5. Examples of risk assessments

5.1 INTRODUCTION

There are three types of risk assessment outputs:

- Qualitative risk assessments
- Semi-quantitative risk assessments
- Quantitative risk assessments

In this section, we give an example of each type of assessment. In each you are nominated as leader of the risk assessment team and, from time to time, background information is provided in boxes. For example, we point you towards review articles, which can quickly give you information on a hazard that causes illness from seafoods. These reviews are included in the Resources Bank.

In normal text we include typical material, which is included in a risk assessment. While each assessment uses fictitious information for the exposure assessment module, this gives you some idea of how to generate exposure information.

For characterizing risk, a semi-quantitative tool called Risk Ranger is used. It is a versatile tool and you can find how to use it in Section 4. In the text, all inputs to Risk Ranger are contained in boxes.

Risk assessment examples

The following four examples have been chosen and developed to show you how risk assessment work can help you solve food safety problems with specific fisheries.

i. Qualitative risk assessment: mercury in fish

Mercury contamination of seafoods occurred in Japan in the 1950s when several hundred people suffered terrible symptoms, which included brain damage. Since this time, mercury intake has been monitored in many countries and the problem managed by limiting consumption of large predaceous fish, such as sharks. More recently, research has suggested that, in its early stages, the human foetus may be susceptible to the effects of mercury, with symptoms such as impaired learning ability emerging in childhood.

Because there are, at present, no data on levels of mercury in the diet that may cause childhood difficulties, the hazard: product pairing is best evaluated in a qualitative risk assessment.

ii. Semi-quantitative risk assessment: ciguatera in reef fish

With the spread of air travel, remote communities are now able to use tourist flights to freight seafoods to destinations where reef fish are considered delicacies. Some species are extremely valuable. In Hong Kong Special Administrative Region, China, for example, a 1 kg (plate-size) live coral trout is worth more than $30 to the exporter. Unfortunately, some species from tropical and subtropical waters can accumulate ciguatoxin in their muscle and ciguatera fish poisoning (CFP) is the most prevalent illness caused from consumption of finfish.

In this example, your country, a series of atolls in the south Pacific, has the opportunity to export reef fish to nearby countries. Unfortunately, a number of locations are endemic for ciguatera, and CFP occurs among tourists and your own people. You are required to do a risk assessment in a very short time frame and the

example points the way to doing this, with a semi-quantitative risk assessment using Risk Ranger to generate a risk ranking plus predicted annual illnesses.

iii. Semi-quantitative risk assessment: histamine fish poisoning

Histamine fish poisoning (HFP) is another cause of illness from particular species of finfish. Your country has an export industry based on fish caught by small boats that troll for tuna on overnight trips. Traditionally these boats have not carried ice but, after product from your country has been implicated in an outbreak of HFP in the importing country, you are required to do a risk assessment. Your country lacks the laboratory facilities or resources to provide backup, so you rely on the predictive microbiology approach and gather information on temperatures and times of product throughout the catching-processing-transport and marketing stages.

The assessment leads to a risk management and risk communication exercise by stakeholders in your country after which there is follow-up assessment work that you must do.

iv. Quantitative risk assessment: Vibrio parahaemolyticus ***on oysters***

In 1997 and 1998 there were large outbreaks of food poisoning from consumption of oysters in North America in which *Vibrio parahaemolyticus* was the cause. Your country is an exporter of oysters to the United States and, after that country does a risk assessment of *V. parahaemolyticus* in oysters, there is pressure on your country to provide risk estimates for product that you are exporting to the United States. You decide to use the United States risk assessment model and to insert data from your own country. In this example, we follow how your team does the risk assessment and then communicates the estimates to authorities in the importing country.

5.2 HOW TO PERFORM A QUALITATIVE RISK ASSESSMENT: MERCURY IN SEAFOOD

The situation

There are reports that methyl mercury (MeHg) can damage the foetus during its early stages of development.

The Health Department in your country has become concerned about the possible effects of MeHg on the foetus during the early stages of its development.

Seafood consumption patterns in your country indicate that several high-mercury species are consumed, including sharks and billfishes.

Because of time constraints the risk managers in the Health Department require you to complete a qualitative risk assessment within one month of mercury intake from seafood in your country.

Available to you are seafood catch statistics, which tell you the quantity of high-mercury fish that are landed in your country, and there are also two research reports on mercury levels.

Based on the outcomes of the assessment, the managers will set tolerable intakes for pregnant women.

5.2.1 Purpose of the assessment

The purpose of the assessment is to estimate the risk of mercury poisoning to the foetus. The risk estimate will be qualitative.

5.2.2 Hazard identification

The only documented account of mercury poisoning involving seafoods occurred in people living around Minamata Bay in Japan during the 1950s. In all, there were more

than 700 cases of poisoning and 46 deaths with victims suffering severe mental and neurological conditions.

Low levels of mercury are naturally present in the environment and in all foods. Inorganic mercury is poorly absorbed via the diet, but in aquatic environments bacteria can convert inorganic mercury to MeHg, which is readily absorbed by the human body. MeHg is accumulated in the aquatic food chains, so all fish contain it in their muscle tissue. Predatory fish or mammals (particularly whales) at the top of the food web have the largest amounts.

Mercury levels in most commercially harvested oceanic fish are <0.5 mg/kg MeHg, but some large predators, such as sharks, marlin and swordfish, may have higher levels. Numerous studies have shown that nearly all the human exposure to MeHg occurs via seafood (predominantly finfish) consumption. Therefore individuals who regularly consume large amounts of fish (particularly those fish with high mercury levels) could be exposed to high levels of mercury (FDA, 1994; National Academy of Sciences, 2000).

Farmed finfish are likely to have lower levels of MeHg because they are generally fed formulated diets that should have low mercury content. As well, mercury accumulates in fish during their lifetime, and tissue concentrations are greater in older and larger fish. Since farmed fish are usually harvested young, they would be expected to have low tissue concentrations (FAO/NACA/WHO, 1999).

Nearly all the human exposure to MeHg occurs via fish consumption. There are two exceptions: accidental releases (industrial processes) and mercury used in tooth filling amalgams (Richardson, 1995).

5.2.3 Hazard characterization

Your task

You need to read some reviews on the effect of MeHg on adults and foetuses. Some are listed as references in the Resources Bank.

You will find that there are widely different views on how much mercury is safe to eat in our intake of seafood. Since these views are held by respected bodies such as FAO/WHO, the National Academy of Sciences (NAS, USA), the Environmental Protection Agency (EPA, USA), the best way to resolve any discrepancies is work with their recommendations

Illness caused from high-level exposure

In 2000, the NAS in the United States reviewed mercury in foods. MeHg obtained from the diet typically resides in the human gut for several weeks from where it enters the brain of adults and foetuses, where it accumulates and is converted to inorganic mercury. MeHg is highly toxic and causes severe effects. These effects were seen following MeHg incidents in Iraq (contaminated grain) and Japan (contaminated seafood). In individuals who were exposed at the foetal stages, symptoms included mental retardation, cerebral palsy, deafness and blindness. People who were exposed to high mercury levels when they were adults underwent sensory and motor impairment.

Illness caused from low-level exposure

Recently, it has been suggested that low-dose exposure of the foetus to MeHg may lead to impaired performance, which appears when the individual reaches early childhood. According to Kjellstrom *et al.* (1989a, 1989b), Davidson *et al*. (1998), Johnson (1998), Levin (1998), Mahaffey (1998) and Myers (1998), young children exposed as foetuses perform badly in tests that measure attention, language, memory and fine-motor

function (called neurobiological tests). There is also evidence that exposure to MeHg can affect the cardiovascular system (blood pressure regulation, variable heart rate and heart disease). Exposure during the first trimester (three months) of pregnancy appears to be the critical period.

Studies on mercury intake in children

Two studies of children exposed to mercury via fish consumption have been undertaken: the Seychelles Islands in the Indian Ocean and the Faeroe Islands in the North Atlantic Ocean. Both countries have diets that are highly dependent on marine life.

The initial findings from the Seychelles study indicate that no significant mercury effect was found in children who had been exposed to a wide range of mercury levels during the foetal stages. The Seychellois usually eat fish twice a day with an average mercury content of 0.3 mg/kg. It should be noted, however, that the developmental tests used in the Seychelles study were less sensitive in detecting subtle cognitive and motor disturbances than tests used in the Faeroe study.

By contrast, the Faeroe study reported that children who were exposed prenatally to the highest mercury levels had slight abnormalities in development when tested at age seven. However, the biological significance of these findings remains unclear, as whale meat consumed by the Faeroe islanders contains other contaminants such as PCBs and has a higher mercury level than fish. Also, the Faeroe community often eats an entire whale in a short period of time, causing a spike in mercury levels that may affect the body differently than the lower consistent levels experienced in the Seychelles.

These initial results have been interpreted as indicating that the health effects of mercury on childhood development may be less severe than previously believed. A panel set up by the NAS found that children in the Seychelles study had no significant mercury effect. However, the NAS panel took a conservative course and recommended the retention of the EPA's reference dose (RfD) of 0.1 µg/kg body weight/day (see below).

Allowable intake – how much mercury is safe to take in from seafood consumption?

There are two recommended allowable intakes, based on the findings, on the one hand, of the US EPA and, on the other hand, by the Joint Expert Committee on Food Additives (JECFA) of FAO/WHO.

1. United States EPA Reference Dose

This is an estimate of the daily exposure of the human population (including sensitive subpopulations) that is likely to cause no adverse effects when experienced over a lifetime. The level is 0.1 µg/kg body weight/day (0.7 µg/kg body weight/week).

2. Joint FAO/WHO Expert Committee on Food Additives

This committee established a provisional tolerable weekly intake (pTWI) for MeHg of 5 µg/kg body weight/week.

There is a sevenfold difference between these recommended intakes, which has an important effect on how much fish a person is able to eat. The JECFA recommendation allows much more fish to be eaten.

Tables 20 and 21 give the weekly consumption of fish required to reach the recommended limits established by JECFA and the United States EPA. A range of mercury levels in fish is presented, which takes in species that do not accumulate much mercury (0.15 mg/kg fish flesh) and those that do (1.0 and 1.5 mg/kg fish flesh). Because the permitted intake of mercury varies according to the body mass, weight ranges are given for a typical 2 year old (13 kg), 12 year old (40 kg), adult female (60 kg) and adult male (70 kg).

As can be seen from Table 20, for non-predatory fish (average mercury level 0.15 mg/kg) an adult is able to consume almost 2.5 kg of fish per week before reaching the pTWI. Even if high mercury fish is consumed (1 mg/kg), an adult could consume 316–368 g/week without exceeding the limit.

When the EPA recommended levels are considered, by contrast, only very small quantities of mercury-containing species are able to be consumed. Using the EPA level of 0.1 µg/kg body weight/day (Table 21) adults would be able to consume only 44–52 g/week of those species with a mercury content of 1 mg/kg.

In summary, the hazard characterization indicates:

- a large discrepancy of allowable intake between regulatory bodies;
- inconclusive evidence that ingestion of mercury at the foetal stage is a hazard in childhood.

These factors will be integrated into the risk characterization matrix.

TABLE 20
Weekly consumption of seafood required for an individual of a given weight to reach the pTWI of 5 µg/kg body weight/week

Mercury level in seafood (mg/kg)	Weekly consumption (g)			
	13 kg	40 kg	60 kg	70 kg
0.15	456	1 404	2 105	2 456
0.5	137	421	632	737
1.0	68	211	316	368
1.5	46	140	211	246

TABLE 21
Weekly consumption of seafood required for an individual of a given weight to reach the EPA RfD of 0.1 µg/kg body weight/day

Mercury level in seafood (mg/kg)	Weekly consumption (g)			
	13 kg	40 kg	60 kg	70 kg
0.15	64	197	295	344
0.5	19	59	88	103
1.0	10	30	44	52
1.5	6	20	30	34

5.2.4 Exposure assessment

Your task

In this section you must estimate the quantity of mercury ingested per week by the target consumers – pregnant women in the first three months of pregnancy.

You will probably be able to find the quantity of high-mercury species landed in your country from annual catch statistics.

The next task is to determine the mercury content of the target species. The Health Department may have done some studies. Otherwise look for data from another country (see the Resources Bank).

Then you will need to convert it to an edible portion – 50 percent fillet yield is a good estimate.

Finally, you must make a decision on how frequently high-mercury species are eaten by pregnant women.

The following section is an example of how you make these calculations based on hypothetical data

Production of predatory species and number of servings

Annual catch statistics for landings of potentially high-mercury species, such as shark, billfish, swordfish and marlin, are presented in Table 22. Shark is the main component of high-mercury fish landed with lesser quantities of billfish, swordfish and marlin totalling 16 000 tonnes per annum. Since the edible portion for these species is around 50 percent of the gross weight, 8 000 tonnes are actually consumed, equivalent to 80 million servings of 100 g each serving.

Estimation of consumption pattern

Your country has a population of 20 million and there are consumption data showing that only 33 percent ever eat shark and gamefish. This means the 80 million servings are

TABLE 22
Production of species associated with elevated mercury levels

	Production (t)	Edible portion (t)	Servings ($x10^6$)
Shark	12 000	6 000	60
Billfish	2 200	1 100	11
Swordfish	1 200	600	6
Marlin	600	300	3
Total	16 000	8 000	80

TABLE 23
Mercury levels in predatory fish

	Mean mercury (mg/kg)	
	Study 1	Study 2
Swordfish	1.9	2.4
Marlin	2.2	3.1
Shark	1.1	0.9
Billfish	1.5	0.9

eaten by 6.5 million of your countrymen and women, an average of one serving per month. The birth rate in your country is around 250 000 a year and, if it is assumed that the same proportion of pregnant women eat the high-mercury species as in the general population, then 33 percent of 250 000 (around 80 000) are at risk, or rather their foetuses are at risk. Since the critical period is the first three months, at any one time there are around 25 000 pregnant consumers eating fish that may have a high mercury content. These consumers eat one serving (100 g) once a month.

Studies on mercury levels in predaceous fish

The Health Department in your country has commissioned two studies of mercury levels in predaceous fish (summarized in Table 23 from which it can be seen that shark and billfish have mercury contents around 1 mg/kg with swordfish and marlin around 2–3 mg/kg).

In summary, based on the data contained in Tables 22 and 23, on an annual basis, pregnant women in their first trimester:

- number 25 000;
- consume around 300 000 servings of 100 g each per year;
- shark servings number 240 000 and contain 1 mg/kg of mercury, and gamefish servings number 60 000 and contain 2–3 mg/kg of mercury.

5.2.5 Risk characterization

The risk characterization requires inputs for exposure assessment, hazard characterization and links with epidemiology in your country.

Table 24 estimates the total intake of mercury by a 60 kg woman during the first three months (13 weeks) of her pregnancy.

TABLE 24
Total mercury intake during the first trimester (3 months) and comparison with intakes allowed by EPA and JECFA

	Shark	Gamefish
Number of servings in three months	2	1
Total quantity consumed (g)	200	100
Mercury content (mg/kg)	1	2-3
Mercury ingested (mg)	0.2	0.2–0.3
Total intake (shark + gamefish)	0.4–0.5 mg	-
Allowable intake for 60 kg woman over 13-week period	-	-
EPA RfD (0.7 µg/kg body weight/week)	0.5 mg	-
JECFA pTWI (5 µg/kg body weight/week)	3.9 mg	-

Based on monthly consumption of high-risk species, she will consume two servings (100 g) of shark and one of gamefish for a total mercury intake over the critical period of 0.4–0.5 mg mercury. This is the same as the limit allowed by EPA (0.5 mg) but well within that allowed by JECFA (3.9 mg) recommendations.

Table 25 is a template, which can be used for qualitative risk assessment, based on four factors: severity of the hazard, likelihood that the hazard will occur, exposure in the diet and linkage with illness.

Table 25 contains ratings that are somewhat subjective. For example:

- Severity of the hazard is rated low-medium for its effect on the foetus. Most countries follow the JECFA recommendations, rather than those of the EPA.

- Likelihood that predaceous fish are consumed reflects a medium rating since sharks are often a moderate component of the total finfish catch.
- Exposure in the diet is 0.4–0.5 mg over the critical period, which is within the EPA allowance and much lower than the JECFA allowance.
- Linkage with illness in young people has not yet been conclusively made.

TABLE 25
Qualitative risk ranking of mercury in predaceous fish

	US EPA	JECFA
Severity of hazard	Low-medium	Low-medium
Likelihood of occurrence	Medium	Medium
Exposure in diet	Low	Very low
Linkage with illness	None	None
Risk ranking	Low	Low

It is worth comparing the exposure in this assessment with exposure in the Minamata Bay incident, where finfish and shellfish harvested from the area contained mercury levels up to 29 mg/kg and were eaten at least daily by most people to give an estimated average MeHg intake of 0.3 mg/day (Coultate, 1992). For a woman weighing 60 kg this equates to 6 µg/kg body weight/day, or 42 µg/kg body weight/week, more than eight times the pTWI and 90 times the RfD.

5.2.6 Risk estimate

When all the inputs to Table 25 are considered, the risk ranking of consumption of predaceous fish by pregnant women is low.

5.2.7 Identification of critical data gaps

The assessment was constrained by time (only one month) and relied on "average" consumptions. Fish consumption patterns, as opposed to averages, are needed to assess the risk of mercury poisoning, particularly for pregnant women and their foetuses. Obtaining data on groups with above average fish consumption would enhance the assessment. If residents in coastal communities or people who work aboard vessels that fish for marlin and swordfish become pregnant they are, as a group, at a greater risk.

5.2.8 Risk management and communication

Public comment

The risk managers submit your assessment for public comment from stakeholders.
The most important replies are:

1. *The seafood association denies completely that mercury has any role in illness, other than the Minimata incident, where the exposure was extremely high (daily or twice-daily consumption of products extremely high in mercury). They also suggest that limiting consumption of seafoods will have negative health aspects given the unequivocal evidence linking polyunsaturated fatty acids with reduced heart disease.*
2. *The Consumers' Association considers the assessment underestimates the risk to the foetus and that the rating should be "high". Even though evidence is not yet conclusive, the association considers "the jury is still out" and that the assessment should be more conservative. They cite the NAS judgement in favour of the more EPA level as evidence that the assessment should be more conservative.*

Cont.

Risk management

The risk managers make the following observations and decisions:

- *Given the consumption patterns, the risk is borne by around 25 000 pregnant consumers at any one time.*
- *Warnings will be carried in every hospital and every doctor's surgery that consumption of shark and gamefish may lead to motor impairment in the child and that these species should not be consumed more than once a week during the first four months of pregnancy.*
- *These warnings are based on levels recommended by JECFA.*
- *Regulatory bodies in several countries, e.g. United States (FDA) and Australasia (Food Standards Australia New Zealand) have decided to follow JECFA recommendations.*
- *The known benefits of seafood consumption outweigh the possible negatives associated with (as yet unproven) motor impairment.*
- *There are already size limits for sharks, which partially reduce the hazard.*
- *The topic will be kept under constant review and any new evidence will be assessed.*

5.3 HOW TO PERFORM A SEMI-QUANTITATIVE RISK ASSESSMENT: CIGUATERA FISH POISONING

The situation

Your country is composed of a number of atolls in the South Pacific, which have valuable reef fish. A tourist industry has sprung up following the construction of an airstrip capable of taking medium-sized jets. There is also the possibility of exporting reef fish twice a week by air to New Zealand and Australia, where there are large populations of Pacific islanders.

However, there is a large outbreak of ciguatera fish poisoning involving both local people and tourists.

The chief minister is asked by New Zealand authorities to undertake a risk assessment of consumption of reef fish.

You are given the task of doing the risk assessment within a time frame of one month. This allows you time to gather data only from your health department on cases reported, plus data on consumption patterns in your country and in New Zealand.

Your risk assessment will be used by the risk managers, who may require you to do follow-up work on further questions that may emerge from the consultation process with stakeholders.

Your resources include:

- *Information on ciguatera from the Resource Bank (Hazard Identification, Hazard Characterization), which can be used as start-up material.*
- *Risk Ranger for making semi-quantitative risk estimates.*

5.3.1 Purpose of the assessment

The purpose of the assessment is to estimate the risk of CFP from fish caught from the reef systems around your atoll nation. The assessment must examine consumption of reef fish by two populations:

- the local population, including tourists;
- consumption in New Zealand, where a market exists, mainly for expatriates from the Pacific islands.

Because there has been a large outbreak of CFP, you have only one month in which to complete the assessment and report to the risk managers. This is a severe time constraint, which allows you only to do desk-top work; there will be no time to do any laboratory testing for ciguatera in reef fish.

5.3.2 Hazard identification

The illness

It is reported that up to 50 000 people may experience CFP each year, after eating fish caught in subtropical and tropical waters, often near reefs. The fish become toxic because they accumulate naturally occurring toxins produced by marine algae (predominantly *Gambierdiscus toxicus*), which are part of the food chain.

Outbreaks of CFP

Ciguatera is the most common illness caused by consumption of finfish. It is endemic in the Caribbean and in subtropical Indo-Pacific regions. In countries that import reef fish and/or have reef systems, such as the United States, Australia and Canada, CFP is a major cause of seafood-borne illness (Table 26). The largest and most damaging outbreak occurred in Madagascar in 1994 when 500 people were poisoned and 98 died following consumption of shark (*Carcharhinus* sp.).

While it is likely that a large proportion of cases go unreported, CFP rates in some regions are still high. In the Caribbean, Ruff and Lewis (1994) report rates of 30 cases/10 000 population/annum (Guadeloupe) and 73 cases/10 000 population/annum (US Virgin Islands). In the South Pacific, rates are around 100 cases/10 000 population/annum (Kiribati) and 300 cases/10 000 population/annum (Tuvalu).

Fish species that produce CFP

It is thought that, worldwide, less than 100 species produce CFP, the most predominant of which are presented in Table 27. Both common and Latin names are included.

It is important to use correct names because sometimes a marketing name can hide the fact that the species is potentially ciguatoxic. For example, in Australia in 2000 an outbreak of CFP occurred from "Queenfish" which, while not considered a potentially ciguatoxic species by some, was actually *Scomberoides commersonnianus*, a species regularly implicated in ciguatera poisonings.

In the Indian Ocean (Réunion Island), *Plectropomus* spp. (coral trout) was responsible for more than 50 percent of all outbreaks (Quod and Turqet, 1996).

In the United States, ciguatera is most often caused by groupers (*Epinephalus* spp.) in Florida and amberjacks (*Seriola* spp) in Hawaii (Sours and Smith, 1980).

TABLE 26
Outbreaks of CFP in the United States, Canada and Australia

Country	Period	Number of outbreaks	Percentage of all seafood outbreaks	Total ill	References
USA	1990–2000	75	32	328	Smith de Waal *et al.* (2000)
Australia	1990–2000	10	31	616	Sumner and Ross (2002)
Canada	1983–1997	15	Not known	53	Todd (1995)

TABLE 27
Fish species most commonly associated with ciguatera outbreaks

Latin name	Australian common name
Scomberomorus commerson	Spanish mackerel
Scomberomorus spp.	Mackerels
Sphyraena jello	Barracuda
Plectropomus spp.	Coral trout
Epinephelus fuscoguttatas	Flowery cod and other epinephalids
Lutjanus sebae	Red emperor
Lutjanus bohar	Red bass
Scomberoides commersonnianus	Giant dart
Lethrinus nebulosa	Yellow sweetlip
Seriola lalande	Yellowtail kingfish and other seriolids
Caranx sp.	Trevally
Cephalopholis miniatus	Coral cod
Chelinus trilobatus	Maori wrasse

In Australia, mackerels have been responsible for around 75 percent of all cases and outbreaks, with barracuda, coral trout, lutjanids and epinephalids (groupers) bringing the total to >90 percent.

In Fiji, species most commonly connected with ciguatera are similar to those in Australia: *Lutjanus bohar* (Red sea bass), *Sphyraena* (Barracuda), *Epinephelus* (Flowery cod), *Lethrinus miniatus* (Long-nosed snapper), *Plectorhynachus* (Grouper). Moray eel, the most toxic of fish is not usually eaten, except in some Pacific countries, where it is sometimes eaten as a delicacy.

5.3.3 Hazard characterization

Your task

You need to investigate the symptoms of CFP so that you can make the correct choice in Questions 1 and 2 of Risk Ranger – degree of severity of the illness and proportion of the population that is affected.

There is a review by Lehane and Lewis (2000), which provides information on all aspects of CFP. It is especially useful because it has been written in Risk Assessment format. It is contained in the Resources Bank.

The early stages of the illness (3–12 hours after ingestion) are gastrointestinal (nausea, vomiting, diarrhoea and stomach cramps). Between 12–18 hours after consumption, neurological symptoms begin, including numbness of the lips and extremities, muscular paralysis, convulsions, memory loss, headache. Some victims undergo psychological disturbances such as anxiety and depression for some months while others undergo cardiovascular symptoms.

Ciguatera poisoning is usually self-limiting and signs of poisoning often subside within several days from onset. However, in severe cases the neurological symptoms persist from weeks to months and, in rare cases, for several years. Sometimes, patients experience recurrence of neurological symptoms months to years after recovery. There is usually a low incidence of death resulting from respiratory and cardiovascular failure though in one outbreak in Madagascar, of the 500 affected, 98 died (Habermehl *et al*., 1994).

Clinical testing procedures are not available for the diagnosis of ciguatera in humans, which is based entirely on symptoms and recent dietary history. The disease has only recently become known to the general medical community and may be under-reported because of the generally non-fatal nature and short duration of the disease.

All humans are believed to be susceptible to ciguatera toxins. Populations in tropical/subtropical regions are most likely to be affected because of the relatively higher frequency of exposure to toxic fishes. Repeated ciguatoxin exposures are associated with more severe illness (Glaziou and Martin, 1993; Katz, Terrellperica and Sasaki, 1993).

Infectious Dose/Dose Response

Ciguatoxins are lipid-soluble toxins that remain toxic after cooking. Ciguatoxin (CTX-1) is usually the major toxin (on the basis of both quantity and total toxicity) present in fish and typically contributes ~90 percent of total lethality. On the basis of available outbreak data, Lehane (1999) estimated the minimum toxic dose to be ~50/ng in an adult of 50 kg weight (~1ng/kg body weight). However, in one well-documented incident, six United States soldiers became ill after eating fish containing approximately 20ng ciguatoxin/g flesh. They all presented with nausea, vomiting, watery diarrhoea and abdominal cramps 5–8 h after consumption and some also had numbness in the extremities or around the mouth, abnormally slow heartbeat (bradycardia) and paresthesia – tingling of the scalp (Poli *et al.*, 1997).

Some studies indicate that increased toxin dose leads to increased severity of cardiovascular effects in animals and humans (Katz, Terrellperica and Sasaki, 1993). However, Arcilaherrera *et al.* (1998) found no association between the amount of toxic fish ingested and the severity and duration of the symptoms. It is well recognized that, with repeated exposure, more severe and prolonged symptoms occur.

Inputs for Risk Ranger

Question 1: Select MILD HAZARD – sometimes requires medical attention
Question 2: Select GENERAL – all members of the population

5.3.4 Exposure assessment

Your task

In this section you must estimate mass of potentially ciguatoxic fish consumed in your Pacific island nation and in New Zealand, the importing country.

You will find the quantity of potentially ciguatoxic species landed in your country from annual catch statistics.

Then you will need to convert it to edible portion – 50 percent fillet yield is a good estimate for all species except mackerels, which give a filleting yield around 70 percent.

Finally, you must estimate number of servings and consumption patterns in your country and in New Zealand.

An example follows of how you make these calculations based on some hypothetical data.

Calculate volume of potentially toxic fish landed

Table 28 presents landings, yield of edible portion and number of servings of potentially ciguatoxic species in the Pacific island nation.

All species have an assumed 50 percent yield of edible portion with the exception of mackerels which have 70 percent yield. From Table 28 it can be seen that around 600 tonnes of potentially ciguatoxic species are available for consumption, giving around six million servings.

TABLE 28
Production (t) of potentially ciguatoxic species

Species	Landed volume (t)	Edible mass (t)	Servings (x10^6)
Trevally	100	50	0.5
Yellowtail kingfish	100	50	0.5
Mackerels	600	400	4
Groupers	100	50	0.5
Red emperor	100	50	0.5
Total	1 000	600	6

Consumption pattern and number of servings

Of the 600 tonnes available for consumption, 100 tonnes are consumed locally and 500 tonnes exported to New Zealand. Locally, one million servings are consumed by all of the population, which comprises 10 000 people. Thus, on average, every member of the population consumes the target species twice a week, on average. Fish is eaten almost every day, and tuna and dried flying fish (neither of which has a history of ciguatoxin production) are major components of the diet.

The 500 tonnes of exported species yields five million servings, which are consumed by about 25 percent of the total population of four million. Thus, on average, each of the one million consumers eats a serving of potentially ciguatoxic fish five times each year.

Inputs to Risk Ranger for probability of consuming the target species

	Local consumers	NZ consumers
Question 3: Frequency of consumption	Weekly	Few times a year
Question 4: Proportion consuming	All (100%)	Some (25%)
Question 5: Population	10 000	4 000 000

Contamination levels in servings

Unfortunately, all literature searches are negative with no data available for prevalence of ciguatoxin in reef fish from Pacific atolls or islands. Thus it is assumed that one in 1 000 fish will have a ciguatoxin level that can cause illness.

Inputs to Risk Ranger for contamination level through processing to consumption

Question 6: Probability of contamination	Rare (1 in 1 000 servings)
Question 7: Effect of processing	No effect on the hazard
Question 8: Recontamination	No recontamination
Question 9: Effect of post-process handling	No effect on the hazard
Question 10: Post-process increase to illness	None
Question 11: Effect of meal preparation	No effect on hazard

5.3.5 Risk characterization

In characterizing the risk of contracting CFP, two population categories are considered:

- local consumers, for whom reef fish are a major component in the diet;
- consumers in the importing country who rarely eat imported reef fish. In fact, the majority of consumers may be expatriate islanders.

Table 29 lists the inputs that are needed for a semi-quantitative risk characterization for the two at-risk groups. The inputs are identical except for the exposure of the two populations. The local population is exposed on a regular basis. Consumers in the importing country are exposed less frequently but there are more servings.

When information is inserted in Table 29 two estimates of risk are obtained:

- risk ranking;
- predicted illnesses in the target consuming populations.

TABLE 29
Semi-quantitative risk characterization of consumption of ciguatoxic fish species

Risk criteria	Local population	Consumers in importing country
Dose and severity		
Hazard severity	Mild – sometimes requires medical attention	Mild – sometimes requires medical attention
Susceptibility	General – all population	General – all population
Probability of exposure		
Frequency of consumption	Weekly	Few times a year
Proportion consuming	All	Some (25%)
Size of population	10 000	4 million
Probability of contamination		
Probability of raw product contaminated	0.01% ciguatoxic	0.01% ciguatoxic
Effect of processing	Does not eliminate the hazard	Does not eliminate the hazard
Possibility of recontamination	None	None
Post-process control	Not relevant	Not relevant
Increase to infective dose	None	None
Further cooking before eating	Not effective in reducing hazard	Not effective in reducing hazard
Total predicted illnesses per annum in selected population	520	3 000
Risk ranking (0-100)*	61	51

* Note that an increment of "six" is equivalent to a tenfold change in risk

In the above, risk characterization processing has no effect on ciguatoxin, so no matter if the fish is chilled, frozen or dried, the level of ciguatoxin will not change. Storage prior to consumption similarly does not affect the level of toxin and neither

does the type of cooking. The level of ciguatoxin at the point of capture is identical with that at consumption.

5.3.6 Risk estimate

Based on the above assumptions, the Risk Ranking for fish consumed locally is 61, reflecting the greatly increased exposure to the hazard, with 520 illnesses predicted per annum in the total population of 10 000 islanders.

In the importing country, the Risk Ranking is 51 with 3 000 annual illnesses predicted in the New Zealand population of 4 million.

5.3.7 Reality check

Since an assumption was made of a key component in exposure to the hazard – prevalence of fish that have a ciguatoxic dose – it is useful to do a reality check to see whether the estimates of illness are of the correct order of magnitude. By expressing cases of CFP/ 10 000 population we can compare the prevalence in the present assessment with those published for island communities. Lehane and Lewis (2000) quote 100 cases/10 000 population per annum in South Pacific island nations. The same authors also consider under-reporting to be common and the present assessment, 520 cases/10 000 population, is therefore of the same magnitude as that quoted by Lehane and Lewis.

5.3.8 Data gaps in the present assessment

A major lack of information surrounds prevalence of ciguatoxic fish landed. If possible, some work should be done using test kits. Serological test kits for the detection of ciguatoxin are now available commercially, one of which is Cigua-Check Fish Poison Test Kit Oceanit Test Systems, Inc., http://www.cigua.com. There are other kits available.

5.3.9 Risk management and communication issues

Public comment on the risk assessment

Your assessment is submitted by the risk managers to public comment and, one week later, a meeting is held at which a number of issues emerge:

- *The Health Department says your estimate of 520 cases per annum is about right, their records indicate they treat about ten people a week for ciguatera-like symptoms. They sometimes administer mannitol-based solutions intravenously to assist in treating symptoms. They believe as many as 10–20 percent of the population may suffer CFP symptoms to some degree each year.*
- *The Tourism Department provides news clippings from New Zealand and Australian newspapers reporting that more than 20 people from the same tour group had CFP symptoms. They also report a fall in bookings following the problem.*
- *The fishermen's association states that there is no evidence that CFP occurs and that the alleged symptoms have never been followed up to confirm the cause. They say their livelihood cannot be taken away without firm evidence.*

Risk management – round one

The risk managers who represent health, political, legal and commercial interests in your island nation submit two issues for your further assessment, to be completed in two weeks:

1. *Examine all data from the Health Department and try to confirm whether CFP does occur at the rate suggested by the risk estimates.*
2. *Assess the fishermen's association claim that CFP is not the cause of illnesses.*

Health Department data and the fishermen's association claims

Health Department records include name, age, address, date of illness, type of fish consumed and symptoms for each person. Staff is very knowledgeable on symptoms of CFP. Health Department data are summarized in Table 30.

TABLE 30
Health Departments records for CFP cases 2000–2001

Date	Probable cases of CFP*	Suspected cases of CFP**
Jan–Mar 2000	44	108
April–June 2000	112	323
July–Sept 2000	6	21
Oct–-Dec 2000	4	15
Jan–Mar 2001	34	79
April–June 2001	69	287
July–Sept 2001	18	43
Oct–Dec 2001	4	9
Total	291	885

*Probable cases have typical CFP symptoms which respond to mannitol treatment.
** Suspected cases of symptoms that do not require mannitol treatment

Health Department data reveal a number of key facts:

- In the last two years there have been almost 1 200 reported cases of illness, the symptoms of which are consistent with CFP.
- Most illnesses are family outbreaks involving most or all members.
- The younger members are often more badly affected and need treatment with mannitol.
- Almost invariably, the family has consumed reef fish just prior to the illness.
- Most cases are in the first half of each year, during and after the cyclone season, when the reef is always damaged. Reef damage is often a precursor to colonization by dinoflagellates and build-up of ciguatera fish poison in reef fish.

Risk communication

Taken together, these facts point firmly to CFP as the cause of the problems that your country is encountering.

When the data are presented to the fishermen's association they are received more sympathetically and the association asks what can be done about the problem.

There is now acceptance by all parties to work together to promote tourism and exports and to eradicate the almost endemic CFP among your local population.

Risk management

The risk managers take two courses of action:

- *Not taking reef fish after the cyclone season or when reef damage occurs. The Fisheries Department will police this;*
- *Importing finfish from New Zealand for the tourist industry.*

The two strategies will virtually eliminate risk because there will be no exposure to the hazard. However, intuition tells you that the reefs will still be fished and that CFP will still occur in the local population.

As well, you still have no data on the prevalence of ciguatoxin in reef fish.

You persuade the fishermen's association to lobby the government for funds to buy diagnostic kits for determining presence of ciguatoxin and its approximate concentration.

Over the next two years you will test reef fish as they are landed at the fishermen's cooperative and try to pinpoint ciguatera "hot spots". If this is related to reef damage and any other likely factors, you may be able to reassess the banning of reef fishing for such a significant part of the year.

5.4 HOW TO PERFORM A SEMI-QUANTITATIVE RISK ASSESSMENT: HISTAMINE FISH POISONING

The situation

Your country exports chilled tuna by air.

Almost all the catch goes to a single importing country.

Recently, your Minister of Fisheries learned that there have been cases of HFP in one importing country, and the product from your country is under suspicion.

As a result, the authorities in the importing country are insisting that you carry out a risk assessment of histamine production in tuna produced in your country.

Fish is caught on lines from small, twin-hull, open boats which carry no refrigeration. More than 200 small boats operate, fishing overnight trips.

Your country has five processing plants which operate HACCP plans and there are daily flights which transport chilled product to the importing country.

You have a three-month time frame in which to carry out the assessment and it may be necessary to conduct a second risk assessment to evaluate any industry changes following the first assessment.

5.4.1 Purpose of the assessment

The purpose of the assessment is to estimate the risk of HFP from fish caught and processed in your country.

Risk Ranking will form a semi-quantitative assessment.

You have three months in which to complete your assessment so there are time constraints that will prevent you doing laboratory work. You can, however, do temperature:time studies and use the predictive microbiology approach.

5.4.2 Hazard identification

Traditionally, HFP has been associated with consumption of scombroid fish from the families *Scombridae* and *Scomberosocidae* (mackerels, tunas and kingfish). More recently, non-scombroid fish have also caused identical symptoms and so "Scombroid poisoning" may not be the best description – hence the use of HFP to describe the symptoms (below).

The illness

The illness has a range of symptoms (Table 31).

Questions have been asked whether histamine is the sole cause of the illness. Lehane and Olley (1999) and Clifford and Walker (1992) both consider compounds other than histamine are involved. However, it is probable that histamine is the main hazard because:

- Symptoms are typical allergic reactions caused by histamine – often within a few minutes of consuming the affected food item.
- Antihistamine therapy works relatively quickly (usually less than eight hours).
- High levels of histamine are often found in seafood that has caused the reaction.

TABLE 31
Symptoms of scombroid fish poisoning

Type	Symptoms
Cardiovascular	Flushing, urticaria (nettle-rash), hypotension (low blood pressure) and headache
Gastrointestinal	Abdominal cramps, diarrhoea, vomiting
Neurological	Pain and itching associated with the rash

TABLE 32
Outbreaks of HFP in United States, United Kingdom and Australia

Country	Period	Number of outbreaks	Percentage of all seafood outbreaks	Total ill	Reference
USA	1990–2000	103	43	680	Smith de Waal *et al.* (2000)
UK	1992–1999	47	32	-	Scoging (1998)
Australia	1990–2000	10	31	28	Sumner and Ross (2002)

Outbreaks of HFP

Histamine poisoning occurs throughout the world and is perhaps the most common form of toxicity caused by the ingestion of fish. However, reliable statistics about its incidence do not exist because the poisoning incidents are often unreported because of the mild nature of the illness, lack of adequate systems for reporting food-borne diseases or ignorance by medical personnel who misdiagnose histamine poisoning as a food allergy (Taylor, 1986; Lehane and Olley, 2000). Japan, the United States and the United Kingdom are the countries with the highest number of reported incidents, although this possibly reflects better reporting systems. Frequent incidents have been reported elsewhere in Europe, Asia, Africa, Canada, New Zealand and Australia (Ababouch *et al*., 1991; Lehane and Olley, 2000). Table 32 shows, however, that the number of people affected in outbreaks is usually not great.

Fish species most commonly implicated

Species in the families *Scombridae* and *Scomberosocidae* that have been implicated in outbreaks of HFP include: mackerel (*Scomber* spp.), tuna (*Thunnus* spp.), saury (*Cololabis saira*) and bonito (*Sarda* spp.). Non-scombroid fish include: mahi-mahi (*Coryphaena* spp), sardines (*Sardinella* spp.), pilchards (*Sardina pilchardus*), marlin (*Makaira* spp.), bluefish (*Pomatomus* spp.), sockeye salmon (*Oncorhynchus nerka*), yellowtail (*Seriola lalandii*) and Australian salmon (*Arripis trutta*).

Formation of biogenic amines

The biogenic amines are produced in fish tissues by bacteria in the family *Enterobacteriaceae,* e.g. *Morganella*, *Klebsiella* and *Hafnia*. The bacteria produce decarboxylases that convert amino acids in the fish to biogenic amines:

Histidine → Histamine
Ornithine → Putrescine
Lysine → Cadaverine

The bacteria are naturally occurring in the gills and intestines of the fish and may be spread to other sites in the fish during handling. The nape of the neck appears to be more heavily contaminated than other parts of the fish, possibly due to the gilling and gutting process.

Once histidine decarboxylase has been produced, it may continue to produce histamine, even though bacterial growth has been prevented by chilling to 4 °C. Ababouch *et al.* (1991) showed that histamine production can increase even in ice storage.

5.4.3 Hazard characterization

Your task

You need to investigate the symptoms of HFP so that you can make the correct choice in Questions 1 and 2 of Risk Ranger – degree of severity of the illness and proportion of the population which is affected.

There is a review by Lehane and Olley (2000) which provides information on all aspects of HFP. It is especially useful because it is written in Risk Assessment format.

There is also a large review by the United States Institute of Food Technologists (IFT) on biogenic amines

HFP is caused by the ingestion of foods that contain high levels of histamine and possibly other amines and compounds. Neither cooking, canning, nor freezing reduces the toxic effect (Shalaby, 1996; FDA, 1999).

Infectious dose/dose response

The threshold toxic dose for histamine is not precisely known and scombroid poisoning has occurred at histamine levels as low as 50 mg/kg. However, most incidents involve fish with histamine levels of 200 mg/kg and over (Fletcher, Summers and van Veghel, 1998). The variation may reflect the role that biogenic amines other than histamine play in scombroid poisoning.

Simidu and Hibiki (1955) estimated the threshold toxic dose for histamine in fish at approximately 60 mg. Shalaby (1996) reviewed the oral toxicity to humans of histamine and other biogenic amines in foods. He considered that histamine-induced poisoning is, in general, slight at ≤40 mg, moderate at >40 mg and severe at >100 mg. Based on an analysis of recent poisoning episodes, Shalaby (1996) suggested the following guideline levels for histamine content of fish:

- <5 mg/100 g (safe for consumption)
- 5–20 mg/100 g (possibly toxic)
- 20–100 mg/100 g (probably toxic)
- >100 mg/100 g (toxic and unsafe for human consumption)

It has also been suggested that neither histamine nor biogenic amines are responsible for HFP (Clifford and Walker, 1992). In the period 1976–86, over half the cases in the United Kingdom were associated with histamine levels of less than 50 mg/kg, a level not normally considered to be toxic. Further, volunteers who were fed mackerel with 6 000 mg/kg histamine reported only mild tingling around the mouth. Taken together these two facts led Clifford and Walker (1992) to suggest that the role of dietary histamine in scombroid poisoning may be slight. The same authors also suggest that Saxitoxins (Paralytic Shellfish Poison) may be involved in scombroid poisoning symptoms associated with salmon. Lehane and Olley (1999) speculate that urocanic acid may be the missing factor ("scombroid toxin") in histamine fish poisoning.

However, histamine levels are still used by regulatory bodies. In the United Kingdom, guidelines for histamine levels in fish (Scoging, 1998) are:

- Safe <10 mg/100 g
- Potentially toxic 10–50 mg/100 g
- Probably toxic 50–100 mg/100 g
- Toxic >100 mg/100 g

The United States FDA guidelines, established for tuna, mahi-mahi and related fish, specify 50 mg/100 g as the toxicity level, and 5mg/100 g as the defect action level because histamine is not uniformly distributed in fish that has undergone temperature abuse. Therefore, if 5 mg/100 g is found in one section, there is a possibility that other units may exceed 50 mg/100 g (FDA, 2001a). FDA requires the use of the AOAC fluorometric method (Rogers and Staruszkiewicz, 1997).

The European Union (EU, 1991, 1995) requires that nine samples be taken from each batch of fish species of the following families: *Scombridae, Clupeidae, Engraulidae* and *Coryphaenidae*. These samples must fulfil the following requirements:

- Mean value of all samples must not exceed 10 mg/100 g
- Two samples may be >10 mg/100 but <20 mg/100
- No sample may exceed 20 mg/100

However, fish belonging to these families that have undergone enzyme ripening in brine may have higher histamine levels, but not more than twice the above values. Examinations must be carried out in accordance with reliable, scientifically recognized methods, such as high-performance liquid chromatography (EU, 1991; 1995).

In Australia and New Zealand, the level of histamine in a composite sample of fish or fish products, other than crustaceans and molluscs, must not exceed 20 mg/10 g. A composite sample is a "sample taken from each lot, comprising five portions of equal mass from five representative samples".

Susceptible populations

It is widely believed that all humans are susceptible to scombroid poisoning (FDA, 1999) though symptoms can be severe for the elderly (FDA, 1999) and for those taking medications such as isoniazid, a potent histaminase inhibitor (Morinaga *et al.*, 1997).

Inputs for Risk Ranger

Question 1: Disease is mild, requiring medical attention only rarely
Question 2: General population is at risk with no susceptible population categories

5.4.4 Exposure assessment

Your task

In this section you must identify, from annual catch statistics, the tonnage of fish that are able to produce histamine.

Then you will need to convert the landed amount to edible portion – 80 percent fillet yield is a good estimate.

Finally, you must estimate number of servings and consumption patterns in the country to which you export species capable of producing histamine.

Following is an example of how you make these calculations based on hypothetical data.

Volumes of species known to produce histamine

Volumes of each species exported from your country and that may cause HFP are presented in Table 33. The catch data were gained from analysing receival dockets at each processing plant for one year. Small boats land 6 000 tonnes, which is processed and exported chilled to one country.

Edible weight and number of servings

After processing, the actual weight exported is 4 800 tonnes and, assuming that 100 g is a typical serve, there are 48 million annual servings exported.

Consumption patterns in consumer country

Market data tells you that a few (5 percent) people in the importing country ever eat chilled tuna. The population of the importing country is 270 million, which means that 48 million servings of tuna are eaten by 13 million consumers. This means that each consumer has an average of four servings each year.

TABLE 33
Species and volumes (tonnes) exported

Common name	Latin name	Volume (t)	Edible portion (t)	Servings (10^6)
Yellowtail kingfish	*Seriola* spp.	1 000	800	8
Tunas	*Thunnus* spp.	4 000	3 200	32
Mahi-mahi	*Coryphaena* spp.	1 000	800	8
Total		6 000	4 800	48

Inputs to Risk Ranger for probability of consuming fish that may have histamine

Question 3: Frequency of consumption	Few times a year
Question 4: Proportion consuming	Very few (5 percent)
Question 5: Population	250 000 000

Contamination levels in servings

Your task

In this section you estimate the number of servings capable of causing HFP:

- *Estimate histamine levels of fish on board the boats.*
- *Estimate increase in histamine levels during processing and transport.*
- *Assess potential for product to reach toxic levels during marketing and retailing.*
- *Determine effect of meal preparation on toxin levels.*

This is difficult because of time constraints. If you had several months you could do a survey of measuring histamine levels of fish on boats and then through the processing and transporting chain.

Or, you could survey levels of histamine-producing bacteria at every stage of catching, processing and transporting.

These are large, time-consuming and expensive surveys. One day you may wish to do them but there is another way of estimating histamine levels – by using predictive microbiology.

Predictive microbiology is especially suitable for estimating histamine production because, if you know the temperature of product on the boat, and in the processing and transporting chain, you can predict the amount of bacterial growth.

This is done using data on growth rates of histamine-producing bacteria at key temperatures and integrating them with the temperature:time parameters of product.

You need to generate temperature:time data from the moment the fish are landed on the boat, then during processing and transport, to the moment they are placed in their final storage medium in the country of destination.

This is done using small data loggers which record temperatures at intervals. On board the vessel, loggers are placed in the gills and the gut.

Back on land, the data loggers are downloaded and a temperature:time profile generated (see Figures 2 and 3)

Figure 2 summarizes the process by which tuna and other species capable of accumulating histamine are caught, processed and transported to market.

The task is to estimate levels of histamine throughout the process and this is done by examining each stage of the process. Histamine, itself, will not be estimated in this risk assessment. Instead, the growth of histamine-producing bacteria will be predicted using temperature-time measurements of product, coupled with growth rates of histamine-producing bacteria.

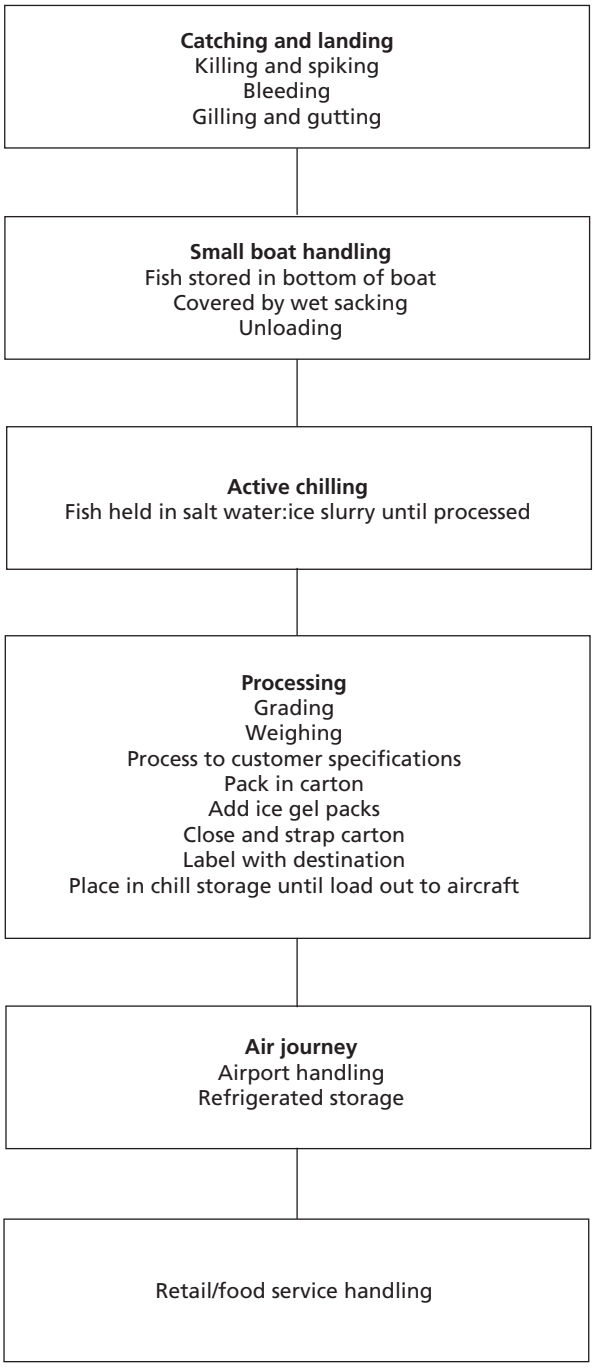
Contamination of fish on the boats

Histamine-producing bacteria such as *Morganella*, *Klebsiella* and *Hafnia* convert amino acids in the fish to biogenic amines like histamine. These bacteria occur naturally in the gills and intestines of the fish and are spread to other sites in the fish during handling.

Factors which affect build up of histamine and other biogenic amines in seafoods include:

- Free histidine levels in fish muscle.
- Location of histamine-producing bacteria: On board the vessel, knife work

FIGURE 2
Process model for catching and processing tuna for chilled air freight from large and small boats



and removing the bloodline will spread histamine-producing bacteria to these sites. These are termed "sites of microbiological concern" because it is here that histamine is produced.

- Temperature at which product is stored: If temperature at the sites of microbiological concern is controlled, histamine production is controlled.

It is important to know the levels of histamine-producing bacteria on tuna after on-board handling. In a study on Pacific mackerel (*Scomber japonicus*), Kim *et al.* (2001) found very low levels of histamine-producers (<10 cm^2 on the gills and <10 g in

the gut), and these organisms produced histamine only slowly at 4 °C and not at all at 0°C. This finding is typical of many others, which indicate that histamine formation is controlled by temperatures at 4 °C or below.

At abusive temperatures (20–30 °C), however, histamine is formed quickly and, importantly, the enzyme histidine decarboxylase is produced and excreted from the bacterial cells onto the fish muscle. The enzyme is active at 0°C as indicated by Ababouch *et al*. (1991) who showed that on sardine held at ambient temperature (approx 25 °C) for 24 hours, histamine continued to be produced even after the fish had been placed in ice storage for a week. Klausen and Huss (1987) similarly showed that after mackerel had been held at 10 °C for two days, histamine continued to increase even when the fish were stored in ice.

So it is vital to quickly cool the sites of microbiological concern on fish to prevent formation of histidine decarboxylase. On ungutted fish these are the skin, gills and gut contents. However, in the system under review, there is no cooling for up to 10 hours.

Temperature: time parameters for fish on boats

Typically, boats fish overnight in a trip of up to 12 hours. Travel to the fishing grounds takes about 3 hours, lines are set and the first fish are landed about 4 hours into the trip. Storage is at ambient temperature (25–28 °C) until unloaded at the processing plant – the first-caught fish have been already stored for up to 10 hours. As fish are caught throughout the trip they are added to the catch in the bottom of the boat and kept moist with wet sacking. Fish from the last set are landed about 4 hours before the vessel arrives home.

A typical temperature:time curve for product at the site of microbiological concern (the gut) is presented in Figure 3 from which it can be seen that the first-caught fish are kept at ambient temperatures for up to 10 hours, prior to rapid chilling in the processing plant.

For inputs to Risk Ranger, only assumptions can be made on the rate at which servings are contaminated.

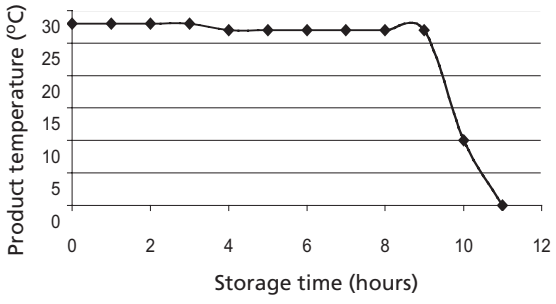
Assumption 1: That all (100 percent) tuna landed contain histamine-producing bacteria in the gills and gut, and on the skin (see Kim *et al*., 2001).

Assumption 2: That these bacteria are present at 10/cm² of gill surface or 10/g of gut contents (see Kim *et al.*, 2001).

Assumption 3: That the contamination is confined to fish surfaces, and the deep muscle tissues remain sterile.

Assumption 4: That a 30 kg tuna will give around 250 servings of 100 g of which 1 percent (servings with external tissues on which histamine has been

FIGURE 3
Fish temperatures (°C) on boats



Although only short (overnight) trips are made, the first-caught fish is kept at ambient temperature of 25–28 °C for up to 10 hours. Once landed, fish are processed (gilled and gutted) and placed in ice:water slurry.

produced) will be contaminated with sufficient histamine to cause illness.

Assumption 5: That during processing, there is a recontamination rate because the numbers of histamine-producers will have multiplied.

Assumption 6: That in fish held at 25–28 °C, histamine-producers have a doubling time of 60 minutes without any delay due to lag phase (typical doubling time for mesophilic *Enterobacteriaceae*).

Over 10 hours storage on the boat, therefore, will cause histamine producers to undergo nine doublings, an increase of 1 000 times (three log scales) over the original assumed level of 10/g or cm² to reach a level of 10 000/cm² at fish surfaces or 10 000/g in the gut. Not only is this a high level of contamination, which will be spread during on-land processing, but significant quantities of histamine decarboxylase will have been secreted onto the fish, and this will continue to produce histamine during transport and marketing.

Inputs to Risk Ranger for contamination with histamine-producing bacteria on fish at time of landing aboard the vessel

Question 6: Frequency of contamination	percent
Question 7: Effect of process	Holding on the boat has no effect on the prevalence of contamination
Question 8: Potential for recontamination	10 percent

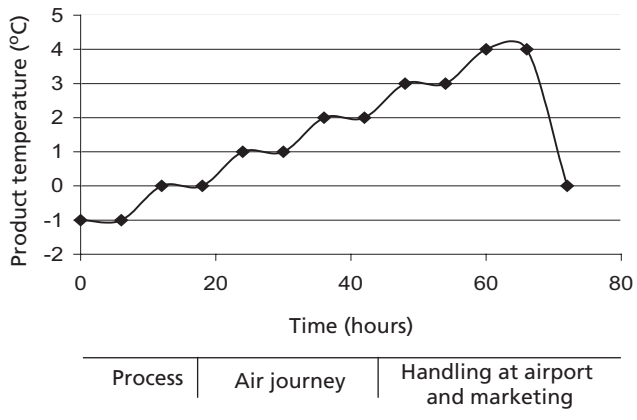
Temperature: time parameters of product in process, transport and retail/ food service

At the processing plant, fish are gilled and gutted, then stored in ice until packed for air transport to the consumer country. The HACCP contains details of how the exporter maintains product temperature throughout the 24–36 hour journey. By inserting data loggers in product, a typical temperature profile of tuna during processing, transport and handling in the importing country is shown in Figure 4.

As indicated in Figure 4, product temperature is controlled during all land-based activities although histamine can be expected to increase because of histidine decarboxylase activity.

Again the inputs to Risk Ranger must be assumed.

FIGURE 4
Temperature (°C) and time (hours) during transport to customer



Product temperatures gradually rise during transport but there will be no increase in histamine unless the temperature rises above 4 °C for several hours. Once with the customer, product will be stored near zero.

Assumption 1: Histamine-decarboxylase activity leads to a ten-fold increase in histamine during processing, air freight and marketing.

Inputs to Risk Ranger for post-process storage and handling

Question 9: Effectiveness of post-processing ten-fold increase in hazard

Assess potential for product to reach toxic level

At this stage you must decide how much the growth of histamine-producers will cause fish to become toxic to consumers.

In the United Kingdom, levels of histamine >10 mg/100g fish are considered to be potentially toxic (Scoging, 1998) while in Australia the Food Standards Code has set 20 mg/100 g as the upper limit in any sample. The United States FDA set a level of concern at 10 mg/100 g.

Fletcher *et al*. (1998) showed that histamine-producers generally must reach a level $>10^7/cm^2$ to cause levels of histamine >5 mg/100 g so, for the present assessment, an assumption was made that a level of $10^8/cm^2$ was needed for fish to be toxic.

A summary of exposure assessment data is presented in Table 34, together with the amount of growth required in the processing, air freight and marketing sectors for histamine to reach levels ($10^8/cm^2$) that are associated with HFP.

TABLE 34
Increase in histamine-producing bacteria during processing air freight and marketing

Risk Ranger		Level on first caught fish	Total histamine producers
Question 6	Initial bacterial level on fish	$10/cm^2$	$10/cm^2$
Question 7	Increase on board	1 000x	$10\ 000/cm^2$
Question 9	Post-process increase	10x	$100\ 000/cm^2$
Question 10	Increase needed to toxic level	1 000x	$100\ 000\ 000/cm^2$

Inputs to Risk Ranger for increase to intoxication level

Question 10: Increase to intoxication: 1 000-fold increase in histamine producers

Determine effect of meal preparation on toxin levels

Histamine is heat-stable and so the method of preparation in the home or restaurant has no effect on the level of toxicity in the fish.

Inputs to Risk Ranger for effect of meal preparation

Question 10: Effect of meal preparation: Preparation has no effect on the hazard

5.4.5 Risk characterization

In this section you use information obtained from the hazard characterization and exposure assessment for input into Risk Ranger to examine the effect of temperature control aboard the vessel on the risk of getting HFP. The estimate of risk will be a risk ranking.

Inputs for fish caught from small boats are inserted into Table 35. This is a record of the risk assessment that allows reviewers to see exactly how the final estimate was obtained.

TABLE 35
Semi-quantitative risk characterization of HFP of fish from small boats

Risk criteria	Inputs to Risk Ranger
Dose and severity	
Hazard severity	Mild – sometimes requires medical attention
Susceptibility	General – all population
Probability of exposure	
Frequency of consumption	Monthly
Proportion consuming	Few (5%)
Size of population	270 million
Probability of contamination	
Probability of raw product contaminated	1%
Effect of processing	No change in prevalence, but there is 1 000x increase in histamine producing bacteria
Possibility of recontamination	10%
Post-process control	Allows 10-fold increase in hazard
Increase to infective dose	1 000 times
Meal preparation	Not effective in reducing hazard
Predicted annual illnesses	40 000
Risk ranking (0–100)	41

5.4.6 Risk estimate

The risk ranking is 41 with estimated annual illness of 40 000 from total servings numbering around 40 million.

5.4.7 Identification of critical data gaps

In making this assessment several assumptions were made:

Assumption 1: That all (100 percent) tuna landed contain histamine-producing bacteria in the gills and gut, and on the skin (see Kim *et al.*, 2001).

Assumption 2: That these bacteria are present at 10/cm^2 of gill surface or 10/g of gut contents (see Kim *et al.*, 2001).

Assumption 3: That the contamination is confined to fish surfaces, and the deep muscle tissues remain sterile.

Assumption 4: That a 30 kg tuna will give around 250 servings of 100 g of which 1 percent (servings with external tissues on which histamine has been produced) will be contaminated with sufficient histamine to cause illness.

Assumption 5: That, in fish held at 25–28 °C, histamine-producers have a doubling time of 60 minutes without any delay due to lag phase (typical doubling time for mesophilic *Enterobacteriaceae*).

Assumption 5: That during processing, there is a recontamination rate of 10 percent because the numbers of histamine-producers have multiplied and will be transferred to other areas of the fish.

Assumption 6: Histamine-decarboxylase activity leads to a tenfold increase in histamine during processing, air freight and marketing

5.4.8 Risk management and communication issues

Risk management is made difficult because of the need to accommodate a number of competing interests. The following scenario is typical of how risk managers, communicators and assessors must cooperate to achieve the best and safest outcomes.

The risk managers consider all boats should ice fish immediately after landing aboard the vessel so that the sites of microbiological concern are reduced to a temperature that will control histamine-producing bacteria.

Public comment

The decision to make icing of fish mandatory is communicated to several hundred operators. The operators respond that:

- *At least 100 kg of ice would be needed for each boat for each trip – a total of 30 tonnes for the entire fleet – a need that is impossible to service because the ice plant does not have the capacity.*
- *There is an added cost for the purchase of ice.*
- *There are safety concerns about having the extra load aboard the boat.*
- *There is no room aboard the vessels for an ice chest.*
- *Product from small boats has never killed anyone or made them ill.*

During election years several thousand votes come from the small fisheries sector.
The Minister of Fisheries asks the risk managers to reconsider all aspects of the situation:

- *Public health concerns in the consumer country.*
- *Potential loss of an export market if there is a problem in the consumer country.*
- *Loss of several hundred incomes if the fishery is closed down.*
- *Inability to supply sufficient ice.*
- *On-board safety concerns.*
- *Possible legal action by the small boat cooperative.*

Risk management decisions

The risk managers decide:

- *An ice-plant can be built and ice made available at reasonable (subsidized) cost.*
- *Boats can be modified so that the seats become insulated containers. Other spaces can also be modified so that the boats are capable of carrying up to 100 kg of ice.*

It is stated that typical catches are 50–80 kg/trip but that, sometimes, up to 200 kg is caught. Fishers wish to take only 50 kg of ice for each trip for reasons of space and cost. This will result in only partial icing.

Further risk assessment work

You are required to study the effect of partial icing on histamine formation.

Specifically, if fish are gilled and gutted immediately on landing aboard the vessel and the temperature of the sites of microbiological concern is reduced, how will this affect predicted histamine levels.

This is a data-logging/predictive microbiology exercise, for which you are allowed one month.

Risk assessment of partial icing of fish from small boats

By inserting data loggers just below the skin of the gut cavity of fish (a site of microbiological concern) the temperature:time parameters over the trip are determined. Figure 3 shows temperature profiles for fish caught early in the fishing trip.

From Figure 5 it can be seen that, on early-caught fish, the sites of microbiological concern are quickly brought below 5 °C. However, as more fish are caught and ice slowly melts, product temperatures gradually rise to around 10 °C. Chilling in ice imposes a lag phase on mesophilic histamine-producing bacteria which, together with very slow growth rates at 5–10 °C, will prevent growth of histamine-producers for the duration of the fishing trip. The result will be little production of histamine decarboxylase. Once on land, fish are actively chilled in ice slurry and product surfaces are quickly returned to zero.

From Table 36 it can be seen that many of the inputs to Risk Ranger remain the same as for the initial risk assessment. The initial prevalence of contamination remains at 1 percent; recontamination during processing is 10 percent. The critical difference is

Small alias with an icebox ready to locate within the cabin. Space is limited but the catch can now be cooled immediately on landing aboard the vessel

FIGURE 5
Fish temperatures (°C) for partially iced fish

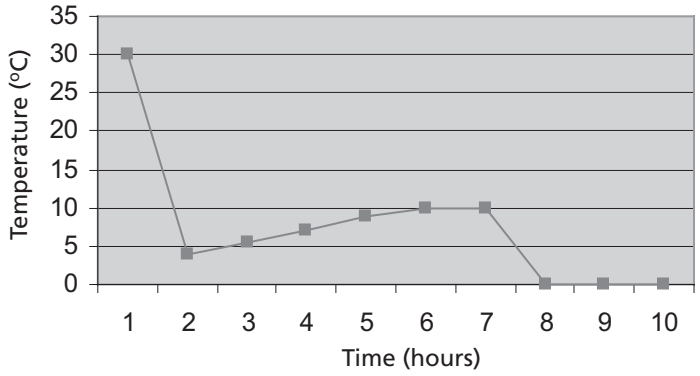


TABLE 36
Semi-quantitative risk characterization of HFP of partially-iced fish

Risk criteria	Inputs to Risk Ranger
Dose and severity	
Hazard severity	Mild – sometimes requires medical attention
Susceptibility	General – all population
Probability of exposure	
Frequency of consumption	Monthly
Proportion consuming	Few (5%)
Size of population	270 million
Probability of contamination	
Probability of raw product contaminated	1%
Effect of processing	No effect on prevalence or on population of histamine producing bacteria
Possibility of recontamination	10%
Post-process control	None
Increase to infective dose	10 000 000 times
Meal preparation	Not effective in reducing hazard
Predicted annual illnesses	4 cases per decade
Risk ranking (0–100)*	12

* Note that a change in risk ranking by an increment of "six" is equivalent to a tenfold change in risk

the effect of partial icing on preventing increase in histamine-producing bacteria on fish during storage on the boat. This has two important effects on inputs to Risk Ranger for Questions 9 and 10.

For Question 10, since there is no production of histidine decarboxylase on the boat, there is no enzymatic production of histamine during processing, air freight and marketing.

For Question 11, the level of histamine-producers linked with illness remains at 10^8/cm^2 or /g. But, because of temperature control on the boat, the level of histamine producers is contained around 10 cm^2 or /g making the increment needed to cause illness 10^7/cm^2 or /g.

Risk estimate

The risk ranking is 12, compared with 41 for un-iced fish. The reduction in ranking (29) is equivalent to a reduction

in risk of almost 100 000. Estimate of illness is four every decade, compared with 40 000/annum for fish held on the boat at ambient temperature.

5.5 PATHOGENIC *VIBRIO PARAHAEMOLYTICUS* IN OYSTERS EATEN RAW: QUANTITATIVE RISK ASSESSMENT

The situation

Your country has a flourishing oyster industry and supplies your own domestic market and several export markets. Following outbreaks of food poisoning in the United States caused by Vibrio parahaemolyticus*, and a QRA by that country, your government decides to undertake its own risk assessment.*

Your task is to assemble a team to do this process and you are given six months to complete a QRA.

5.5.1 Purpose of the assessment

The purpose of the assessment is to estimate the risk of disease caused by *V. parahaemolyticus* in oysters grown in your country to two populations:

- your domestic population of five million;
- populations in countries which import your oysters (combined populations of 300 million).

The risk estimate will be annual predicted illnesses from *V. parahaemolyticus* in oysters.

5.5.2 Your approach to the QRA

Team selection

You select a team which comprises:

- the technical director of the Oyster Association, who will supply data on production, consumption, export data and research information;
- a shellfish microbiologist who has specialist knowledge on vibrios;
- a modeller who has experience with risk assessments;
- a food technologist who has knowledge of how oysters are processed and packaged;
- an epidemiologist who will research vibrio-induced illness in your country.

You will coordinate this team and prepare the risk assessment report.

Strategy

Your team is aware that a QRA already exists and believes that it is important to use the same modelling approach but to modify it in two ways:

- make the model reflect the growing, harvesting and processing practices in your country;
- include data specific for your country.

Your team believes this approach will satisfy importing country requirements and, at the same time, reflect the situation in your industry.

Assessing data gaps

Your team assesses the data available to the QRA and finds a number of relevant studies on total *V. parahaemolyticus* levels according to season. There are two data gaps that must be filled as soon as possible:

- levels of pathogenic strains of *V. parahaemolyticus* in oysters at the time of sale;
- consumption patterns, especially the percentage eaten raw or lightly cooked.

Work programme

A study is begun to isolate pathogenic strains using gene probe technology. This will take three months. The oyster industry will also survey consumption patterns, again with a three-month deadline. You initiate a series of meetings to set up the farm-to-fork model and your modeller examines the United States model in detail because it will form the basis for your assessment.

5.5.3 Hazard identification

There are a number of sources that summarize the evidence establishing *Vibrio parahaemolyticus* as a hazard in seafood consumption, for example, the United States FDA risk assessment (FDA, 2001b) and an appraisal: *Opinion of the Scientific Committee on Veterinary Measures relating to Public Health on* Vibrio vulnificus *and* Vibrio parahaemolyticus *in raw and undercooked seafood* issued by the European Commission. Both reports are included in the Resources Bank.

In summary, it is a marine micro-organism occurring in estuarine waters throughout the world, first identified as a food-borne pathogen in Japan in the 1950s (Fujino *et al*., 1953). By the late 1960s and early 1970s, *V. parahaemolyticus* was recognized as a cause of diarrhoeal disease worldwide, although most common in Asia and the United States. Vibrios concentrate in the gut of filter-feeding molluscan shellfish such as oysters, clams, and mussels where they multiply. Although thorough cooking destroys these organisms, oysters are often eaten raw and, at least in the United States, are the most common food associated with *Vibrio* infection (Hlady, 1997).

In Asia, *V. parahaemolyticus* is a common cause of food-borne disease. In general the outbreaks are small in scale, involving fewer than ten cases, although they occur frequently. Prior to 1994, the incidence of *V. parahaemolyticus* infections in Japan had been declining, however, in 1994–95 there were 1 280 reports of infection due to the organism (IDSC, 1999) and during this period, *V. parahaemolyticus* food poisonings outnumbered those of *Salmonella* food poisoning. For both years, the majority of the cases occurred in the summer, with the largest number appearing in August.

Between 1986 and 1995, 197 outbreaks of food-borne disease were caused by *V. parahaemolyticus* in Taiwan (Pan *et al*., 1997) while in 1997 over 200 outbreaks were reported, including an outbreak of 146 cases acquired from boxed lunches (ISID, 1999).

During 1997 and 1998 there were more than 700 cases of illness due to *V. parahaemolyticus* in the United States, the majority of which were associated with the consumption of raw oysters. In two of the 1998 outbreaks a serotype of *V. parahaemolyticus,* O3:K6, previously reported only in Asia, emerged as a principal cause of illness for the first time. Subsequent studies on these strains have revealed their pandemic spread.

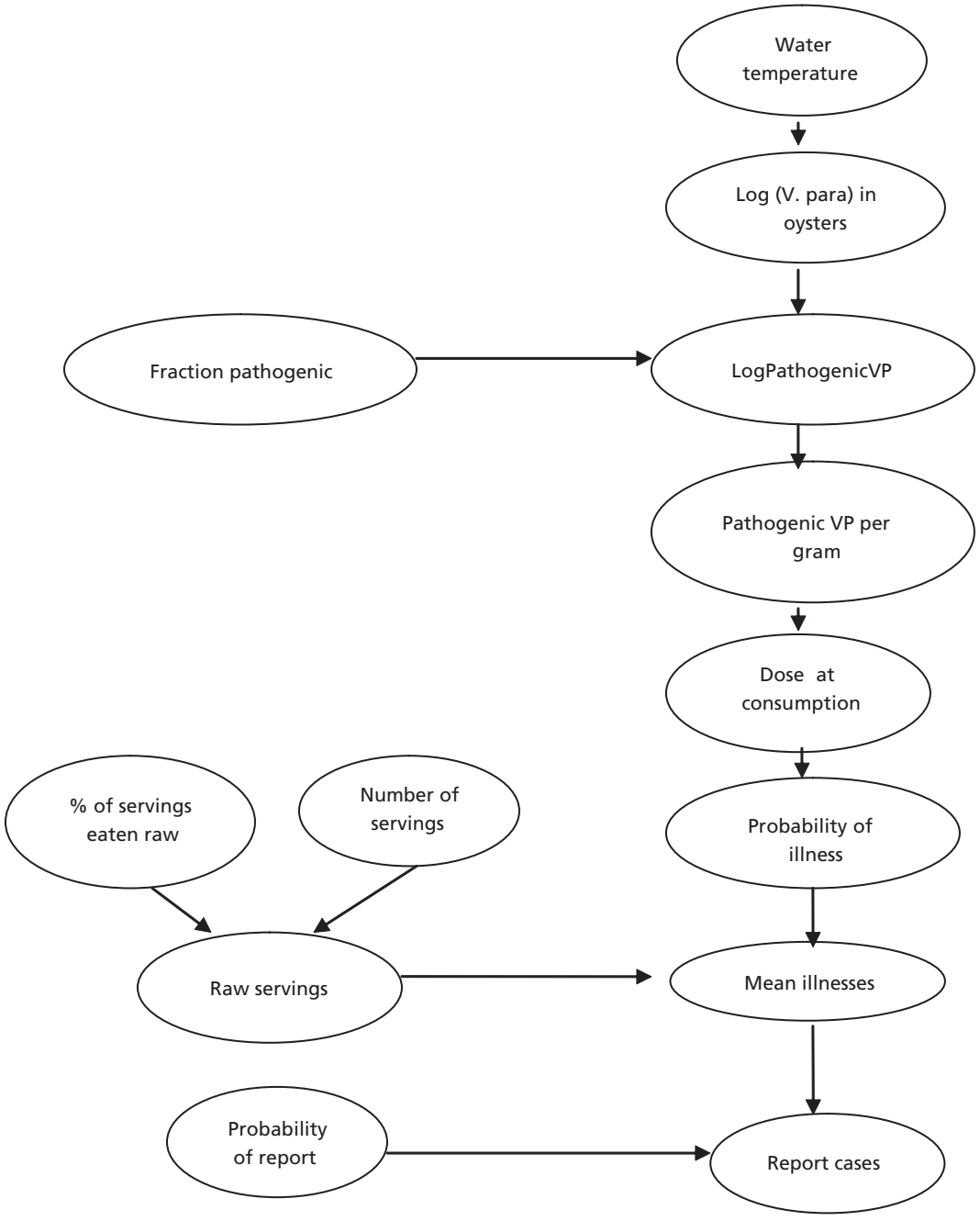
In Europe few data exist on the incidence of *V. parahaemolyticus* infections, one of the reasons being that such infections are not notifiable.

5.5.4 Exposure assessment

Stage 1: Modelling the process

The purpose is to quantify the exposure of consumers to pathogenic *V. parahaemolyticus* from the consumption of raw oysters. Often this is done using a model that incorporates all phases in the harvest – post-harvest – consumption continuum to identify steps that contribute most to risk, so that effective risk reduction strategies can be designed. The first stage is for the modeller on your team to construct a conceptual model linking all important stages for which information is required. Such a model is presented below, and it can be constructed in risk assessment software so that data can be included directly.

The model sets out the data you need to obtain in order to do the assessment and links them, showing how they influence other factors. The model also sets your work program over the next three months, in order to gather the data for the modeller.



Stage 2: Obtaining water temperature data

It is well known that appearance of *V. parahaemolyticus* in natural waters is linked with water temperature, so you need to find at least one year of temperature recordings at your major oyster growing areas. This presents no problem because all shellfish farmers measure temperatures and salinities as part of their management system. You are able to obtain a full year's data (Table 37) from which it should be noted that, as a southern hemisphere country, your summer is December–April.

***Stage 3: Linking water temperature with numbers of* V. parahaemolyticus**

There have been several studies in which the researchers measured water temperatures and populations of *V. parahaemolyticus* in oysters (Table 38).

This analysis is extremely important for your risk assessment because it establishes the link between water temperature and populations of *V. parahaemolyticus* in

oysters. It is especially important for your assessment because of your time constraints. Your modeller will tell you the above data "anchor" the whole risk assessment. This means that the data provide a point of reference that can be used to compare risks as higher or lower without knowing the actual size of the risk. This is useful in international trade negotiations, which are based on the idea of "equivalence".

TABLE 37
Water temperature recordings (°C) at a major oyster growing area

	Minimum	Mean	Maximum
Jan	19	23	26
Feb	19	24	27
Mar	20	23	25
April	19	20	22
May	17	19	21
June	15	18	20
July	14	17	19
Aug	13	15	18
Sept	13	15	17
Oct	15	17	18
Nov	16	18	20
Dec	18	20	23

TABLE 38
Summary of water temperature and *V. parahaemolyticus* in oysters

Water temperature (°C)	*V. parahaemolyticus*/ g oysters
<15	Not detected
15–20	<10
20–25	10–100
>25	100–1000

Stage 4: Measuring levels of **V. parahaemolyticus** *in oysters*

Ideally, you need to know how many *V. parahaemolyticus* are in market-ready oysters over an annual cycle. You do not have time for a whole cycle but, fortunately, you can sample at the warmest months, when the *V. parahaemolyticus* concentration in oysters will be highest. You also need to know how many of the organisms are pathogenic.

You are able to purchase gene probes, which can highlight *V. parahaemolyticus* colonies on culture plates and can also distinguish pathogenic types. So you have a straightforward method of gathering information, and it is just a question of obtaining samples for the laboratory to do the testing.

This laboratory phase of the work is done during the warmest months and produces the following data on total *V. parahaemolyticus* and on pathogenic strains (Table 39).

Stage 5: Gathering consumption data

While the scientists are doing the laboratory work your industry experts gather data on consumption patterns in the country to which you are exporting. Remember, this country is your customer and you are aiming the risk assessment at their situation.

It is not difficult to get export statistics that tell you the tonnage exported, from which you can calculate the number of oysters eaten. You know the population of the country but obviously not everyone eats your oysters so you need to find out the proportion that does. This is impossible to define except in broad terms, but your marketing agents are able to tell you a great deal of useful information. In summary, you are able to confirm that each year:

- Your oysters are sold in around ten major cities and are eaten either in markets or restaurants.
- Most people buy six oysters, to give a serving size of 100 g; 12 oysters is the next popular serving size (200 g).
- More than 95 percent are eaten raw or lightly cooked.

You are able to calculate that you export the equivalent of 10 million servings of six oysters (100 g).

TABLE 39
Total and pathogenic *V. parahaemolyticus* in oyster meat

	Total *V. parahaemolyticus*		Pathogenic *V. parahaemolyticus*	
	Prevalence	Mean log/g (antilog)	Prevalence	Mean log/g (antilog)
Jan	45/50	1.5 (31)	10/50	0.8 (6)
Feb	50/50	2.2 (160)	15/50	1.2 (16)
Mar	50/50	25 (315)	15/50	1.8 (63)

Stage 6: Preparing the data for modelling

You now have the exposure data needed to give to the modeller. It is important to assemble the team to go over the data and make the modeller familiar with the data; they are not just numbers – the modeller must fully understand the data and what they mean.

Modellers are interested in the quality of the data, specifically the variability and uncertainty. They need to measure these properties and incorporate them into the calculations of a risk assessment. Modellers handle variability and uncertainty in the data in a similar way – by making a series of distributions for the important parameters of the model. One commonly used distribution is called Triangular (or 'triang') and involves describing the range of possible values by the minimum, maximum and most likely value.

Your modeller tells you that data in Table 37 (Monthly water temperatures) are already set out as a distribution (max, min and mean, or most likely) for each month.

In Table 38 (Population of *V. parahaemolyticus* as affected by water temperature), bacterial numbers are described as the most likely range. Your modeller modifies these data by making a triang of the most likely range and a triang of the variability (Standard Deviation).

In Table 39 (Mean numbers of pathogenic *V. parahaemolyticus*), the modeller again makes triangular distributions (min, max, most likely) of the monthly means.

After examining the consumption data, your modeller tells you there is great variability. Apparently the most popular serving is 6 (approx. 100 g), followed by 12 oysters. But a proportion of the population eats 24 oysters at one sitting and some people may eat up to 60 at one time. At the other end of the scale, some consumers only eat one oyster. Again this variability can be modelled with a triangular distribution using min = 20 g, mean = 100 g and max = 500 g.

The data are processed through special software by the modeller so they are ready for analysis using risk assessment software.

5.5.5 Dose-response

The dose-response developed in the United States study is shown below.

The dose-response curve is based on four feeding trials of volunteers and, because of the small number of people used during these studies, there is considerable uncertainty about the best estimate of the dose-response. Almost all volunteers became ill when they were fed between 1 million and 1 billion *V. parahaemolyticus* but there are no points on the upward part of the curve. This is going to lead to great uncertainty and your modeller notes that the United States modellers use several statistical methods for characterizing the uncertainty of the dose-response parameters, including likelihood ratio-based confidence regions and bootstrapping techniques (parametric or non-parametric).

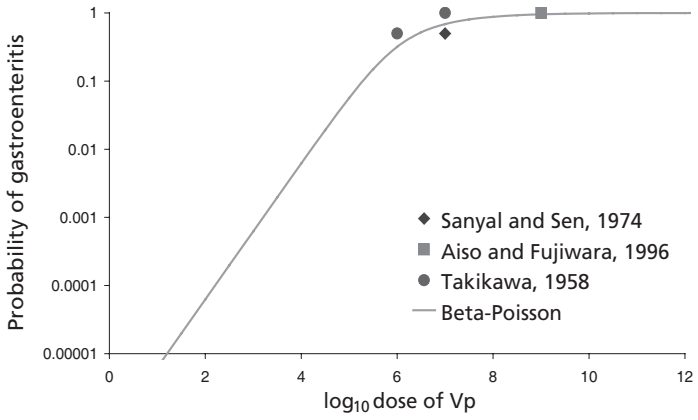
As well as uncertainty, the modeller reminds you that a number of assumptions have been made, including that:

- The way healthy volunteers respond to oral challenge is typical of the general population.
- The virulence of the pathogens or susceptibility of the host does not vary.
- The Beta-Poisson dose-response model is reasonable for use in characterizing risk of illness when consuming *Vibrio* spp.

5.5.6 Risk characterization

Your modeller now puts all the data and distributions into a software package designed to calculate the risk estimates and runs a large number of simulations (iterations). The risk assessment software samples all possible combinations of distributions, although it samples the more likely values more frequently than those at the maximum and

FIGURE 6
An example of a dose-response curve



minimum. Your modeller now works with the outputs to produce a risk estimate of number of cases per year in the importing country.

The outputs are summarized in Figure 7, which describes the relationship between the probabilities of illness per serving with the probability that the estimate is correct. For example, the graph peaks at a 50 percent probability that 1 in 100 000 serves will cause illness. If all the probabilities under the graph are added, the most likely result is that one meal in 1 million serves will cause illness.

Since there are 10 million servings exported, the most likely result is that they will cause 10 illnesses. The assessment also predicts the range of illnesses will be 1–800/annum. From the results the modeller can state, with 95 percent confidence, that there will be fewer than 316 illnesses from 10 million of your oysters.

Reality check

The results of the assessment, with its prediction of illnesses, make you examine the situation at home, where around 30 million servings are consumed. According to the assessment, there should be 30 cases each year. The epidemiologist on the team examines health records for the past decade and finds that there have been no recorded illnesses from consumption of *V. parahaemolyticus* in oysters. This evidence tells you with certainty that there have been no outbreaks, because they would have been reported. However, there may well have been sporadic cases of mild gastroenteritis, where consumers did not visit their doctor because the symptoms did not warrant it. You conclude that the risk estimate is not greatly removed from reality.

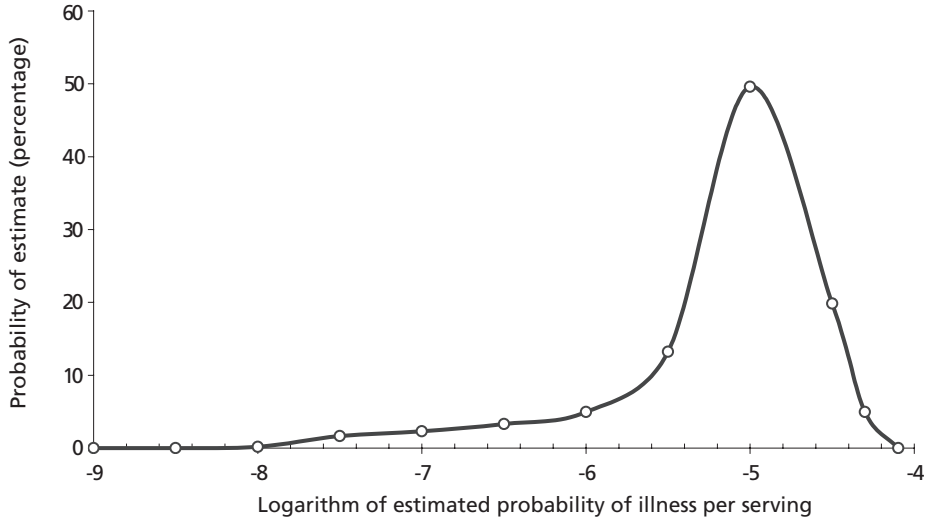
Uncertainty and variability

There is considerable uncertainty surrounding the dose response because only a small number of subjects were involved in the trials and they were not very representative of the whole population. Because you have not followed an annual cycle of pathogen numbers in oysters there is variability in the dose consumed.

Sensitivity analysis

You modeller is able to say that the only strong correlation with risk is water temperature and that the analysis indicates almost all cases were predicted for the warmer months (December–April).

FIGURE 7
Probability of illness per serving versus probability that the estimate is correct



Reporting the results

You report to your customer (the importing country). The risk estimate (ten cases per annum) is seen against the predictions from their own assessment of more than 2 000 cases per annum. There are discussions between your countries' governments on mitigation strategies. Your government proposes not exporting chilled product during the warmest months. It is an offer to reduce the risk to the importing country because you will retain the highest risk product at home. After consultation, the importing country government decides the risk associated with importing your product is an acceptable one.

The risk assessment has uncertainties and variabilities, but it has served its purpose by providing your customer with information on which to make an informed decision.

References

Ababouch, L., Afilal, M.E., Benabdeljelil, H. & Busta, F.F. 1991. Quantitative changes in bacteria, amino acids and biogenic amines in sardine (*Sardina pilchardus*) stored at ambient temperature (25–28 °C) and in ice. *International Journal of Food Science and Technology*, 26: 297–306.

Aiso, K. & Fujiwara, K. 1996. Feeding tests of the pathogenic halophilic bacteria. Annual Research Report Institute of Food Microbiology Chiba University, 15: 34–38.

Arcilaherrera, H., Castellonavarrete, A., Mendozaayora, J., Monterocervantes, J., Gonzalezfranco, M.F. & Britovillanueva, W.O. 1998. Ten cases of ciguatera fish poisoning in Yucatan. *Revista de Investigacion Clinica*, 50: 149–152.

Bryan, F. 1979. Epidemiology of food-borne diseases. *In* H. Riemann & F. Bryan, eds. *Food-borne infections and intoxications*. New York, USA, Academic Press.

Cassin, M.H., Lammerding, A.M., Todd, E.C.D., Ross, W. & McColl, R.S. 1998. Quantitative risk assessment for Escherichia coli O157:H7 in ground beef hamburgers. *International Journal of Food Microbiology*, 41: 21–44.

Clifford, M.N. & Walker, R. 1992. The aetiology of scombrotoxicosis. *International Journal of Food Science and Technology*, 27: 725–726.

Conaty, S., Bird, P., Bell, G., Kraa, E., Grohmann, G. & McAnulty, J. 2000. Hepatitis A in New South Wales, Australia from consumption of oysters: the first reported outbreak. *Epidemiology and Infection,* 124: 121–130.

Corlett, D.A. & Pierson, M.D. 1992. Hazard analysis and assignment of risk categories. *In* M.D. Pierson & D.A. Corlett, Jr, eds. *HACCP: principles and applications*, pp. 29–38. New York, USA, Van Nostrand Reinhold.

Coultate, T.P. 1992. *Food: the chemistry of its components.* Royal Society of Chemistry, Cambridge, UK.

D'Aoust, J-Y. 1994. *Salmonella* and the international food trade. *International Journal of Food Microbiology*, 24: 11–31.

Davidson, P.W., Myers G.J., Cox, C. Axtell, C., Shamlaye, C., Sloane-Reeves, J., Cernichiari, E., Needham, L., Choi, A., Wang, Y., Berlin, M. & Clarkson, T.W. 1998. Effects of prenatal and postnatal MeHg exposure from fish consumption on neurodevelopment. *Journal of the American Medical Association*, 280: 701–707.

European Union (1991 and 1995). Council Directive 91/493/EEC and 1995 amendment laying down health conditions for the production and placing on the market of fishery products. *Official Journal of the European Commission,* L268: 15–32.

FAO. 2004. *Assessment and management of seafood safety and other quality aspects*, by L. Ababouch & L. Gram. FAO Fisheries Technical Paper 444. Rome.

FAO/NACA/WHO. 1999. Food safety issues associated with products from aquaculture: report of a joint FAO/NACA/WHO study group. *WHO technical report series*: 883. Joint FAO/NACA/WHO Study Group on Food Safety Issues Associated with Products from Aquaculture (1997: Bangkok, Thailand).

FAO/WHO. 2001. *Codex Alimentarius food hygiene basic texts*. 2nd edition. Rome.

FAO/WHO. 2002. *Principles and guidelines for incorporating microbiological risk assessment in the development of food safety standards, guidelines and related texts*. Report of a Joint FAO/WHO Consultation, Kiel, Germany. Rome.

FDA (United States Food and Drug Administration). 1994. Mercury in fish: cause for concern? *FDA Consumer Magazine*, 28(7).

FDA. 1999. *Bad bug book (foodborne pathogenic microorganisms and natural toxins).* Washington, DC.

FDA. 2001a. *Fish and fishery products hazards and controls guide*. 3rd edition. Washington, DC, Office of Seafood. 326 pp.

FDA. 2001b. *Draft risk assessment on the public health impact of* Vibrio parahaemolytius *in raw molluscan shellfish.* Centre for Food Safety and Applied Nutrition, US FDA, Washington, DC.

Fletcher, G.C. 1995. Histamine and histidine in New Zealand marine fish and shellfish species, particularly kahawai *(Arripis trutta*). *Journal of Aquatic Food Production Technology*, 4: 53–74.

Fletcher, G.C., Summers, G. & van Veghel, P.W.C. 1998. Levels of histamine and histamine-producing bacteria in smoked fish from New Zealand markets. *Journal of Food Protection*, 61(8): 1064–1070.

Fujino, T., Okuno, Y., Nakada, D., Aoyoma, A., Fukai, K., Mukai, T. & Ueho, T. 1953. On the bacteriological examination of shirasu food poisoning. *Med. J. Osaka Univ,.* 4: 299–304.

Glaziou, P. & Martin, P.M.V. 1993. Study of factors that influence the clinical response to Ciguatera fish poisoning. *Toxicon*, 31: 1151–1154.

Grohmann, G. 1997. Viruses, food and environment in food-borne microorganisms of public health significance. *In* A.D. Hocking, G. Arnold, I. Jenson, K. Newton & P. Sutherland, eds. *Food-borne microorganisms of public health significance*. Australian Institute of Food Science and Technology Inc., NSW Branch Food Microbiology Group, North Sydney, Australia.

Habermehl, G.G., Krebs, H.C., Rasoanaivo, P. & Ramialiharisoa, A. 1994. Severe ciguatera poisoning in Madagascar: A case report. *Toxicon*, 32 (12): 1539–1542.

Hlady, W.G. 1997. *Vibrio* infections associated with raw oyster consumption in Florida, 1981–1994. *Journal of Food Protection*, 60: 353–357.

Huss, H.H., Reilly, A. & Ben Embarek, P.K. 2000. Prevention and control of hazards in seafoods. *Food Control*, 11: 149–156.

IDSC (International Disease Surveillance Center). 1999. *Vibrio parahaemolyticus*, Japan 1996–1998, IASR Infectious Agents Surveillance Report, 20 (7): 1–2.

ISID (International Society for Infectious Diseases. 1999. *Vibrio parahaemolyticus*, Taiwan: Background. PROMED-digest, 28 May 1999.

Johnson, B.L. 1998. Testimony of Barry L. Johnson, Ph.D., Assistant Surgeon General Assistant Administrator, Agency for Toxic Substances and Disease Registry Public Health Service, US Department of Health and Human Services Before the Subcommittee on Clean Air, Wetlands, Private Property, and Nuclear Safety Committee on Environment and Public Works United States Senate, 1 October 1998. Accessed on 2 September 1999 from http://www.senate.gov/~epw/105th/joh_10-1.htm.

Katz, A. R., Terrellperica, S. & Sasaki, D.M. 1993. Ciguatera on Kauai – investigation of factors associated with severity of illness. *American Journal of Tropical Medicine & Hygiene*, 49: 448–454.

Kim, S-H., Field, K.G., Chang, D-S., Wei, C-I. & An, H. 2001. Identification of bacteria crucial to histamine accumulation in Pacific mackerel during storage. *Journal of Food Protection*, 64(10): 1556–1564.

Kjellstrom, T.P., Kennedy, P., Wallis, S. & Mantell, C. 1989a. Physical and mental development of children with prenatal exposure to mercury from fish. Stage 1: preliminary tests at age 4. National Swedish Environmental Protection Board Report 3080. Solna, Sweden.

Kjellstrom, T.P., Kennedy, P., Wallis, S., Stewart, A., Friberg, L., Lind, B., Wutherspoon, T. & Mantell, C. 1989b. Physical and mental development of children with prenatal exposure to mercury from fish. Stage 2: interviews and psychological tests at age 6. National Swedish Environmental Protection Board Report 3642. Solna, Sweden.

Klausen, N.K. & Huss, H.H. 1987. Growth and histamine production by *Morganella morganii* under various temperature conditions. *International Journal of Food Microbiology*, 5: 147–156.

Lees, D. 2000. Viruses and bivalve shellfish. *International Journal of Food Microbiology,* 59: 81–116.

Lehane, L. 1999. *Ciguatera fish poisoning. A review in a risk-assessment framework.* National Office of Animal and Plant Health, Agriculture, Fisheries and Forestry Australia.

Lehane, L. & Lewis, R.J. 2000. Ciguatera: the risk remains. *International Journal of Food Microbiology*, 61: 91–125.

Lehane, L. & Olley, J. 1999. *Histamine (scombroid) fish poisoning: a review in a risk-assessment framework*. National Office of Animal and Plant Health, Canberra.

Lehane, L. & Olley, J. 2000. Histamine fish poisoning revisited. *International Journal of Systematic Microbiology*, 58: 1–37.

Levin, L. 1998. Statement of Leonard Levin, Ph.D. EPRI Palo Alto, California to US Senate Subcommittee on Clear Air, Wetlands, Private Property, and Nuclear Safety Committee on Environment and Public Works, Washington, DC. 1 October 1998. Accessed 2 September 1999 from http://www.senate.gov/~epw/105th/lev_10-1.htm.

Lindqvist, R. & Westöö, A. 2000. Quantitative risk assessment for *Listeria monocytogenes* in smoked or gravad salmon and rainbow trout in Sweden. *International Journal of Food Microbiology*, 58: 181–196.

Linnan, M.J., Mascola, L., Lou, X.D., Goulet, V., May, S., Salimen, C., Hird, D.W., Yonekura, M.L., Hayes, P., Weaver, R. *et al.* 1988. Epidemic listeriosis associated with Mexican-style cheese. *The New England Journal of Medicine*, 319(13): 823–828.

Mahaffey, K. 1998. MeHg exposure and neurotoxicity (Editorial). *Journal of the American Medical Association*, 280(8): 737–738.

Mascola, L., Tormey, M., Dassey, D., Kilman, L., Harvey, S., Medina, A., Tilzer, A. & Waterman, S. 1996. *Vibrio vulnificus* infections associated with eating raw oysters – Los Angeles, 1996. *Morbidity and Mortality Weekly Reports*, 45(29): 621–624.

McAnulty, J. 1990. *Vibrio* warning. *NSW Public Health Bulletin,* 1: 12.

Mead, P.S., Slutsker, L., Dietz, V. *et al.* 1999. Food-related illness and death in the United States. *Emerging Infectious Diseases*, 5: 607–625.

Morinaga, S., Kawasaki, A. Hirata, A.H. Suzuki, S. & Mizushima, Y. 1997. Histamine poisoning after ingestion of spoiled raw tuna in a patient taking isoniazid. *Internal Medicine*, 36(3): 198–200.

Myers, G. 1998. Statement by the University of Rochester Research Team Studying the Effects of MeHg Read Before the Senate Subcommittee on Clean Air, Wetlands, Private Property and Nuclear Safety, Committee on Environment and Public Works, 1 October 1998 (available at http://www.senate.gov/~epw/105th/mye_10-1.htm).

National Academy of Sciences. 2000. *Toxicological effects of mercury*. The National Academy of Sciences, USA.

Pan, T.M., Chai, T.-J.,Lee, C.L., Chien, S.W. & Horng, C.B. 1997. Foodborne disease outbreaks due to bacteria in Taiwan, 1986 to 1995. *Journal of Clinical Microbiology*, 35: 1260–1262.

Poli, M. A., Lewis, R.J., Dickey, R.W., Musser, S.M., Buckner, C.A. & Carpenter, L.G. 1997. Identification of Caribbean ciguatoxins as the cause of an outbreak of fish poisoning among US soldiers in Haiti. *Toxicon*, 35: 733–741.

Quod, J.P. & Turquet, J. 1996. Ciguatera in Reunion Island (SW Indian Ocean): Epidemiology and clinical patterns. *Toxicon*, 37(1): 779–785.

Richardson, G.M. 1995. *Assessment of mercury exposure and risks from dental amalgam*. Medical Devices Bureau, Environmental Health Directorate, Health Canada.

Rogers, P. & Staruszkiewicz, W. 1997. Gas chromatographic method for putrescine and cadaverine in canned tuna and mahimahi and fluorometric methods for histamine (minor

modification of AOAC Official Method 977.13): *Collaborative study. Journal of AOAC International*, 80(3): 591–602.

Rose, J. B. & Sobsey, M.D. 1993. Quantitative risk assessment for viral contamination of shellfish and coastal waters. *Journal of Food Protection,* 56: 1043–1050.

Ross, T. & Sumner, J. 2002. A simple, spreadsheet-based, food safety risk assessment tool. *International Journal of Food Microbiology*, 77: 39–53.

Ruff, T.A. & Lewis, R.J. 1994. Clinical aspects of ciguatera: An overview. *Memoirs of the Queensland Museum*, 34: 609–619.

Sanyal, S.C. & Sen, P.C. 1974. Human volunteer study on the pathogenicity of *Vibrio parahaemolyticus*, p. 227-230. *In* T. Fujino, G. Sakaguchi, R. Sakazaki & Y. Takeda, eds. International Symposium on *Vibrio parahaemolyticus*. Tokyo, Saikon Publishing Company.

Scoging, A. 1998. Scombrotoxic (histamine) fish poisoning in the United Kingdom: 1987 to 1996. *Communicable Disease and Public Health*, 1: 204–205.

Shalaby, A.R. 1996. Significance of biogenic amines to food safety and human health. *Food Research International*, 29(7): 675–690.

Simidu, W. & Hibiki, S. 1955. Studies on putrefaction of aquatic products. 23. On the critical concentration of poisoning for histamine. *Bulletin of the Japanese Society of Scientific Fisheries*, 21:365 (cited by Taylor, 1986).

Smith de Waal, C., Alderton, L. & Jacobsen, M.F. 2000. *Closing the gaps in our federal food-safety net*. Center for Science in the Public Interest, Washington, DC.

Sours, H.E. & Smith, D.G. 1980. Outbreaks of foodborne disease in the United States, 1972-78. *Journal of Infectious Diseases*, 142: 122–125.

Sumner, J. & Ross, T. 2002. A semi-quantitative seafood safety risk assessment. *International Journal of Food Microbiology,* 77: 55–59.

Takikawa, I. 1958. Studies on pathogenic halophilic bacteria. *Yokohama Medical Bulletin*, 9: 313–322.

Taylor, S.L. 1986. Histamine food poisoning: Toxicology and clinical aspects. *Critical Reviews in Toxicology*, 17(2): 91–128.

Todd, E.C.D. 1995. Estimated costs of paralytic shellfish, diarrhetic shellfish and ciguatera poisoning in Canada, p. 831-834. *In* P. Lassus, P. Arzul, E. Erard, P. Gentien & C. Marcaillou, eds. *Harmful marine algal blooms*. Paris, Lavoiser Publishing.

WHO. 1995. Application of risk analysis to food standards issues. Report of the Joint FAO/WHO Expert Consultation, Geneva, Switzerland. 13–17 March 1995. Geneva.

In recent years, the concept of risk has become paramount in international food regulation, and industries are increasingly required to undertake product risk assessment, particularly in the export arena. This publication has been developed as a complete package on how to undertake risk assessment for use by seafood technologists, regulators and health professionals. It is designed in five parts to guide the user through the risk assessment process. This publication also includes a CD-ROM – the Resources Bank – that provides extensive additional information for the would-be risk assessor.

ISBN 92-5-104951-3 ISSN 0429-9345

9 789251 049518

TC/M/Y4722E/1/04.04/1700