.

In February 1998, OSHA personnel conducted compliance inspections aboard five crab-processing vessels that were selected based on availability in waters surrounding Dutch Harbor, Alaska. Vessel gross tonnage ranged from 1087 to 4948 tons. The number of processing and nonprocessing workers on each vessel ranged from 118 to 248 employees.

A sample of 25 workers, selected by OSHA personnel based on job title and a willingness to participate voluntarily in the survey, was evaluated for crab allergen exposure. Six personal samples were collected on Vessel 1; five samples each on Vessels 2, 3, and 5; and four personal samples on Vessel 4. Job title distribution by vessel is described in Table I.

As part of routine compliance voluntary employee interviews, OSHA personnel administered respiratory illness questions to 82 workers aboard the five vessels, and identifiers were removed according to University of Washington Human Subjects Review Committee requirements. Data were analyzed in accordance with the University of Washington Human Subjects Review Committee.

Vessels were characterized qualitatively by the following criteria which were thought a priori to impact worker exposure: (1) manual or automated butchering and degilling machinery; (2) enclosed or open-air butchering and degilling machinery; (3) combined or separate butchering and degilling operations; (4) butcher blade position relative to the breathing zone; (5) crab cooking location in relationship to butchering, degilling, and sorting activities; and (6) local and general exhaust ventilation in the cooking area.

Exposure Assessment

Aerosol breathing zone samples were collected on closed-face cassettes with polytetrafluoroethylene (Teflon™) filters at 4 L/min (Gillian pumps, Sensidyne/Gilian, Clearwater, Fla.L). Sample duration ranged from 2 to 8 hours, depending on the time the OSHA team was aboard each vessel and time demands associated with competing compliance activities. Air sample collection and the immunochemical filter analyses followed published protocols.[4] Briefly, a preparation of crab cooking water (dry weight allergen designation of 45 mg/mL) was used as the allergen standard. Crab specific IgE containing sera from known sensitized individuals were pooled and used to quantify the crab cooking water and airborne allergens. Airborne crab allergen mass was quantified by the referent crab cooking water. The limit of detection for the method was approximately 100 ng/filter. Each sample was assayed in duplicate and results were expressed as a mean value.

Respiratory Symptoms Assessment

During the processing season, workers were asked a subset of questions from two standardized respiratory questionnaires designed and validated for use in epidemiologic research of bronchitis and asthma.[8,9] The modified ATS questionnaire[8] elicited reports of ''usual'' symptoms of cough, phlegm, wheeze, and

TABLE II. Crab-Processing Operation Information

Vessel No.	Gross Tons	Work Force[A]	Butchering Degilling Operations[B]	Butcher Blade Fixed or Adjustable	Butcher Blade Position	General Exhaust Ventilation in Cooking Area[C]	Cooking Separate Deck from Butchering
1	4273	148	separate	adjustable	hip	no	no
2	1087	118	combined	fixed	midabdomen	no	no
3	4948	140	combined	adjustable	hip	no	yes[D]
4	4190	140	separate	adjustable	hip	yes	no
5	3468	248	separate	adjustable	hip	yes	no

[A]Processing and nonprocessing workers.
[B]Aboard some vessels the butchering and degilling activities were combined at the same workstation.
[C]Local exhaust ventilation over cookers was present aboard all vessels.
[D]Cooking operation on deck level below butchering and degilling operations.

breathlessness experienced over the previous 4 weeks of processing, compared with a baseline period prior to the season. A questionnaire designed by Venables and colleagues elicited reports of additional symptoms of wheeze and chest tightness.[9] Two or more positive responses on this instrument are considered a reliable index of asthma-like illness or bronchial hyperresponsiveness. Employees were asked to recall preseason respiratory symptoms and report current symptoms during the same interview. Table I describes the questionnaire respondents by job title and vessel.

Data Analysis

Descriptive data regarding job, vessel, allergen level, and respiratory symptom prevalence were analyzed using SPSS Version 8.0 (Chicago, Ill.) software. Associations between respiratory symptoms and crab allergen exposure levels were assessed by chi-square tests; multivariate analyses were not applied, given the small numbers in job title categories.

RESULTS

Work Stations

Crab-processing operations aboard each vessel were generally similar (Table II). Aboard each vessel the butchering and degilling operations were done manually and were not enclosed. In the processing areas on Vessels 2 and 3, the butchering and degilling operations were combined at a single job station (butcher-degillers), whereas on Vessels 1, 4, and 5 these operations were performed at separate work stations by distinct butchers and degillers. Butchering blades were adjusted to hip level on all vessels except on Vessel 2, where the butchering blades were stationary and positioned generally at midabdomen level. Aboard Vessel 3, crab cooking was performed on a different deck level from the butchering-degilling operations. Local exhaust ventilation systems were present over the cooking pots aboard all vessels. Vessels 4 and 5 also had overhead fans to remove cooking steam, although on Vessel 5 the general exhaust fan was observed to direct cooking steam toward the cooker's breathing zone.

Crab Allergen Exposures

Vessel crab allergen concentrations obtained from personal sampling ranged from 79 ng/m³ to 21,093 ng/m³, with a mean concentration of 2797 ng/m³ (SD=4576 ng/m³, median 1506 ng/m³, n=25). The highest allergen exposures were observed on Vessel 2, with a mean allergen concentration of 8744 ng/m³ (range 967–21,093 ng/m³, SD=8193 ng/m³, median 9333 ng/m³). In descending order, Vessel 1 mean antigen concentration was 1685 ng/m³ (range 869–2,239 ng/m³, SD=606 ng/m³, median 1840 ng/m³). Vessel 4 had a mean exposure of 1546 ng/m³ (range 825–2413 ng/m³, SD=699 ng/m³, median 1473 ng/m³), followed by Vessel 3 with a mean of 1239 ng/m³ (range 196–2504 ng/m³, SD=1056 ng/m³, median 1128), and lastly Vessel 5 with a mean of 745 ng/m³ (range 79–1845 ng/m³, SD=792 ng/m³, median 366 ng/m³) (Table III).

The workers in the combined butcher/degiller workstations had the highest mean antigen exposure of 7443 ng/m³ (range 246–21,093 ng/m³, SD=8010 ng/m³, median 5726 ng/m³). Butchers had the next highest average allergen level at 1915 ng/m³ (range 1300–2239 ng/m³, SD=533 ng/m³, median 2207 ng/m³); followed by degillers, with a mean concentration of 1369 ng/m³ (range 124–2173 ng/m³, SD=735 ng/m³, median 1473 ng/m³); and lastly the cookers/chillers with a mean of 1132 ng/m³ (range 79–2504 ng/m³, SD=859 ng/m³, median 918 ng/m³). Vessel 2 was the smallest processing vessel and had very high

TABLE III. Allergen Concentration by Vessel and Job Title

Job Title	Vessel Mean (SD) (ng/m³) Range (ng/m³)	Vessel 2 Mean (SD) (ng/m³) Range (ng/m³)	Vessel 3 Mean (SD) (ng/m³) Range (ng/m³)	Vessel 4 Mean (SD) (ng/m³) Range (ng/m³)	Vessel 5 Mean (SD) (ng/m³) Range (ng/m³)
Butcher/Degiller	N/A	13,721 (6423) 9333–21,093	1164 (937) 246–2119	N/A	N/A
Butcher	2223 (23) 2207–2239	N/A	N/A	None	1300 (n/a) 1300
Degiller	1644 (747) 1116–2173	N/A	N/A	1473 (430) 1168–1777	989 (1224) 124–1854
Cooker/Chiller	1188 (451) 869–1508	1278 (441) 967–1590	1350 (1632) 196–2504	1619 (1123) 825–2413	223 (203) 79–366

TABLE IV. Respiratory Symptoms Prior to and During the Crab-Processing Season

Symptom	Prevalence[A] Preseason (n = 82)	During Season (n = 82)	New Onset
Do you usually cough?	3 (4%)	25 (30%)	23 (28%)
Do you usually have phlegm?	0 (0%)	9 (11%)	9 (11%)
Do you usually wheeze?	0 (0%)	3 (4%)	3 (4%)
Grade 2 dyspnea?[B]	0 (0%)	0 (0%)	0 (0%)
Any symptom	3 (4%)	29 (35%)	27 (33%)

Note: From the ATS-DLD-78 Questionnaire.
[A]Individuals were asked to recall whether they had experienced symptoms prior to the season.
[B]Positive response to "Do you have to walk slower than people your age on the level because of breathlessness?"

antigen levels at the butcher/degiller workstation compared with other vessels and other job titles. The butchering blades at these workstations were stationary and positioned at the workers' midabdomen.

Respiratory Symptom Reporting

Reported respiratory symptoms are presented in Table IV. Only 3 (4%) workers recalled any respiratory symptoms prior to the crab-processing season. In contrast, 25 (30%) workers reported having cough and 9 (11%) reported having phlegm during the season. Relatively fewer workers reported development of symptoms more specific for asthma; 3 workers (4%) reported development of wheezing and no workers reported dyspnea during the previous 4 weeks of crab processing (ATS questionnaire). Similarly, on the Venables asthma questionnaire 3 workers (4%) reported two or more positive symptom responses, suggestive of bronchial hyperactivity. Notably, 13 workers (16%) reported having one symptom, with 2 workers (2%) reporting wheezing specifically during processing procedures.

DISCUSSION

Exposure to airborne crab allergens aboard crab-processing vessels has not previously been described. In this cross-sectional survey of crab-processing vessels, a wide range of exposure to crab allergens was observed, with exposure on one vessel during butcher/degilling operations considerably higher than personal breathing zone concentrations reported for land-based facilities.[4] Mean butcher/degiller (7443 ng/m^3), butcher (1915 ng/m^3), degiller (1369 ng/m^3), and cooker (1132 ng/m^3) exposures were substantially higher in this study than allergen concentrations in a land-based facility where concentrations measured were approximately 5000 ng/m^3 during crab cracking (similar to butchering) and less than 604 ng/m^3 during the other work activities evaluated.[4] Although NIOSH has conducted measurements of protein, crab cooking water allergen, and kanimiso allergen concentrations in an Alaskan land-based facility, results cannot be compared directly due to differences in sampling and analysis methods.[3,5]

Several factors may account for the higher personal exposures to crab allergen for workers aboard vessels compared with land-based facilities, including (1) more confined conditions aboard vessels; (2) lack of automated and enclosed butchering and degilling machines; (3) quality of ventilation system(s); and (4) proximity of processing areas to crab cooking facilities. The relatively higher allergen concentrations observed for butcher-degiller workers suggests that a lack of engineering controls, such as enclosure of this process, may be a contributing factor. It is also notable that the highest allergen concentrations were observed aboard the smallest vessel, suggesting that restricted spaces may be an important risk factor for exposure. Further, the butcher blades aboard this vessel were not height adjustable, and were positioned at mid-abdomen level, compared with the other vessels where workers adjusted butchering blades to hip level. The shorter distance between the point of crab particulate generation and the worker's breathing zone may account for the higher concentrations measured at this job station, and provide an additional factor in increasing crab allergen exposures. The lower crab allergen concentrations measured aboard Vessel 3, where cooking was performed on a separate deck level, suggest that cooking adjacent to other production areas likely contributes to allergen dispersion.

The reported prevalence of respiratory symptoms was high among crab-processing workers, with 29 (35%) workers reporting development of bronchitic symptoms of cough or phlegm during the season (ATS questions), and 13 (16%) reporting at least one symptom response on the Venables questionnaire. Although the high prevalence of symptoms could suggest an irritant airway response, with potential bronchitis or airway reactivity, these findings should be considered preliminary and limited by possible recall or selection bias.

Of note, both asthmatic and bronchitic symptoms have been described in previous studies of land-based and ocean-based facilities. In a study of 303 Gulf of Saint Lawrence snow crab workers, Cartier [2,10] reported a 16% prevalence rate for occupational asthma. Unlike in the present study, Edelman[11] studied one vessel and reported a remarkably high rate (70%) of "asthma-like" symptoms. In an investigation of 46 crab-processing workers, NIOSH investigators observed upper respiratory tract symptoms (cough) associated with exposure to crab cooking steam,[1] with an incidence of two cases per 100 workers per month of crab processing. In a land-based, longitudinal study of 107 workers, Ortega and colleagues described an increased incidence (new onset) of bronchitic symptoms, with 26% developing usual morning cough, 30% developing usual morning phlegm, and 26% of the workers developing "asthma-like" symptoms.[5]

There are several important limitations to this cross-sectional survey: (1) small number of measurement samples, limiting comparisons across specific job categories; (2) lack of quantitative information regarding ventilation systems, size of processing areas, and vessel production volumes; (3) inability to characterize use of additives or preservatives; (4) inability to assess the representativeness of crab exposures over time; (5) potential recall bias of employee reports of preseason respiratory symptoms; (6) possible selection bias of employees who volunteered for the OSHA interview or exposure survey; and (7) lack of work force demographics and smoking habits data that may have impacted overall symptom reporting.

CONCLUSION

These findings indicate substantial variability in crab allergen aerosol exposures among five crab-processing vessels, with extremely high exposure concentrations on one vessel during butcher/degilling activities. Although allergen levels were greatest for

butcher/degiller workers, concentrations were high among all processing workers. The high prevalence of respiratory symptoms among workers in all processing activities raises concerns regarding the effects of crab allergen exposure on the respiratory tract of the workers. Additional exposure characterization, immunology testing, and respiratory illness evaluation are necessary to confirm allergen concentration differences between vessel processors and land-based facilities, to identify and understand the factors that influence exposure, and to further assess the association between allergen exposure and respiratory function.

ACKNOWLEDGMENTS

The authors wish to thank the workers who participated in the study and the supervisors, managers, and owners of the processing facilities for their cooperation. In addition, the contributions of Dick Stiefken and Todd Jordan, CIH, with the OSHA survey team, and Sarah Bell's administrative support are appreciated.

REFERENCES

1. **National Institute for Occupational Safety and Health:** Asthma-like illness among crab-processing workers—Alaska. *Morb. Mort. Wkly. Rep. 31*(8):95–96 (1982).
2. **Cartier, A., J.L. Malo, F. Forest, et al.:** Occupational asthma in snow crab-processing workers. *J. Allergy Clin. Immunol. 74*:261–269 (1984).
3. **Ortega, H.G., S. Berardinelli, Hazards, Evaluations and Technical Assistance Branch:** "HETA 98-0069, UniSea, Inc., Dutch Harbor, Alaska". Cincinnati, Ohio: NIOSH, 2000.
4. **Weytjens, K., A. Cartier, J.L. Malo, et al.:** Aerosolized snow-crab allergens in a processing facility. *Allergy 54*:892–893 (1999).
5. **Ortega, H.G., F. Daroowalla, E.L. Petsonk, et al.:** Respiratory symptoms among crab processing workers in Alaska: Epidemiological and environmental assessment. *Am. J. Ind. Med. 39*:598–607 (2001).
6. **Silverstein, B., J. Burt, J. Fernald, et al.:** *Upper Extremity Cumulative Trauma Disorders in Fish Processing Plants, A Preliminary Report.* Washington, D.C.: Safety and Health Applications and Research for Prevention (SHARP) Division, Department of Labor and Industries, 1991.
7. **Leung, P.S., Y.C. Chen, M.E. Gershwin, S.H. Wong, H.S. Kwan, and K.H. Chu:** Identification and molecular characterization of *Charybdis feriatus* tropomyosin, the major crab allergen. *J. Allergy Clin. Immunol. 102*:847–852 (1998).
8. **Ferris, B.G.:** Epidemiology standardization project. *Am. Rev. Resp. Dis. 118*(6):1–120 (1978).
9. **Venables, K.M., N. Farrer, L. Sharp, B.J. Graneek, and A.J. Newman Taylor:** Respiratory symptoms questionnaire for asthma epidemiology: Validity and reproducibility. *Thorax 48*:214–219 (1993).
10. **Cartier, A., J.L. Malo, H. Ghezzo, M. McCants, and S.B. Lehrer:** IgE sensitization in snow crab-processing workers. *J. Allergy Clin. Immunol. 78*:344–348 (1986).
11. **Edelman, P.A.:** "Exposure Assessment and Prevalence of Asthma among Maritime Crab Processing Personnel." Paper presented at the American Industrial Hygiene Conference and Exposition, May 1994, Los Angeles, Calif.