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# Seafood-Associated Bacterial Pathogens: Risks and Food Safety Implications

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The increase in the consumption of seafood worldwide has resulted in the increased mobility of fishery products across the globe. Fish produced in one part of the world make it to another part as fresh or in the form of various fishery products. This trend, though desirable as a means of meeting the food demands of the increasing global population, has also raised concerns on the human health problems from seafood.

Microbial pathogens are a major threat to human health through the consumption of contaminated foods, including seafood. Though the food production systems have undergone enormous transformation from traditional ways to scientifically sound, technologically robust systems that produce safe, healthy and nutritionally balanced foods, food-borne pathogens are still a great challenge to human health in the modern world. The eating habits are constantly on the change with the modern population preferring ready-to-cook and ready-to-eat foods that save time spent otherwise on preparation of food. This has enormously increased the responsibility of food processing firms to produce food that is very safe and free from human pathogens. Further, the consumer population is also diverse. Consumers with compromised immunity due to underlying health debilitations such as cancer, viral infections and liver dysfunction are readily prone to infections by pathogens present in very low numbers, which otherwise do not pose any health risk to healthy consumers. Therefore, managing food safety involves a variety of factors, which can make the process quite complex.

Seafood is known to cause illnesses due to the presence of agents harmful to human health, which may or may not be intrinsic to the aquatic food. The potentially harmful agents in fish or shellfish are chemicals, heavy metals, marine toxins or infectious agents. The biological agents of infections in seafood are bacteria, viruses and parasites. In developed countries such as the United States, Europe and Canada, seafood is responsible for a significant proportion of outbreaks (Iwamoto et al. 2010). Between 1973 and 2006, 188 seafood-borne outbreaks leading to 4020 illnesses, 161 hospitalizations and 11 deaths were recorded by the Food-borne disease outbreak surveillance system in the USA (Iwamoto et al. 2010). A large proportion of outbreaks were caused by bacterial pathogens (76%), followed by viruses (21%) and parasites (2.6%). The majority of the seafood-borne outbreaks involved molluscan shellfish (45%), followed by fish (39%) and crustaceans (16%) (Iwamoto et al. 2010). Among bacterial agents, Gram-negative bacteria such as *Escherichia coli*, *Salmonella enterica*, and *Campylobacter jejuni* are prominent (Amagliani et al. 2012). Birds and animals are the reservoirs of these pathogens, and their presence in seafood is solely due to faecal contamination of the aquatic environment. Others, such as vibrios are naturally present in the coastal-marine environments and are found in fish and shellfish harvested from such environments. *V. cholerae*, *V. parahemolyticus* and *V. vulnificus* are the prominent human pathogenic vibrios found in fish and shellfish. Though these bacteria are natural contaminants of seafood, their numbers in seafood depend on the way in which seafood is handled at various stages of processing till the final product is prepared.

The occurrence of human pathogens in wild-caught seafood has been widely reported from India and abroad. In the last two decades, however, aquaculture of fish and shellfish has increased dramatically all over the world. With farmed fish and shrimp gradually becoming a major part of food fish, the quality and safety of these have become an important issue. Nearly half the seafood consumed in the US is imported from other countries, mainly from Asia. India exports its marine products worth USD 3.5 billion to nearly 100 countries, with Southeast Asia, the European Union, the United States and Japan being the major importers. India is also the second largest producer of aquaculture shrimp, and frozen shrimp is the largest exported item in terms of value. In 2013, India produced 2.9 million tons of shrimp by aquaculture. The modern intensive method of aquaculture with varieties of inputs such as seed, feed, vaccines and antimicrobials offers a formidable challenge of food quality and safety management. The globalization of trade has resulted in the worldwide movement of seafood. The food produced in one corner of the globe may be consumed in the other and this has made the problem of quality and safety assurance very intricate.

The problem of seafood contamination with pathogenic microorganisms is becoming increasingly important in developing and highly populous countries such as India, where anthropogenic contamination of aquatic bodies is quite common. The routes of contamination of seafood are several and often very difficult to identify. Contamination of coastal water bodies such as estuaries, creeks and backwaters takes place from direct discharge of domestic sewage and as a consequence, fish and shellfish harvested from such water bodies may harbor enteric pathogens. Fish and shellfish harvested from deep seawaters are free from enteric pathogens though they may harbor the naturally occurring vibrios. However after landing of fresh seafood, introduction of pathogens can occur through several portals of contamination. Washing of fresh fish with coastal water is highly undesirable and is the major source of contamination. The poor quality of ice used in landing centers as well as by retail fish sellers results in contamination of fish and shellfish after harvest. Often, the quality of water used for making ice is not tested and the ice prepared from non-potable water can severely compromise the quality of iced fish and shrimp. Unhygienic handling of fish in the landing centers, retail markets and during transportation are other important routes of contamination. This problem is more pronounced in seafood meant for domestic consumption and sold in open retail markets in developing countries. In India for example, fish are sold in the open, often without ice and handled extensively by both fish sellers and the customers, compromising the quality of fish. Flies, dust and dirt from fish storage containers and the environment are other important sources of contamination. In comparison to wild caught seafood, farmed fish and shellfish are raised in a closed system and are handled differently. Nevertheless, the routes of contamination by the pathogenic microorganisms are virtually the same or even more in aquaculture systems owing to several inputs such as the organic fertilizers, feeds, seeds etc. The use of antimicrobials, disinfectants and probiotics greatly influence the microbial composition of water and the sediment and the types of human pathogens present in farmed shrimps. The presence of human pathogenic bacteria compromises the safety and acceptability of seafood and can lead to detentions and rejections leading to economic losses to the producer. Therefore, good manufacturing practices and identification and management of possible sources of contamination of shrimps from farm to the consumer are necessary to produce shrimps free from human pathogens. Some of the bacterial pathogens that can compromise the safety of farmed fish and shrimps and their importance to human health are discussed here.

The *Vibrio* group is one of the most important food pathogens of human health significance in seafood. Vibrios are naturally present in coastal-marine waters and as result, are found in variable numbers in all seafoods. Their numbers can vary depending on several factors such as the season, physical parameters of water such as temperature, salinity, and nutrient concentrations. A large number of *Vibrio* species are widely distributed in coastal-marine waters, of which *V. cholerae*, *V. parahemolyticus* and *V. vulnificus* are important human pathogens that can cause a variety of infections such as gastroenteritis, wound infections, septicemia etc. *V. cholerae*, the causative agent of cholera, is also found in association with chitinous organisms such as copepods, crustaceans as well as with microalgae, zooplankton and fish (Colwell 1996).

***Vibrio cholerae***

*V. cholerae* are of two types, O1 and non-O1 based on their agglutination with O1 antiserum. O1 *V. cholerae* and one non-O1 *V. cholerae* (O139 Bengal) are responsible for



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cholera and all other non-O1 and non-O139 *V. cholerae* do not infect humans or only cause mild illnesses (Datta et al. 2013). The virulence *of V. cholerae* O1 and O139 Bengal are primarily due to their ability to produce cholera toxin CTX. The El Tor variant *V. cholerae* O1 strain has three *ctxB* genotypes: *ctxB*1, *ctxB*2, and *ctxB*3, whereas *V. cholerae* O139 has three *ctxB* genotypes, including *ctxB*4, *ctxB*5, and *ctxB*6 (Takahashi et al. 2021). Whole-genome analysis of a seafood isolate from Andhra Pradesh revealed it belongs to a unique clone of the seventh pandemic *V. cholerae* O1 El Tor carrying the Haitian cholera toxin (*ctxB7*) gene. It shows sequence variations in type 6 secretion system (T6SS) genes (*vasX and vgrG*) and regulatory genes (*ompU and toxR*). The isolate contains pandemic (*VC2346)*, virulence *(hlyA, rtxA, mshA, makA, toxR, ace, ctxA, ompU, zot, and als*), pathogenic, and pandemic island genes. It also harbors antibiotic resistance genes for co-trimoxazole, streptomycin, chloramphenicol, and fluoroquinolone (Ayyappan et al. 2025). Infection by *V. cholerae* occurs when contaminated water or improperly cooked seafood is consumed. A surveillance study by the National Institute of Cholera and Endemic Diseases (NICED), India, from 1996 to 2016, revealed that cholera transmission and spread were higher in socioeconomically deprived populations, regardless of whether they were in urban or rural areas. Additionally, many Indian states have remained endemic to cholera (Saha and Ganguly, 2021). Studies from India have shown the occurrence of *V. cholerae* in aquacultured fish and shellfish. Importing countries such as USA and Canada prescribe zero tolerance for *V. cholerae* in ready to eat foods. There have been instances of seafood rejection due to the presence of *V. cholerae* in the past and recently, shrimp from China was rejected by Australia following the detection of *V. cholerae*. However, aquacultured shrimp has not been implicated in any case of human cholera. Though several studies have reported the occurrence of non-O1 *V. cholerae* in aquaculture pond water, sediments and shrimp (Gopal et al. 2005), the presence of O1 *V. cholerae* has rarely been found. Therefore, the perceived health risk from *V. cholerae* in aquacultured shrimp is very low (Karunasagar 2008). Nevertheless, routine surveillance of farmed fish and shrimp, environments and finished products is necessary to ensure that these are free from choleragenic *V. cholerae*.

***Vibrio parahemolyticus***

The halophilic pathogenic bacterium *V. parahemolyticus* is widely distributed in coastal waters worldwide and is commonly found in seafood, sometimes in numbers as high as $10^3$-$10^4$/g in oysters and <$10^2$/g in tropical shrimp (Kaneko and Colwell,1973; Gopal et al. 2005; Deepanjali et al. 2006). Physical properties of water such as temperature and salinity influence the abundance of these in temperate waters (Kaneko and Colwell, 1975; DePaola et al. 2003). Food-borne infections occur when *V. parahemolyticus* are present in numbers exceeding $10^5$

cfu. The highest detection of *V. parahemolyticus* in fish during warm months indicates a possible connection between increased temperatures and bacterial prevalence (Al-Garadi et al. 2025). Farmed oysters, mussels and scallops have been responsible for *V. parahemolyticus* infections world-wide. Furthermore, in less developed countries, *V. parahaemolyticus* has been linked to as much as 20% of acute diarrheal cases (Zaher et al. 2021). Severe watery diarrhea, abdominal cramps, nausea, vomiting and fever are some of the symptoms of *V. parahemolyticus* infection. Gastroenteritis occurs when shellfish such as oysters and clams are consumed raw or minimally cooked. However, not all *V. parahemolyticus* are pathogenic, but those producing either a thermostable direct hemolysin (TDH) and/or a TDH-related hemolysin (TRH) are pathogenic (Honda et al. 1988; Okuda et al. 1997). TDH and TRH are encoded by *tdh* and *trh* genes that have about 70% nucleotide sequence similarity (Nishibuchi et al. 1989). Studies have shown that <1% of the seafood isolates of *V. parahemolyticus* are $tdh^+$, while the occurrence of $trh^+$ *V. parahemolyticus* is much higher, with some studies reporting as high as 60% (Deepanjali et al. 2005). Since 1996, a pandemic clone of O3:K6 which was first detected in Calcutta, India (Okuda et al. 1997) has been responsible for many outbreaks in Asia and the USA (WHO 1999; Chowdhury et al. 2004). These strains harbor *tdh* gene but not the *trh* gene. *V. parahemolyticus* can be found in farmed shrimp, and recently, the occurrence of early mortality syndrome (EMS) has been attributed to *V. parahemolyticus* in *Litopenaeus vannamei* farms (Tran et al. 2013). In *L. vannamei* farms using ground saline water for aquaculture in India, infection of juvenile shrimps by *V. parahemolyticus* has been reported (Kumar et al. 2014). However, the levels of human pathogenic strains of *V. parahemolyticus* in farmed shrimps in India are very low and so far, no significant outbreaks of gastroenteritis have been attributed to farmed shrimp. Studies from Southeast Asia have shown however, that cultured shrimps, aquaculture pond water and sediments harbor *V. parahemolyticus* and some studies have reported a high prevalence (7-15%) of $tdh^+$ *V. parahemolyticus* in shrimp culture environs (Mohammad et al. 2005) ; Sujeewa et al. 2009). Obviously, the presence of high levels of *V. parahemolyticus* constitutes a health risk and increases of chances of cross-contamination of foods with the pathogen. *V. parahaemolyticus* isolates from retail seafood products from Qidong market exhibited high resistance to ampicillin, showed intermediate resistance to cefuroxime and cefazolin, and remained sensitive to the other antibiotics tested (Huang et al. 2024). A combination of a phage cocktail and 500 µg/mL citric acid effectively act as a bacteriostatic agent to control *V. parahaemolyticus* in seafood (Zheng et al. 2024).

Since *V. parahemolyticus* cannot grow at low temperatures, proper icing or chilling after harvesting farmed shrimp will prevent the multiplication of this pathogen in fresh shrimp. Importantly, the contamination of ready-to-eat products should be strictly prevented to avoid such foods being vehicles of *V. parahemolyticus*. Furthermore, *V. parahaemolyticus* exhibits the ability to form biofilms, underscoring the importance of cleaning and disinfection in seafood handling environments (Wang et al. 2022). Perillaldehyde (PAH) could be used alone or alongside other preservation methods to manage *V. parahaemolyticus* infection and its biofilm in seafood (Zhu et al.2024). The limit for *V. parahemolyticus* in seafood is$10^2$/g and levels of >$10^4$/g are regarded as unacceptable.

***Vibrio vulnificus***

*V. vulnificus* is another important human pathogenic vibrio associated with fish and shellfish. *V. vulnificus* is known to cause serious infections in people with compromised immunity, liver diseases and iron-overloaded conditions, with a fatality rate as high as 50%. *V. vulnificus* infections are associated with eating raw molluscan shellfish which accumulate this pathogen from surrounding waters. *V. vulnificus* has been reported to be responsible for more than 95% of deaths associated with consumption of seafood. Two thousand nine hundred and eighty-nine *V. vulnificus* cases were reported from 2000 to 2022 in the United States, including 656 (22%) foodborne and 1,619 (54%) non-foodborne cases (Hast et al. 2025). A meta-analysis of the selected studies found that the overall prevalence of seafood-borne *V. vulnificus* in Asia is 10.47%, with bivalve shellfish like oysters, mussels, clams, and cockles being the most contaminated. Japan had the highest prevalence, with 47.6% of seafood samples testing positive for *V. vulnificus* (Tanveer et al. 2024). *V. vulnificus* can cause fatal wound infections since the bacterium can enter into the circulatory system and cause septicemia. Necrotizing fasciitis and inflammatory infection (sepsis) are caused by *V. vulnificus* infections, which have a high mortality rate (64.9%) and are linked to liver dysfunction in 91.6% of cases (Fatima et al. 2025). Low salinities (5 to 25 ppt) and warm temperatures (20 to 35°C) have been favorable for this organism (Parvathi et al. 2004). Most seafood-derived isolates and all 15 clinical isolates carried the virulence-associated gene *vcgC* and 16S rRNA type B. These isolates displayed a variety of virulence factors (VFs), such as flagella, outer membrane proteins, RTX toxins, and several secretion systems (Long et al. 2025). Foodborne isolates of *V. vulnificus* contain virulence-associated genes that are almost identical to those found in clinical strains (Xu et al. 2025). Filter-feeding oysters and mussels which concentrate *V. vulnificus* to several-fold higher concentrations than the surrounding water have been commonly responsible for infections in the past. However, the occurrence of this organism in frozen processed shrimp suggests a potential health hazard if such products are consumed raw. Though there are no reports of *V. vulnificus* infection due to the consumption of farmed raw shrimp, there is one report of *V. vulnificus* infection following the consumption of raw mantis shrimp (Centre for Health Protection 2012).

***Listeria monocytogenes***

*L. monocytogenes* is widely distributed in nature and is an important pathogen of humans, especially those with underlying immunological debilitations or whose immune response is compromised (Gahan and Hill 2014). Listeriosis is a rare foodborne illness caused by *L. monocytogenes*, with an incidence of 0.1 to 10 cases per million people annually, as reported by the World Health Organization (WHO). It can grow in temperatures from 1°C to 50°C, tolerate freezing conditions, and become inactivated at 60°C for 30 minutes (Batt and Tortorello, 2014). Of 13 serovars of *L. monocytogenes*, 1/2a and 4b are commonly involved in food-borne listeriosis. The infection occurs when foods containing high levels of *L. monocytogenes* are consumed. Most outbreaks have occurred with ready-to-eat, minimally processed foods. *L. monocytogenes* is not indigenous to marine environment and hence may not be found in farmed shrimp. However, post harvest contamination can result in the introduction of this pathogen into shrimps or contamination of ready-to-eat products can occur after preparation of the product and when such products are held at temperatures suitable for the growth of *L. monocytogenes*, the numbers increase rapidly to infectious levels. There are only a few reports of seafood-borne *L. monocytogenes* infections and often cold smoked fish are involved in the outbreaks (Frederiksen 1991; Miettinen 1999). *L. monocytogenes* contamination was a leading cause of microbiological food recalls in Australia, Europe, the US, and Canada between 2012 and 2022 (Australian food recall statistics, 2025). *L. monocytogenes* can grow in refrigeration temperatures of up to 3.3 °C and hence for storage of RTE products, temperatures of < 3 °C are recommended. USFDA has imposed zero tolerance limit for *L. monocytogenes* in ready-to-eat seafood products such as smoked fish or crab meat. *L. monocytogenes* isolates from raw fish showed complete resistance to meropenem, cefoxitin, cefotaxime, rifampicin, and trimethoprim-sulfamethoxazole, along with significant resistance to ciprofloxacin (91.7%), clindamycin (83.3%), tetracycline (75.0%), erythromycin (75.0%), benzylpenicillin (70.8%), and nitrofurantoin (70.8%). Molecular analysis identified blaTEM (100%), ampC (37.5%), and ereB (37.5%) as the most common antimicrobial resistance genes in *L. monocytogenes (*Sołtysiuk et al. 2025). In food processing environments, controlling *L. monocytogenes* relies on strict sanitation practices, environmental monitoring programs, and the use of strong preventive controls. Facilities implement Good Manufacturing Practices (GMPs) and Hazard Analysis and Critical Control Point (HACCP) systems designed to reduce contamination risks, especially in high-risk areas like slicing, packaging, and post-lethality zones (Luber, 2011).

***Salmonella enterica***

*Salmonella* contamination of the marine environment has been recognized as a serious threat to human health worldwide (Gomez et al. 1997). *Salmonella* is considered the major disease-causing microorganism in humans and animals, and is one of the four major causes of diarrhoeal diseases worldwide, representing a significant threat to human health (Wei et al. 2022). Seafood harvested from contaminated water acts as an important vehicle of transmission of salmonellosis and the human infection is generally associated with the consumption of raw or undercooked bivalve mollusks (Heinitz et al., 2000). Though *Salmonella* is not indigenous to the marine environment, the organism has been isolated from the marine environment throughout the world, which is primarily attributed to the discharge of domestic sewage into the marine-estuarine environment and due to land runoff (Heinitz, et al., 2000; Martínez-Urtaza, 2003). Filter-feeding animals such as oysters and clams concentrate pathogenic bacteria present in the surrounding water in their tissues and thus act as reservoirs of *Salmonella.* Hence, most of the seafood-associated salmonellosis worldwide have been associated with the consumption of shellfish (Rippey, 1994). In India, past studies have reported the widespread presence of *Salmonella* in wild-caught and farmed fish and shellfish (Hatha and Lakshmanaperumalsamy 1997; Kumar et al. 2003).

*Salmonella* involved in human infections *via* seafood generally belong to non-typhoid serotypes. The occurrence of *Salmonella* in fish and shellfish is primarily due to faecal contamination of culture environments, as well as post-harvest contamination through various routes, such as ice prepared from non-potable water, contaminated water used for washing fish and shellfish, and contact with fish handlers. Seafood plays a significant role in transmitting non-typhoidal *Salmonella enterica* (NTS), with human infections frequently linked to the consumption of raw or undercooked fish and shellfish (Elbashir et al. 2023). The prevalence of *Salmonella* in aquaculture environments has been reported (Reilly et al. 1992; Reilly and Käferstein 1997). The accumulation of organic matter in the sediment provides a conducive environment for pathogen survival and accumulation in aquaculture ponds (Reilly and Käferstein 1997; Phan et al. 2005; Shabarinath et al.2007). Studies reported by the USFDA showed that farmed seafood was more likely to contain *Salmonella* than wild-caught seafood (Koonse et al. 2005). The prevalence of *Salmonella* in seawater and seafood is influenced by climate conditions, the most critical of which are rainfall and stormwater (Bienfang *et al.*, 2011).

The presence of *Salmonella* is a major reason for detentions of imported shrimps by the US and EU (Wan Norhana et al 2010). Many countries including the USA, EU, New Zealand and Australia recommend the absence of *Salmonella* in 25 g of raw or RTE shrimps (Wan Norhana et al. 2010). Certain serovars such as *S.* Weltevreden, commonly reported from Asian shrimp culture systems, are also significant agents of non-typhoidal salmonellosis. Their presence in farmed shrimp is a definite human health risk, and there are possibilities of these gaining more virulence due to complex interactions in the aquatic environment, and the exposure to antibiotics used in aquaculture farms can lead to the development of resistance to these agents. *Salmonella* can enter the shrimp culture environments through water, feed, manure and even probiotics (Wan Norhana et al. 2010). The use of organic manure increases the risk of introducing *Salmonella* into the culture environment.

The use of antimicrobial agents in aquaculture to treat microbial infections or as prophylaxis has raised concerns on the emergence of antibiotic-resistant bacteria. Unlike in terrestrial animals in which antibiotics are administered orally or injected, antibiotics are fed *via* feed to fish or shrimp Shrimps eat less than 25% of the feed put in the pond and the remaining 75% of the feed pollutes the water and the sediment and if they contain antibiotic substantial quantities of antimicrobials leach into water and the sediment, exposing the resident bacterial flora to sub-lethal concentrations of antimicrobials resulting in the development of antimicrobial resistance (FAO 1999; Heuer et al. 2009 ). It is well established that exposure of bacteria to concentrations of antibiotics below their minimal inhibitory concentrations lead to gradual development of antibiotic resistance. Antibiotic susceptibility testing showed that the *Salmonella* seafood isolates from Indian waters were resistant to third-generation cephalosporins, quinolones, fluoroquinolones, and tetracycline antibiotics, but they were sensitive to ceftazidime, aztreonam, carbapenems, chloramphenicol, and aminoglycosides (Prabhakar et al. 2025). In addition, bacteria may also acquire resistance mechanisms via acquisition of mobile genetic elements such as plasmid, transposons, bacteriophages etc (Dever and Dermody 1991; Kumar and Varela 2012). Human pathogenic bacteria in aquaculture environment can become antibiotic resistant by acquisition of genes via horizontal transfer mechanism (Kruse and Sorum1994; Aoki 1997). The presence of antibiotic residues in shrimps has been responsible for several rejections between 2003 and 2006. Though the use of antibiotics is banned, they continue being used in shrimp farms. Many of these antibiotics are critically required for treating human infections and any development of resistance to them can make several bacterial infections untreatable. Therefore, the unwanted use of antimicrobials in aquaculture need to be discouraged and controlled with suitable laws to prevent the emergence and spread of resistant bacterial communities.

***Arcobacter spp.***

*Arcobacter* spp. are considered important foodborne pathogens associated with both human and animal diseases (Wang et al. 2021). *Arcobacter* spp. has been identified in various food items derived from animals, including chicken, seafood, milk, pork, and beef. Considering seafood, the overall prevalence of *Arcobacter* spp. was 28.8% in mussels, 35.3% in oyster and

40.0% in clams (Mudadu et al. 2021). Arcobacters are commonly found in the intestinal tract and feces of both healthy and diseased animals. (Ho et al., 2006). The overall prevalence of *Arcobacter* spp. was found to be 34.96%, with the highest rates observed in water at 50%, followed by mollusks at 46.15%, finfish at 33.8%, and cephalopods at 27.59%. Polymerase chain reaction using specific primers for the *Arcobacter* genus and species was used to confirm the isolates. Out of 112 Arcobacter isolates, 62 were identified as *A. butzleri*, 17 as *A. skirrowii*, 14 as *A. cryaerophilus*, and 19 as other species of *Arcobacter* (Salam et al. 2025). *A. butzleri* has been recognized as an emerging foodborne pathogen that can be present at any stage of the food chain, from farm to table. The most probable route of transmission to humans is through ingestion of contaminated food or water. (Collado et al. 2011). *Arcobacter* spp. are associated with gastroenteritis, abdominal cramps, and occasionally systemic infections in humans. Various species belonging to the *Arcobacter* genus have been linked to enteric diseases and other extraintestinal conditions, such as bacteremia and peritonitis (Ferreira et al. 2016). *A. butzleri* is considered the fourth most common campylobacter-like organism found in diarrheal human feces (Collado et al. 2013).

***Campylobacter spp.***

*Campylobacter spp.* are recognized as major foodborne pathogens that present a health risk to consumers worldwide. The pathogen causes human campylobacteriosis and other severe health issues that lead to high case-fatality rates and disability-adjusted life years (DALYs) (Mwangi et al. 2025). The species most associated with human disease are *C. jejuni* and *C. coli*, both recognized for causing gastrointestinal infections, particularly gastroenteritis (Sheppard et al. 2015). Symptoms typically emerge 2 to 5 days after bacterial ingestion and can persist for up to a week, predominantly presenting as gastroenteritis. However, the infection may worsen and cause more serious complications, such as Guillain–Barré syndrome, an autoimmune condition leading to paralysis, as well as reactive arthritis, bacteremia, and, in rare cases, endocarditis (Imbrea et al. 2024). The Campylobacter CadF (Campylobacter adhesin to fibronectin), FlpA (fibronectin-like protein A), and JlpA (Jejuni lipoprotein A) are fibronectin-binding proteins that play a central role in biofilm formation, serving as essential factors for initial cell adhesion and invasion (Sabotič et al. 2023). These adhesins are crucial virulence factors for the pathogenesis of *Campylobacter*, aiding in adherence, colonization, and invasion of host cells. Hazardous *Campylobacter* in economically important shellfish can be quickly, precisely, and sensitively detected using a colorimetric method. This approach allows for high-throughput, on-site testing facilitated by the smartphone–biosensor platform (Wang et al. 2025).

**Conclusion**

The global rise in seafood consumption has heightened concerns about foodborne illnesses caused by bacterial pathogens such as *Vibrio cholerae, Vibrio parahaemolyticus, Vibrio vulnificus, Listeria monocytogenes, Salmonella enterica, Arcobacter* spp., and *Campylobacter* spp.. These pathogens pose significant risks to human health, especially in regions with inadequate food safety practices and compromised consumer immunity. Effective management of seafood safety requires strict hygiene, routine surveillance, and responsible use of antimicrobials throughout the supply chain, from aquaculture and harvesting to processing and retail. Adhering to good manufacturing practices and implementing robust monitoring systems are essential to minimise contamination, prevent outbreaks, and ensure the safety of seafood products for consumers worldwide.

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