REVIEW

Occupational seafood allergy: a review

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Abstract
***Background*—Recent years have seen increased levels of production and consumption of seafood, leading to more frequent reporting of allergic reactions in occupational and domestic settings. This review focuses on occupational allergy in the fishing and seafood processing industry.**
***Review*—Workers involved in either manual or automated processing of crabs, prawns, mussels, fish, and fishmeal production are commonly exposed to various constituents of seafood. Aerosolisation of seafood and cooking fluid during processing are potential occupational situations that could result in sensitisation through inhalation. There is great variability of aerosol exposure within and among various jobs with reported allergen concentrations ranging from 0.001 to 5.061(µg/m^3). Occupational dermal exposure occurs as a result of unprotected handling of seafood and its byproducts. Occupational allergies have been reported in workers exposed to arthropods (crustaceans), molluscs, pisces (bony fish) and other agents derived from seafood. The prevalence of occupational asthma ranges from 7% to 36%, and for occupational protein contact dermatitis, from 3% to 11%. These health outcomes are mainly due to high molecular weight proteins in seafood causing an IgE mediated response. Cross reactivity between various species within a major seafood grouping also occurs. Limited evidence from dose-response relations indicate that development of symptoms is related to duration or intensity of exposure. The evidence for atopy as a risk factor for occupational sensitisation and asthma is supportive, whereas evidence for cigarette smoking is limited. Disruption of the intact skin barrier seems to be an important added risk factor for occupational protein contact dermatitis.**
***Conclusion*—The range of allergic disease associated with occupational exposure to crab is well characterised, whereas for other seafood agents the evidence is somewhat limited. There is a need for further epidemiological studies to better characterise this risk. More detailed characterisation of specific protein antigens in aerosols and associated establishment of dose-response relations for acute and chronic exposure to seafood; the respective roles of skin contact and inhalational exposure in allergic sensitisation and cross reactivity; and the contribution of host associated factors in the development of occupational seafood allergies are important areas for future research.**
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Seafood refers to any aquatic organism that is intended for human or animal consumption. Recent years have seen a growing demand for seafood, which has led to increased production.[1] About 72% of harvested fish and shellfish worldwide are used for human food. It is estimated that between 1985 and 1989, world harvests of all seafood species increased by 15% (shellfish increased as a rate of 22% and finfish at a rate of 14%).[2] Increased levels of production and consumption of seafood have led and continue to lead to the more frequent reporting of adverse reactions, including immunologically mediated reactions. Allergy to fish is common among fish eating populations and in fish processing communities.[3] The prevalence of immediate type fish allergy is higher when the intake of fish constitutes a greater part in the diet of the community.[4] Despite these reactions being a common occurrence in the general population, their prevalence in the occupational setting has until recently been largely unstudied. Indeed, the bacterial and parasitic diseases associated with exposure to seafood have only recently been reviewed in detail.[5] This review focuses on occupational allergy associated with fishing and seafood processing activities. To identify relevant manuscripts, MEDLINE searches were undertaken for 1966–2000 for studies on occupational seafood allergy, asthma, and dermatitis. Review articles identified in the process were surveyed for additional and earlier citations. Dissertation abstracts and Current Contents were also searched to identify more recently published and unpublished studies and case reports.

Populations at risk from exposure to seafood

Although reactions to seafood have been documented mainly among consumers, immunologically mediated reactions have also been documented at work. This has been found to occur

Table 1 Common processing, preservation, and storage techniques used for seafood groups that are sources of potential occupational exposure to seafood products

Seafood category	*Processing techniques*	*Preservation techniques*	*Packaging of final products*	*Sources of occupational exposure to seafood products*
Crustaceans:				
Crabs, lobsters, crayfish	Cooking (boiling or steaming), "tailing" lobsters, "cracking", butchering, and degilling crabs, manual picking of meat, cutting, grinding, mincing, scrubbing and washing, cooling	Deep freezing, pasteurising, sterilisation, liquid freezing	In refrigerated containers, polyethylene bags, or in cans	Inhalation of wet aerosols from lobster "tailing", crab "cracking", butchering and degilling, boiling, scrubbing, and washing, spraying, cutting, grinding, mincing, prawn "blowing", cleaning processing lines/tanks with pressurised water
Prawns	Heading, peeling, deveining, prawn "blowing" (water jets or compressed air)	Deep freezing, drying	In refrigerated containers or in cans	Dermal contact from unprotected handling of prawn; hand immersion in water containing extruded gut material
Molluscs:				
Oysters, mussels clams, scallops, abalone	Washing, oyster "shucking", shellfish depuration, chopping, dicing, slicing	Deep freezing, freezing, sterilisation, smoking, cooking	In refrigerated containers or in cans	Inhalation of wet aerosols from oyster "shucking", washing Dermal contact from unprotected handling of molluscs
Finfish:				
Various species	Heading, degutting, skinning, mincing, filleting, trimming, cooking (boiling or steaming), spice/batter application, frying, milling, bagging	Deep freezing, drying, smoking, sterilization, liquid freezing	Loose in refrigerated containers, cans, or in bags	Inhalation of wet aerosols from fish heading, degutting, boiling Inhalation of dry aerosols from fishmeal bagging Dermal contact from unprotected handling

primarily through inhalation of aerosols generated during cutting, scrubbing or cleaning, cooking or boiling, and drying.[6] Reactions can also occur through the skin as a result of direct handling of the seafood itself.[7] Occupational exposure to seafood allergens occurs mainly in the food and fishing industry. Workers in several of these industries are exposed to seafood, especially those involved in either manual or automated processing of crabs, prawns, mussels, fish, and fishmeal. Other occupations associated with exposure to seafood include oyster shuckers, laboratory technicians and researchers, jewellery polishers, restaurant chefs, fishmongers, and fishermen.[7 8]

The Food and Agriculture Organisation of the United Nations (FAO) estimates that between 1970 and 1990, the number of people engaged in fishing, aquaculture, and related activities doubled from 13 million to 28.5 million worldwide.[9] Among these workers 52% worked aboard fishing trawlers, 32% were involved in aquaculture production (marine and freshwater), and 16% worked inland as capture fishermen or other land based activities such as processing. In 1990, 95% of the world fishermen and fish farmers were from developing countries, producing 58% of the 98 million tonnes of world fish. In many countries, labour in the fishing industry tends to be divided by sex with men almost exclusively going out to sea to catch the fish and women doing most of the on land processing.[10] Most of these workers are seasonal workers. The degree of exposure is likely to be highest during the harvest season when most of the processing occurs.

Seafood processing work environment

Seafood processing plants vary in the levels of technology, with some of the smaller workplaces relying entirely on manual handling of the seafood and larger companies using modern highly automated processes. There is great variation in processing procedures for the different types of seafood.[2 11] Common processing, preservation, and storage techniques used for the major seafood groupings, and sources of potential exposure to seafood products are outlined in table 1.

Studies of environmental exposure assessments to measure aerosol particulate and allergen concentrations among seafood processing workers are summarised in table 2. The lack of standardised methods for environmental sample collection, extraction, and analysis makes comparisons between various studies difficult, although some similarities can be found. It is notable that generally much higher allergen concentrations were obtained with personal than with area sampling. There is great variability of exposure within and among various jobs involved in seafood processing with reported allergen concentrations ranging from 0.001 to 5.061 μg/m^3.

Aerosolisation of the seafood (meat, exoskeleton, blood, endolymph) during processing has been identified as a potential high risk activity for sensitisation through inhalation.[17 20 22 23] Identified processes with high potential for exposure to aerosols include butchering or grinding, degilling, "cracking" and boiling of crabs; "tailing" of lobster; "blowing "of prawns, washing or scrubbing of shellfish, degutting, heading, and cooking or boiling of fish, mincing of seafood, and cleaning of the processing line and storage tanks with high pressured water. Despite high levels of automation in larger workplaces, workers employed there are also often found to be at high risk due to inadequate and poorly designed local exhaust ventilation systems.[20] Furthermore, processes that generate dry aerosols (prawn blowing with compressed air) seem to generate higher concentrations of particulates than wet processes (prawn blowing with water jets).[19] It has been suggested that because water provides general aerosol suppression, it may also influence the size, lifetime, or other dynamics of small protein particles as water is a major feature of this work environment.[18] There is also the possibility that workplace exposure factors other than those of seafood origin—for example, hypertonic saline aerosols, cold air, strenuous physical activity—may also trigger allergic respiratory symptoms.

Dermatological symptoms experienced by workers are the result of direct contact with the actual seafood or a systemic response to inhalational exposures. Occupational dermal exposure can occur as a result of unprotected handling of various seafoods and their products (fish juice, meat, skin, skin slime or mucin, entrails) at various stages in the production process.[24–26] This generally occurs under wet and low temperature conditions.[27] Manual cutting and generation of fish juice in various work processes can expose the skin to mechanical damage (inoculation by spinous appendages) and fish enzymes. This can result in keratinolysis thereby leaving the human skin open to potential penetration by protein fragments capable of causing dermatological symptoms.[28] The average protein concentration in the fish juice associated with these symptoms in the study by Halkier-Sorensen *et al*[28] was estimated to be 8.5 µg/l.

Constituents of seafood

Adverse non-immune and immune reactions to seafood are commonly found among consumers of seafood. These reactions can result from exposure to the seafood itself or to various non-seafood components present in the product. Such non-seafood components include various contaminants—such as parasites (*Anisakis simplex*),[29] protochordates (*Hoya*),[30] and algae (dinoflagellates—*Hematodinium*),[5 22] bacteria (Vibrio),[5] viruses (hepatitis A),[5] marine or bacterial toxins (saxitoxins, scombroid toxin, histamine),[5 31] gases produced by anaerobic decomposition of fish (hydrogen sulphide),[32] chemical additives (sodium metabisulphite), spices (mustard, paprika, flour additives, garlic),[33] and hidden ingredients (casein)—in canned or processed fish products.[3] The three most important seafood groupings containing the marine species most often consumed or handled by humans are Arthropoda, Mollusca, and Pisces (sub-phylum Chordata). Among the arthropods, the crustacean class includes some of the most allergenic species of seafood. The phylogeny of the commercially important seafood causing occupational allergies is presented in table 3.[2 34]

Seafood allergens are primarily high molecular weight proteins ranging in molecular weight from 10 kDa to 70 kDa.[35] It is these proteins present in aerosols that have been associated with the allergic respiratory symptoms.[34] The composition of aerosols generated by snow crab and king crab processing has been found to contain crab exoskeleton, meat (mainly

Table 2 Studies of environmental assessments of exposure among seafood processing workers

Study	*Seafood type*	*Work process or job type*	*Total particle concentration (mg/m³) Range*	*Allergen concentration (µg/m³) Range*	*Particle fraction measured*
Orford *et al*[12] (1985)	King crab	Claw saw operator	0.176 (A)	ND	Total (W)
		Band saw operator	0.014 (A)	ND	(30% ≤5 µm)
		Background	0.039–0.052 (A)	ND	
Beaudet[13] (1994)	King crab	Band saw operator	0.110–0.160 (P)	ND	Total (W)
		Crab "scoring" line	0.030 (P)	ND	
Edelman[14] (1994)	Tanner crab	Butchering and packing	0.140–0.680 (P)	ND	Total (W)
Griffin *et al*[15] (1994)	Common crab	Claw cutting	0.003–0.004 (Pr) (A)	0.012–0.032 (A)	Total (W)
		Meat flotation	0.002–0.004 (Pr) (A)	0.011–0.053 (A)	
		Meat mincing	0.003–0.005 (Pr) (A)	0.009–0.115 (A)	
		Packing	0.001–0.002 (Pr) (A)	0.001–0.003 (A)	
		Cold store	0.001 (Pr) (A)	0.003–0.004 (A)	
Malo *et al*[16] (1997)	Snow crab	Boiling water	0.009† (Pr) (P)	1.700† (Pr) (P)	Total (W)
Weytjens *et al*[17] (1999)	Snow crab	Crab cracking	ND	0.084–0.547 (A)	Total (W)
		Boiler outlet	ND	0.053 (A)	
		Cooling basin outlet	ND	0.100 (A)	
		Final selection	ND	0.063 (A)	
		Crab cracker	ND	4.961–5.061 (P)	Total (W)
		Crab sorter: cooling basin	ND	0.196–0.604 (P)	
		Crab sorter: underwater jet cleaning	ND	0.204–0.220 (P)	
		Crab sorter or cleaner	ND	0.179–0.191 (P)	
Ortega *et al*[18] (1999)	Snow crab	Butchering	0.032–0.081 (Pr) (P)	<—140*	Total (W)
		Degilling	0.034–1.500 (Pr) (P)	<—570*	
		Packer-sorter	0.010–0.020 (Pr) (P)	<—150*	
		Cooking	0.010–6.400 (Pr) (P)	<—66*	
		Shipping or case up	0.039 (Pr) (P)	<—220*	
		Loading dock or forklift	0.011 (Pr) (P)	<—830*	
	Pollock	Processing plant	0.004 (A)	ND	Total (W)
Gaddie *et al*[19] (1980)	Prawn	Prawn blowing (compressed air)	1.8–3.3 (A)	ND	Total (W)
		Prawn blowing (water jets)	0.1–0.3 (A)	ND	Total (W)
Douglas *et al*[20] (1995)	Salmon	Wet—for example, fish gutting, grading	2.71–3.57 (A)	0.100–1.00 (A)	Respirable (CM)
		Dry—for example, fish packing in store	0.04–0.05 (A)		
		Office	<0.01 (A)		
Taylor *et al*[21] (2000)	Whiff megrim/hake	Fish market	ND	0.002–0.025 (A)	Total (W)

A=area sample; P=personal sample; W=time weighted average; CM=continuous monitoring; Pr=protein concentration; ND=not done; <=not detectable.
*Relative allergen units (RAU)/m³.
†µg Allergen per filter.

Table 3 Classification of seafood groups causing occupational allergies

Phylum	*Class*	*Family (common name)*
Arthropoda	Crustacea	Crabs, lobsters, prawns, shrimp
Mollusca	Gastropoda	Abalone
	Bivalvia	Clams, oysters, mussels
	Cephalopoda	Squid (cuttlefish)
Pisces (subphylum Chordata)	Osteichthyes (bony fish)	Salmon, plaice, tuna, hake, cod, herring, sardine, trout, anchovy

muscle protein), gills, kanimiso (internal organs) and background material such as sodium chloride crystals, cellulose, synthetic fibres, silicate, pigment constituent particles, and inorganic particles (silicon, aluminium, iron).[12 14 18] Most of the particles are irregular and at least 30% of airborne particulate are within the respirable range (⩽5 µm). Environmental monitoring of clam and shrimp processing workers indicated that most of the filters examined under light microscopy showed the presence of dust comprising corn starch (95%), guar gum, cellulose, clam (traces), and shrimp (1%).[36] Sherson *et al* in their investigation of contaminated water isolated gram negative bacteria (*Klebsiella pneumoniae* and *Pseudomonas*) and endotoxin (1 µg endotoxin/ml) in the water from a gutting machine thought to be responsible for the respiratory symptoms among trout processing workers.[37] A recent survey among crab processing workers showed very low concentrations of airborne endotoxin (obtained through personal sampling) despite large numbers of gram negative mesophilic bacteria being isolated through bulk sampling of plant processing tanks. The mean concentrations of endotoxin were 32.6 EU/m^3 (total fraction) and 15.6 EU/m^3 (respirable fraction), lower than the recommended exposure limits of 50 EU/m^3 (inhalable dust).[18]

Constituents of fish juice associated with skin symptoms have been shown to comprise traces of biogenic amines, histamine, and cadaverine[38]; degradation compounds associated with postmortem changes[24]; digestive enzymes (pepsin and trypsin)[39 40]; and high molecular weight proteins (>10 kDa).[28] No well known human pathogenic bacteria were present.[28] It has been suggested that fish muscle proteinases lead to hydrolysis of large muscle proteins which accumulate in fish juice. It is these denatured proteins that are thought to be responsible for inducing skin symptoms.[28] Furthermore, it has been shown that storage conditions may also influence the allergenicity of seafood extracts by influencing the relative distribution of various IgE reactive proteins.[41] Fish kept on ice for several days showed additional high molecular weight allergens and higher IgE binding capacity.

Physical, biochemical, and immunological characteristics of seafood

Although seafood contains a wide variety of proteins, only a few are known allergens.[35] Most seafood allergens are heat stable water soluble glycoproteins with molecular weights between 10 and 70 kDa and an acidic isoelectric point.[42] They are detectable in fish juice, cooking aerosols, and gastric fluid as they are able to resist the effects of processing, cooking, or human digestive processes.[17 28 43 44] Factors known to contribute to antigenicity include allergen dose; route of exposure, allergenic potency, and mucosal permeability in the exposed person.[7] Some proteins that occur in small amounts in seafood can also be important food allergens.[35] There is a considerable body of evidence to suggest that high molecular weight agents (>10 kDa) act through an immune response mediated by IgE antibodies to some antigenic component of the protein.[8 34 45] This view is supported by the presence of a latency period before symptoms after exposure and the temporal nature of adverse reactions resulting from ingestion, dermal contact, or inhalation of various seafood aerosols.

In patients with a history of immediate adverse reactions after ingestion of seafood, various seafood specific IgE antibodies have been shown by immediate skin reactivity with skin prick tests (SPTs) and by radioallergosorbent testing (RAST) of serum samples.[46] Studies of the allergenicity of emissions from boiling fish indicate that the "steam aerosols" from salmon share IgE binding components with raw and boiled salmon.[43 47] IgE sensitisation has also been documented for occupational asthma to various seafoods such as crabs, clams, prawns or shrimp, and salmon.[34] Cartier *et al* showed a highly significant relation between SPT and RAST to crab extracts and the occurrence of occupational asthma.[48] The study also showed good correlation between the results of skin and RASTs with extracts of either meat or snow crab cooking water to which subjects were exposed. More recently, work among crab workers provided strong evidence that airborne proteins derived from snow crabs, released during boiling and cracking of crab legs, are responsible for the immunological reactivity in sensitised or symptomatic workers.[16 17] Alonso *et al* showed herring specific IgE antibodies and a positive histamine release test (HRT) in a food handler with occupational protein contact dermatitis (contact urticaria) due to herring.[49]

Although various other isotypes of seafood specific immunoglobulins—for example, IgG and IgG subclasses, IgM and IgA—have also been detected in patients sensitive to seafood, their potential role in providing protection from or eliciting adverse reactions to various shellfish or bony fish has not been fully evaluated.[46] However, there may be a possible role for IgG in non-smokers involved in prawn and salmon processing and for endotoxin in trout processing.[20 37 50] The role of IgG does not seem to correlate with allergic respiratory symptoms among crab processing workers.[12]

Most of the studies have identified allergens in serum samples from people with typical IgE mediated symptoms who have been sensitised through ingestion. By contrast, the airborne allergens associated with asthmatic reactions have not yet been fully described. Only a few seafood allergens have been isolated, purified, and characterised in detail. This has been the subject of a recent review.[51]

The main allergen in fish, *Gad c*1, a 12 kDa protein from the muscle tissue of cod fish (*Gadus morhua)* was one of the first seafood allergens to be isolated and characterised.[52] More recent studies isolated additional allergens from cod and salmon.[41 53] All these allergens belong to a group of muscle tissue proteins, parvalbumins, that have calcium chelating properties in fish. Allergenic cross reactivity is dependent on specific amino acid sequences present among various fish species—such as hake, carp, pike, whiting, mackerel, herring, plaice and tuna.[3 54 55]

Allergens with notable amino acid homology similar to the major crustacean allergen, shrimp muscle protein tropomyosin, have been isolated from several shrimp species as well as lobster and crab.[51] The allergens have molecular weights of 30-39 kDa and have also been identified as tropomyosin. Recently, a 31 kDa protein has been identified as being responsible for asthma and rhinitis in a woman handling and cooking Norway lobster.[56] A high degree of IgE cross reactivity has been shown between shrimp, crab, lobster, and crawfish allergens.[46] Among the molluscs, major allergens isolated include a 38 kDa allergen in Pacific squid and a 49 kDa protein in abalone.[57 58] However, crustaceans may also share common allergens with molluscs, as has been shown between shrimp and lobster with squid, abalone, oyster, and welk.[59 60]

Health effects associated with seafood processing

The first published report of occupational allergic reactions due to seafood was by Beshce in 1937. He described a fisherman who developed asthma, angioedema, and conjunctivitis when handling codfish.[61] Various studies have subsequently confirmed that occupational seafood allergy can be manifest as rhinitis, conjunctivitis, asthma, urticaria, and protein contact dermatitis. Systemic anaphylactic reactions have also been reported.[8] Another condition known to be associated with occupational exposure to seafood is extrinsic allergic alveolitis.[62]

ASTHMA

The proportion of adult asthma (new and reactivated disease) attributable to occupational exposure is estimated to be 10%.[63] The reported prevalence of occupational asthma due to seafood varies from 7% to 36%. A summary of findings of various published studies are presented in table 4.[34]

Differences in prevalences across studies may be due to varying definitions of occupational asthma; differential exposure to seafood constituents; and the allergenic potential of seafood proteins involved. Occupational asthma has been associated with occupational exposure to all the major seafood groupings in various epidemiological studies, arthropods (crabs, prawns), molluscs (cuttlefish), pisces (salmon), as well as other seafood derived agents (sea squirt, *Anisakis* and red soft coral). A higher prevalence is associated with exposure to aerosols from arthropods (crustaceans) than with pisces (bony fish) and molluscs. Rhinoconjunctivitis and skin symptoms commonly occur in association and usually precede asthmatic symptoms. Upper airway symptoms can therefore be regarded as useful early risk markers for occupational asthma among workers exposed to high molecular weight agents such as seafood.[84]

A few studies have shown a dose-response relation between the level of exposure to occupational agents and the prevalence of sensitisation, non-specific bronchial hyperresponsiveness, or asthma.[85] Gaddie and Friend reported that 83% of workers experienced relief of their occular, nasal, respiratory, and skin symptoms when the concentration of prawn aerosols decreased from 1.8–3.3 to 0.1–0.3 mg/m^3 in the prawn blowing area.[19] Douglas *et al* reported that after fitting a local exhaust ventilation system, the overall mean exposure of respirable aerosol was reduced from 2.37 mg/m^3 to less than 0.01 mg/m^3 and no new cases of occupational asthma occurred during 24 months, versus an initial 8% prevalence over an 18 month period.[20]

The most important host associated risk factors for sensitisation, IgE mediated immunological reactivity and the development of asthma, are atopy and cigarette smoking. Atopy is more consistently associated with sensitisation to high molecular weight agents in general and certain seafood (prawn, shrimp, clam, crab, and cuttlefish) in particular.[19 36 65 71] Smoking has been shown in one study among prawn processors to be an independent risk factor for increased specific IgE production (OR=2.4).[50]

Immunology tests confirm that these asthmatic reactions are predominantly IgE mediated phenomena with IgE sensitisation levels among workers exposed to crustaceans (arthropods) of 5%–60% and bony fish 23% (table 4). Serum precipitating (IgG) antibodies were reported to be present in 60%–62% of workers exposed to crustaceans and 33% of workers exposed to bony fish (table 4). Long term follow up of workers with crab asthma who have ended exposure has shown that the plateau for improvement in spirometry was reached at mean intervals of 1 year, and for bronchial hyperresponsiveness at 2 years.[86] Although there was evidence of a concurrent reduction in the concentrations of specific IgE antibodies, no plateau was generally found even at 5 years. The mean half life of specific IgE antibodies to snow crab allergens detected in workers' serum samples was 20 months. Poor prognostic features of workers with occupational asthma include a longer period of exposure before the development of symptoms, longer duration of symptoms before diagnosis, and severity of disease at time of diagnosis.[87] Recent studies suggest that the risk of workers with occupational asthma due to high molecular weight agents becoming symptomatic is modified by younger age, non-immediate reactions, and continuous exposure.[88] Chronic

Table 4 Epidemiological studies and case reports of occupational asthma due to seafoods

Agent	Occupation	Subjects (n)	Asthma prevalence (%)	Other symptoms	Skin prick or intradermal test (% positive)	Other immunologic evidence (% positive)	Specific bronchoprovocation test (% positive)	Other evidence
Epidemiological studies and case reports of occupational asthma due to arthropods:								
Crab	King crab processors[12 64]	186	13%	ND	60% (of random sample of 15)	Precipitins: 60% of 15	ND	Across shift spirometry
		825	Incidence of 2%/month	ND	ND	ND	ND	ND
	Snow crab processors[18 65]	303	16%	Rhinitis, skin rash, conjunctivitis	22%	ND	72% (of 46 tested)	PEFR + PC_{20}
		107	Incidence of 2%/6 weeks	Rhinitis	ND	RAST: 6–8%	ND	Spirometry
	Rock crab processors[66]	29	7%	Rhinitis, conjunctivitis	25%	ND	14% (of 14 tested)	PC_{20}
Prawn	Prawn processors[19]	50	36%	Rhinitis, itchy eyes and hands	26%	RAST: 16% Precipitins: 62%	100% (of 2 tested)	ND
Shrimp or clam	Processors[36]	56	2% 4%	Rhinoconjunctivitis	16% 5%	RAST: 14% RAST: 7%	67% (of 3 tested)	PC_{20}
Shrimpmeal	Technician[67]	1	NA	Rhinitis	Positive for shrimp	RAST: positive for shrimp, crab	Positive for shrimp	ND
Lobster or shrimp	Fishmonger[68]	1	NA	Rhinitis, hay fever, urticaria	Positive for lobster, shrimp, crab	RAST: positive for shrimp, lobster, crab, crawfish	Positive for lobster, shrimp	ND
Lobster	Chef[69]	1	NA	Urticaria	Positive for lobster, haddock, scallops, oyster, clam, cod	ND	Positive for lobster	PC_{20}
Epidemiological studies and case reports of occupational asthma due to molluscs:								
Cuttle fish	Deep sea fishermen[70]	66	Incidence of 1%/y	Dermatitis, conjunctivitis	ND	ND	ND	ND
	Fishermen[71]	50	ND	Rhinitis, urticaria, eczema	ND	ND	ND	Spirometry
Mussel (?)	Mussel openers[72]	224	20%–23%	ND	ND	ND	ND	Across shift PEFR
Mussel or crustaceans	Cook[73]	1	NA	ND	ND	ND	ND	ND
Cuttle fish bone	Jewellery polisher[74]	1	NA	Urticaria	Positive	ND	Positive	ND
Clam	Cancer drug researcher[75]	1	NA	Rhinitis	Positive	ND	Positive	ND
Oyster (mother of pearl)	Souvenir maker[76]	1	NA	Rhinitis, conjunctivitis	Anaphylactic reaction to mother of pearl	Precipitins: negative to mussel, oyster, mother of pearl	ND	ND
Abalone	Fisherman[77]	1	NA	ND	ND	ND	Positive	ND
Epidemiological studies and case reports of occupational asthma due to Pisces (bony fish):								
Salmon	Fish processors[20]	291	8%	Rhinitis	ND	RAST: 9% of all positive precipitins: 33% of all positive	ND	PEFR
Trout (?)	Fish processors[37]	8	NA	Rhinitis	ND	RAST: 100% of all positive Anti-endotoxin Ab: 13%	ND	PEFR + PC_{20}
Fishmeal	Fishmeal processors[78]	51	2%	Skin rash, rhinitis	23% to mix of pickling, cod, plaice, tunny, salmon, herring, sardine	Precipitins: 100% negative to cod, herring, sardine, plaice	100% (of 1 tested) for fishmeal	Nasal Provocation test

NA=not applicable; ND=not done; RAST=specific IgE; PEFR=peak expiratory flow rate; PC_{20}=methacholine/histamine challenge test; HRT=histamine release test.

Table 4 Continued

Agent	*Occupation*	*Subjects (n)*	*Asthma prevalence (%)*	*Other symptoms*	*Skin prick or intradermal test (% positive)*	*Other immunologic evidence (% positive)*	*Specific bronchoprovocation test (% positive)*	*Other evidence*
Various fish (plaice, salmon, hake, sardine, anchovy, tuna, trout, sole, pomfret)	Fish processors[79]	2	NA	Rhinoconjunctivitis	100% to all species	RAST: 100% of 2 positive to trout, anchovy, and salmon	100% (of 2 tested) for hake tuna, plaice salmon	PEFR + PC_{20}
Yellowfin fish	Dried fish processors[80]	ND	ND	Rhinitis, dermatitis	ND	ND	ND	Spirometry
Epidemiological studies and case reports of occupational asthma due to other agents associated with seafood:								
Hoya (Sea squirt)	Oyster farm workers[30]	1413	29%	Rhinoconjunctivitis	82% of 511 with asthma	RAST: 89% of 180 with asthma positive Precipitins: negative	82% (of 17 tested)	ND
Anisakis	Fishermen/fishmonger[29]	28	18%	Urticaria, angioedema	46%	RAST: 50% positive	ND	ND
Red soft coral	Spiny lobster fishermen[81]	72	9%	Rhinitis, dermatitis, conjunctivitis	2 of 2 with asthma positive to soft coral	RAST: 1 of 2 positive to soft coral, lobster	ND	ND
Daphnia	Fish food store keepers[82]	2	NA	ND	100%	ND	100%	ND (of 2 tested)
Marine sponge	Laboratory grinder[83]	1	NA	Urticaria	ND	RAST: positive to *D herbacea*, other sponge, soft corals Precipitins: positive *D herbacea* HRT: positive to *D herbacea*	ND	Asthma attack at work

NA=not applicable; ND=not done; RAST=specific IgE; PEFR=peak expiratory flow rate; PC_{20}=methacholine/histamine challenge test; HRT=histamine release test.

exposure seems therefore likely to lead to permanent impairment of lung function and its associated sequelae.

As most of the published studies have been cross sectional, the potential for a healthy worker effect operating was high—that is, exposed symptomatic workers will preferentially leave the industry or move from jobs with high exposure to low exposure. This may have resulted in an underestimate of the true prevalence of occurrence of disease among workers in high risk jobs. The presence of such a type of bias was strongly suggested in a recent longitudinal study of crab workers which showed that new workers had higher concentrations of specific IgE and were more likely to develop symptoms and adverse health outcomes than experienced workers over a harvesting season of 6 weeks duration.[18] This study also showed that the incidence of new cases with upper respiratory symptoms was 56% and those with an asthma-like outcome was 26% among all exposed workers.

URTICARIA AND PROTEIN CONTACT DERMATITIS

By contrast with respiratory allergy, dermatological allergy to seafood has been studied and documented less in the medical literature. The major skin manifestations associated with seafood are contact urticaria and eczematous contact dermatitis of various types.[24 89 90] Contact urticaria is associated with direct contact with raw seafood proteins. At least 75% of eczematous dermatitis in the fish processing industry are irritant, and commonly due to contact with water and fish products (fish juice, slime, skin, fillet).[24] Contact with proteinacious material—such as seafood—also causes a chronic recurrent dermatitis commonly known as protein contact dermatitis.[91] However, biochemical sensitisers (garlic, onion, spices) added to seafood can also cause a delayed allergic contact dermatitis.[90] Occupational case studies have shown that the various dermatological outcomes can also coexist in affected people.[92–94]

Contact urticaria and protein contact dermatitis initially manifest as itchy, erythematous, and vesicular lesions. Protein contact dermatitis usually goes on to present as a chronic eczema with episodic acute exacerbations a few minutes after repeated contact with the offending allergen.[90 91] The development of immediate contact reactions usually requires repeated skin contact although earlier sensitisation through ingestion or inhalation and subsequent dermal contact can also result in protein contact dermatitis.[95 96] Predominantly affected areas are the volar aspect of the forearm and dorsum of the hands.[24 97] In the more severe form, local skin contact with seafood may result in generalised urticaria or systemic symptoms (angioedema, wheezing).[92 95 98] The diagnosis can only be made by skin prick tests as patch tests with the responsible allergen are usually negative.[91] Sometimes, specific IgE antibodies can be detected in the serum samples.[90 91]

Table 5 Epidemiological studies and case reports of dermatitis due to arthropods, pisces, and molluscs

Agent	*Occupation*	*Subjects*	*Prevalence (n)*	*Skin prick or intradermal test (% positive)*	*Other immunological evidence*	*Patch test (SPT)*	*Other evidence*
Pisces:							
Cod, coalfish, haddock	Fish stick and fillet processors[104]	102 122	8 3	50% of 16 tested (cod) 50% of 6 tested (cod)	ND	Patch: negative (cod)	ND
Round fish	Fish processors[97]	156	11	ND	ND	ND	Clinical examination
Herring	Dolphinarium worker[49]	1	NA	Positive for herring, anchovy, sardine, salmon, cod, tunny	RAST (herring): positive HRT: positive for herring, sardine, anchovy, cod, salmon, tunny	Open and closed test: negative to all	Rub test: positive to herring, anchovy, sardine (immediate)
Cod	Cook[93]	1	NA	Positive	RAST: positive	Open patch: positive Immediate reaction	Positive provocation test
Arthropods:							
Shrimp	Shrimp processors[105]	110	6	29% of 7 tested	ND	ND	ND
	Waitress[106]	1	NA	ND	ND	Open patch: positive Immediate reaction	ND
	Fishmarket worker[107]	1	NA	ND	ND	ND	Positive scatch test Positive rub test
Molluscs:							
Squid							
Loligo japonica	Cook[108]	1	NA	Positive	Prick prick test: positive RAST: positive	Open patch: positive Immediate reaction	ND
Loligo vulgaris	Fishmonger[92]	1	NA	Positive	Prick prick test: positive RAST: negative	Open patch: positive Immediate and delayed reaction	ND

NA=not applicable; ND=not done; SPT=skin prick test; RAST=specific IgE; HRT=histamine release test.

In the seafood industry, the reported prevalence of occupational protein contact dermatitis is 3%–11% (table 5).[99–103] Seafood identified in occupational protein contact dermatitis include the crustacean class among the arthropods (shrimp), molluscs (squid), bony fish class of pisces (cod, herring) and other agents derived from seafood (soft coral). Crustaceans most often produce an IgE mediated contact urticaria, although a delayed contact dermatitis may develop in certain people.[89] In a study of workers exposed to bony fish, the average duration of employment before the development of symptoms was 2.3 years.[104]

Atopy and skin integrity constitute important host associated risk factors for the development of urticaria and protein contact dermatitis. Various studies among food handlers and caterers have shown an association between atopy and occupational skin diseases induced by crustacea.[89 99 102] Skin integrity and physiological factors (such as temperature below 19°C) also seem to be important in determining the location of skin symptoms (urticaria) and recovery of skin barrier function among workers handling fish.[24]

It has been estimated that up to one third of food handlers and caterers with occupational skin disease may need to find alternative employment because of debilitating symptoms. Moreover, despite ending the exposure to shellfish, some people have persistent symptoms.[89]

In conclusion, the range of allergic disease associated with occupational exposure to crab is well characterised. For other seafood agents the evidence is more limited; moreover, there remain several unanswered or poorly characterised issues of importance that need to be considered in future epidemiological studies. These include better characterisation of specific protein antigens in aerosols, and associated establishment of dose-response relations; importance of inhalational versus dermal exposure routes, and of acute versus chronic exposures, for sensitisation, extent of antigen cross reactivity between major seafood groups and between species within a seafood group, contribution of genetic and other host associated factors—such as atopy and smoking—in determining exposure-related health effects, and establishing pathophysiological mechanisms through animal models.

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Many journals, including the BMJ, have moved to a system of open reviewing, whereby authors know the names of reviewers of their papers. Research has shown that named reviews, although not of better quality than anonymous reviews, are not of worse quality either. Therefore in the interests of transparency, it seems fair to let authors know who has reviewed their paper. At *Occupational and Environmental Medicine* we have considered the issue carefully. There are some concerns that reviewers, especially those who are more junior, might feel intimidated and not wish to make negative comments about papers submitted by senior people in the field. On the other hand, some reviewers might hide behind the cloak of anonymity to make unfair criticisms so as to reduce the chances of publication by rivals. We have decided to introduce initially a system of open reviewing if the reviewers agree explicitly. So when a reviewer is sent a paper, he or she is asked to indicate whether we can disclose their name or not when sending the authors their comments. We will be monitoring this to see how many of our reviewers are happy to be named. If it is most of them, we will move to a system of open reviewing as the norm, with a possible "opt out" clause for reviewers.