International Journal of
Environmental Health Research **12**, 331–342 (2002)

Balancing risks in the management of contaminated first nations fisheries

CLARE L.S. WISEMAN** and FRANK A.P.C. GOBAS*

Center for Environmental Research, J.W. University Frankfurt, Georg-Voigt-Str. 14, 60054 Frankfurt am Main, Germany Tel.: + 49-69-798-23934; Fax: + 49-69-798-28702; E-mail: wiseman@kristall.uni-frankfurt.de

In the 1980s and 1990s, the Government of Canada closed and/or issued advisories for a number of shellfish fisheries in coastal areas of British Columbia because of dioxin contamination. Only the direct health risks (i.e., cancer) of consuming contaminated shellfish for the general population were considered by the Government in the formulation of risk management options. A focus on the direct risks does not provide an adequate basis for risk decisions as the countervailing risks which may be created from management measures may easily be overlooked. This study describes the potential health impacts of risk management options for aboriginal coastal peoples in the management of dioxin contamination. Gold River and Powell River in British Columbia, Canada, are the areas of focus. The cancer risks of consuming dioxin contaminated shellfish for these sites are estimated. To assess the countervailing risks of management decisions for comparison, a scenario was developed in which First Nations peoples substitute shellfish with store-bought foods in their diets in the event of a fishery closure or advisory. Increases in mortality due to coronary heart disease are estimated. The results suggest that the health risks of dietary changes among aboriginal peoples may be as significant as those related to eating dioxin contaminated shellfish.

Keywords: Comparative risk, dioxin contamination, first nations, shellfish, Canada.

Introduction

In the late 1980s, a national sampling program undertaken by the Government of Canada found that shellfish from coastal areas close to pulp and paper mills in British Columbia (BC), Canada contained elevated levels of chlorinated dibenzo-*p*-dioxins and dibenzofurans (Department of Fisheries and Oceans 1988). Further sampling led the Canadian Department of Fisheries and Oceans (DFO) to first close areas in Howe Sound and Prince Rupert to crab, prawn and shrimp harvesting in 1988 (DFO 1988). Additional shellfish fishery closures followed in 1989, which involved the areas of Kitimat Arm, Gold River, Crofton, Nanaimo, Powell River, Campbell River and Cowichan Bay (DFO 1989). In addition, human health advisories for the consumption of certain fish and shellfish organ meats were issued. Figure 1 provides a map for an overview of the location of sites affected by closures and advisories. As of 1992, closures in BC encompassed an area of approximately 900 km^2. The closures have been progressively lifted since 1995 due to reductions in dioxin loadings from coastal pulp mills closures (DFO 1996).

*Current address: School of Resource & Environmental Management, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.
**Corresponding author: Clare Wiseman, Center for Environmental Research, J.W. University Frankfurt, Georg-Voigt-Str. 14, 60054 Frankfurt am Main, Germany. Tel.: + 49-69-798-23934;
Fax: + 49-69-798-28702; E-mail: wiseman@kristall.uni-frankfurt.de

ISSN 0960-3123 printed/ISSN 1369-1619 online/02/040331-12 © 2002 Taylor & Francis Ltd
DOI: 10.1080/0960312021000056438

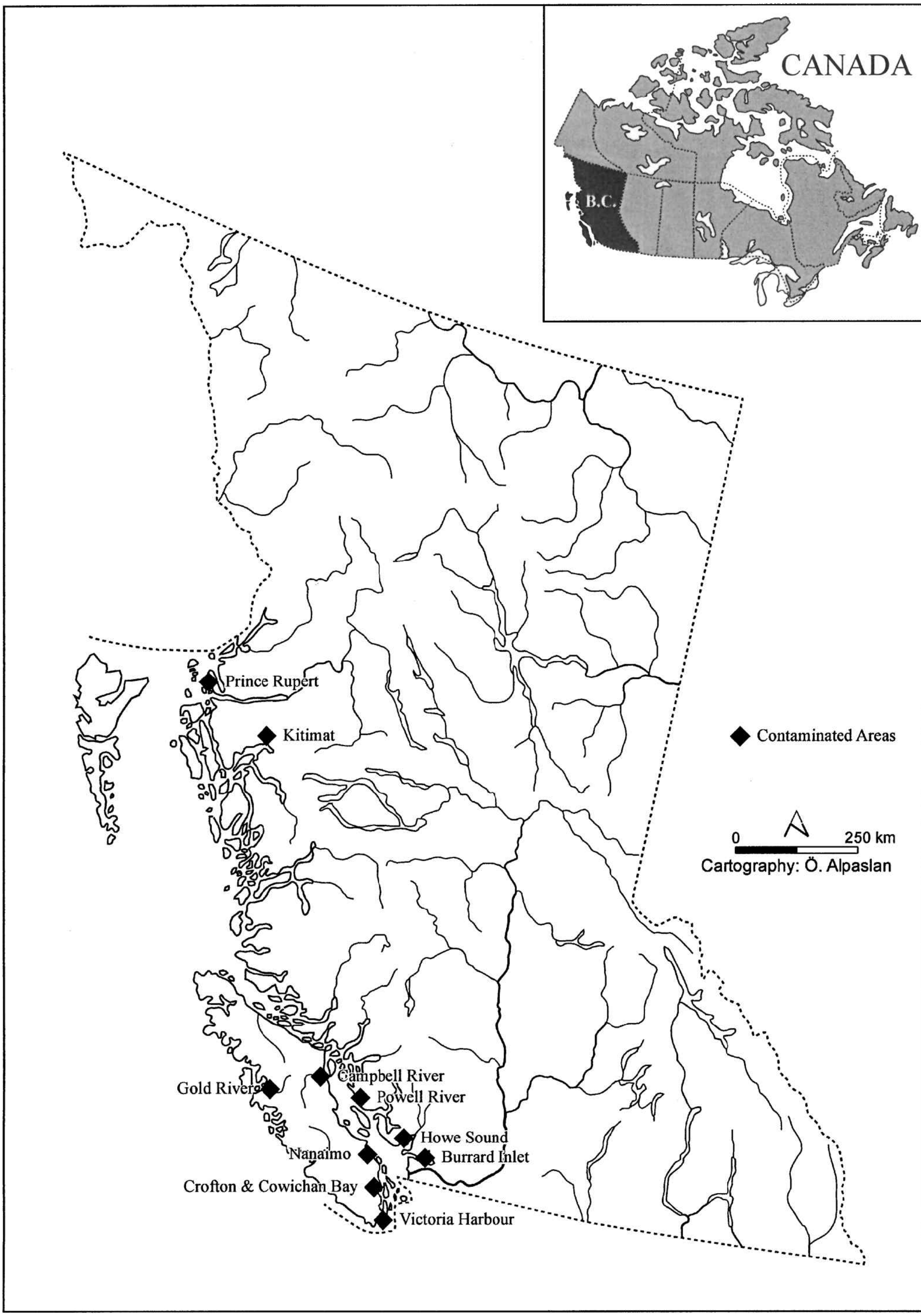

Fig. 1. Map of dioxin-contaminated sites during the 1990s in BC, Canada.

There are significant numbers of First Nations peoples scattered along the entire coastline of BC, for whom fishery resources, including shellfish, comprise a significant part of the diet. The fishery closures and consumption advisories of the 1980s and 1990s encompassed a large number of aboriginal fisheries, forcing many to change their harvesting and eating patterns. From a toxicological risk perspective, such risk management measures appeared to have been a necessary measure to protect the health of both aboriginal and non-aboriginal Canadians. From a nutritional perspective, however, the interruption of traditional harvesting and consumption patterns may also entail health risks. As has been already been argued by others, fishery closures and advisories may, in fact, cause more harm than good in terms of aboriginal health (Wheatley and Paradis 1996, Egeland and Middaugh 1997). Such risk management strategies may also disrupt the cultural and social well-being of First Nations peoples. By advising reduced consumption of contaminated country foods, aboriginal persons may be indirectly encouraged to eat more store-bought foods, which are often nutritionally inferior to country foods (Kuhnlein 1991, 1992, 1995, Health Canada 1994). Market foods generally contain greater amounts of saturated fats. For example, regular ground beef contains about 18 g of fat per 90–g serving (Williams 1995), while the body and leg tissue of Dungeness crab (*Cancer magister*) contains approximately 1 g (King *et al.* 1990). The increased consumption of fat, notably saturated fat, is strongly correlated to, among other diseases, enhanced risks of coronary heart disease or CHD (Feldman 1994). To the extent that fishery closures and consumption warnings encourage diet changes, they may promote the substitution of dioxin-related health risks with that of CHD and potentially other diseases. In other words, a risk trade-off may occur. Past risk management practices involving fishery closures and consumption advisories have often ignored indirect risks and associated risk trade-offs.

This study is a retrospective analysis of the Government of Canada's risk management strategy for coastal areas of BC. The objective is to assess the health risks posed to aboriginal populations related to the consumption of contaminated shellfish and their dietary substitution with more fatty store-bought foods. It must be emphasized that the purpose is not to simply produce measures of risk and conduct direct comparisons. The intent is also not to make recommendations regarding diet as decisions regarding acceptable risk should lie with aboriginal peoples. Rather, the goal of this study is to illustrate the need for government agencies to be culturally sensitive in their assessments of risk and to examine the broader implications of their risk management decisions before they are employed.

Methodology

The excess cancer risks posed to aboriginal peoples in consuming dioxin- and furan-contaminated crustacea and molluska from two of the areas which were targeted by DFO for management, Powell River and Gold River, are quantified. Gold River is located on the west coast of Vancouver Island, a region which belongs to the traditional territory of the Nuu-chah-nulth people, an amalgamation of 14 tribes consisting of about 7,000 members (Read 1995). In Gold River, itself, there is the Ahahminquus community of the Mowachaht Tribe, which had a population of about 200 in 1993. The Sliammon, who are Northern Coast Salish peoples, reside in the Powell River area (Kennedy and Bouchard 1990). The majority of Sliammon peoples (over 500), live on the Sliammon Reserve No. 1, which is located in the fishing zone impacted by closures and advisories.

Estimating the excess cancer risk of shellfish consumption

Ambient concentrations Concentrations in shellfish (C_i in mg/kg) of the 17 dioxin and furan congeners that are of greatest toxicological concern measured by DFO in 1990 were used for the analysis (DFO 1990). Dietary concentrations of each of the dioxin and furans were expressed in terms of an equivalent concentration of 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (TCDD) by multiplying the predicted concentrations of each congener i by the toxic equivalent factor (TEF_i) of that congener to obtain a toxic equivalent concentration (TEC_i):

$$TEC_i = TEF_i \times C_i \tag{1}$$

The recently revised TEFs from WHO (Van den Berg 1998) were used. The total toxic equivalent concentration ($\sum TEC$) was determined by summing the TEC_i for all the congeners assuming that the TEC_i are additive at environmental concentrations. Where non-detectable values were reported for congeners, a value of half the detection limit was used (Travis and Land 1990).

Dietary consumption rates Adult First Nation shellfish consumption rates were estimated from the results of a diet survey carried out by Health Canada in 1994 of members of a First Nation located on the coast North of Vancouver, BC. Although willing to release dietary information to the authors, the Band has requested that their identity not be disclosed. The survey entailed two different question periods, one in summer and one in winter, involving a total of 111 persons out of a total population of approximately 1200. The daily consumption rates which were reported by each adult (i.e., over 18 years) for crab muscle, crab hepatopancreas, clams and shrimp/prawns in both survey periods were averaged to yield daily rates over the course of a year. Due to the absence of oysters in the survey area, the oyster consumption rate reported by survey participants would not be reflective of the oyster intakes by aboriginal peoples in other coastal areas where these molluska are abundant. For this reason, reported clam consumption rates, which were considerably higher, were assumed to equal oyster consumption rate in other communities (i.e., Gold River and Powell River). Estimated arithmetic and geometric averages for the consumption rate of each food item are reported in Table 1. The upper and lower 95th percentiles of the derived lognormal consumption distributions are also shown. It should be noted that the survey population lives in an area that has been impacted by pollution since the early 1970s. The survey results may therefore not be reflective of traditional eating patterns for peoples located in other areas and must be interpreted with caution. Other data sources on the aboriginal consumption of specific shellfish types or species needed to conduct such an analysis of risks as done here were however not available.

For all four shellfish species/tissues combined, the survey participants were estimated to consume an average of 26 g/day, with 59 g/day and 104 g/day at the 90th and 95th percentiles, respectively. For comparison, the US EPA Exposure Factors Handbook (1997) recommends an average consumption rate of 6.6 g/day for freshwater/estuarine fish (finfish and shellfish) and 13.5 g/day for marine fish for the general population. For Native American subsistence populations, an assumed mean intake value of 70 g/day and a 95th percentile of 170 g/day for total fish is recommended. A survey conducted on Asian and Pacific Islanders in King County, Washington (Sechena *et al.* 1999), who are very high consumers of fish and shellfish, reported a mean shellfish consumption rate of 53.8 g/day and a 90th percentile of 107.1 g/day. This is higher than that reported by the survey respondents here, which would suggest that reported

Table 1. Estimated averages for aboriginal shellfish consumption rates (g/day) and the 5th and 95th percentiles from the dietary survey

Species/tissues	*Arithmetic average*	*Geometric average*	*5%*	*95%*
Crab	16.8	9.4	1.5	55.7
Crab organs	1.4	0.8	0.1	4.3
Prawns/shrimp	6.2	3.7	0.7	19.3
Clams	15.9	8.3	1.2	51.5

rates are too low or that Asians and Pacific Islanders consume shellfish in greater proportions than aboriginal populations.

Dioxin risk assessment The exposure dose (E in mg/kg per day) for First Nations peoples consuming a mixed diet located in the study areas was estimated using the calculated TEC in the edible part of consumed species (in mg/kg), the daily consumption rate of each species (F in kg/day) and human body weight (W in kg) as

$$E = \sum \text{TEC} \times F/W \tag{2}$$

It was assumed that the exposure dose and effective dose are the same. Data on body weight was derived from an anthropometric survey of First Nation peoples conducted by the Department of National Health and Welfare in the 1970s (Department of National Health and Welfare 1980). Values reported for *Indian* adults in this survey were used to calculate a mean body weight of 70.5 kg with a standard deviation of 14.9 kg.

To extrapolate dioxin risk to the low dose range, a cancer potency factor (CPF) of 9700 was applied. This CPF was calculated by Keenan *et al.* (1991) using a linearized form of the multistage model and the results of a histopathological re-evaluation of hepatic lesions in female Sprague–Dawley rats exposed to TCDD in the Kociba *et al.* (1978) study.

The excess lifetime cancer risks (R) of consuming contaminated shellfish were calculated probabilistically for each study area using the Monte Carlo simulation program Crystal Ball (Decisioneering Corp.) as

$$R = E \times \text{CPF} \tag{3}$$

Lognormal distributions were used for the model inputs (i.e., TECs, body weight and consumption rates). Uncertainty was then propagated using Latin Hypercube Sampling (LHS). LHS was used because it stabilizes the tails of the output distributions more quickly than does standard Monte Carlo simulation (Burmaster and Anderson 1994). Simulation runs were then executed using 10,000 iterations. Initial 'seed' values were generated by the program in a random fashion.

Estimating the health risks of fishery closures

Based on the observed relationship between dietary fat intakes, serum cholesterol levels (Brown and Smith 1995, Feldman 1994) and enhanced CHD risks, it was postulated that changes in dietary saturated fat and cholesterol intakes due to the substitution of shellfish with store-bought foods would be associated with an increase in CHD risk. Two risk assessment scenarios were developed to estimate potential increases in CHD mortality rates among coastal aboriginal peoples due to possible dietary changes in response to fishery closures and advisories. In scenario 1, it was assumed that shellfish-eaters would eliminate crab muscle from their diets and eat an equivalent amount of a combination of common store-bought protein alternatives, i.e., chicken, beef and pork. For the scenario 2, it was assumed that individuals would substitute crab muscle, clam and prawn/shrimp with equivalent amounts of chicken, beef and pork. This would represent a 'worst case scenario'.

The choice to use chicken, beef and pork as protein substitutes was arbitrary. It was assumed that shellfish from other non-contaminated areas could not be obtained. The assessment of increases in CHD mortality due to the dietary substitution of shellfish with store-bought protein alternatives was conducted as follows. First, the amount of each food item reported to be consumed daily by each adult individual was derived for each person who participated in the survey. Second, the total daily diet consumed by each person was analyzed and the fraction of total energy consumed as saturated fat (DSF in %) was calculated for each person as:

$$\mathrm{DSF} = \mathrm{DFI} \times 9/\mathrm{DEI} \tag{4}$$

where DFI is the total daily saturated fat intake (g), 9 is the amount of energy contained in 1 g of fat (kcal/g) and DEI is the total daily energy intake (kcal). Third, the change in the DSF consumed as a result of diet substitution was then estimated for each individual under each scenario. An overall average change in the DSF was then calculated for males and females separately. Finally, the change in DSF was used to estimate a change in mortality following the work of Browner *et al.* (1991). They calculated that each 1% change in saturated fat intake results in a 3 mg/dl or 0.08 mmol/l change in serum cholesterol concentrations. Estimates in changes in CHD mortality among Americans were then calculated using established risk factors from well-known studies such as the Framingham Heart Study (Anderson *et al.* 1987) for specific serum cholesterol levels. For males, CHD mortality rates were estimated to undergo age-dependent reductions on the order of 5–16% as a result of changes in saturated fat intakes. Age-dependent reductions of 6–10% were predicted to occur for women. Although the assessment methodology by Browner *et al.* (1991) entailed estimating reductions in CHD mortality rates resulting from reductions in fat intakes, the linear relationship used can also be applied to estimate increases in excess CHD deaths as a function of increases in serum cholesterol levels due to dietary changes. To apply this assessment methodology, it was assumed that serum cholesterol levels are the only mediating factor through which saturated fat affects CHD mortality.

Increases in the annual excess CHD mortality (ECHDD) as a result of a dietary change from shellfish to a mix of beef, pork and chicken were assessed as

$$\mathrm{ECHDD} = (\Delta\mathrm{CHDD} \times \Delta\mathrm{SF}/0.07) \times \mathrm{CHDDR} \tag{5}$$

where ΔCHDD is the proportional change in CHD deaths among the U.S. population (from Browner *et al.* 1991) for a 7% change in saturated fat intake, ΔSF is the proportional change in the amount of daily energy consumed as saturated fat among aboriginal peoples due to a dietary change and CHDDR is the annual crude aboriginal CHD death rate. First Nation mortality rates were based on the reported number of CHD deaths (listed as Ischaemic Heart Disease, ICD9

Table 2. Estimated mean and upper 95th percentile of dioxin-related excess cancer risks as expressed by number of individuals affected per 10,000 based on 1990 concentration data

Area	*Mean excess cancer cases/10,000*	*Upper 95% of excess cancer cases/10,000*
Gold River	3	9
Powell River	1	2

Code 410–414, 4292) for British Columbia Status Indian males and females from 1987 to 1993 (Health Canada 1995). Annual crude aboriginal CHD death rates of 10.4/10,000 men and 4.9/10,000 women were calculated according to given annual population estimates for this period. Deaths were unfortunately not reported for age-specific groups.

Again, Monte Carlo Simulation using Crystal Ball (Decisioneering Corp.) and the LHS option was applied to perform a probabilistic analysis of the annual excess aboriginal CHD mortality. Lognormal distributions were used to describe changes in the proportion of total energy consumed as saturated fat for the sample population. Estimated proportional changes in CHD mortality rates from Browner *et al.* (1991) were defined by a triangular distribution, which is often recommended when the actual distribution is difficult to establish (Finley *et al.* 1994). In addition, a uniform distribution was also used to determine the sensitivity of this parameter in terms of the distribution applied.

Results

Table 2 displays the predicted number of individuals at risk of developing dioxin-related cancer per 10,000 over 70 years (i.e., assumed to be an average life-time) from consuming a contaminated mixed shellfish diet for the two study areas in 1990. Approximately three cases of cancer per 10,000 over a 70–year period (mean estimate) are estimated to occur in aboriginal communities in Gold River due to the consumption of a mixed diet of dioxin-contaminated shellfish targeted for management (i.e., crab muscle and hepatopancreas and prawn). In Powell River, a mean of about one cancer case per 10,000 is predicted as a result of consuming a mixed diet of shellfish from the contaminated area (i.e., crab muscle and hepatopancreas and oyster).

Estimated mean excess CHD deaths per 10,000 aboriginal men and women over a 70–year period, due to the replacement of shellfish products by store-bought foods are shown in Table 3. There were no differences in estimates in using a uniform distribution, compared to a triangular one, to describe estimated proportional changes in CHD mortality from Browner *et al.* (1991). The estimated mean excess CHD deaths represent the extra number of CHD-related deaths due to dietary changes, not the expected total. For scenario 1, in which only crab tissues were substituted with store-bought foods, the mean excess CHD mortality was estimated to be six and two deaths per 10,000 populations over 70 years for males and females, respectively. In the event that crab, clam and prawn/shrimp are displaced from the diet as postulated in scenario 2, a mean of 10 deaths per 10,000 males and three deaths per 10,000 females are estimated. The upper 95th percentiles of the excess CHD death rate range between 19 males and seven females for scenario 1 and between 32 males and 10 females for scenario 2.

Table 3. Estimated increases in excess CHD mortality/10,000 among First Nations over a 70–year period

	Males		*Females*		*Both*	
Diet scenario	*Mean CHD deaths/10,000*	*Upper 95%*	*Mean CHD deaths/10,000*	*Upper 95%*	*Mean CHD deaths/10,000*	*Upper 95%*
Scenario 1	6	19	2	7	4	13
Scenario 2	10	32	3	10	6	21

Discussion

A simple comparison of the results suggests that the risks of consuming contaminated shellfish from the study areas in 1990 are comparable to (and may even be somewhat greater than) those associated with diet substitution. Hence the fishery closures and consumption advisories may have resulted in the substitution of one health risk with another that is at least as great. The results highlight the need for government agencies to conduct risk assessments and make decisions that are culturally sensitive, requiring a full analysis of the potential exposed populations and how they may be impacted by different management options.

Caution should be exercised, however, in the interpretation of results. As is the case with most risk assessments, a number of simplifying assumptions were made for analytical purposes. Further, there are some uncertainties associated with the data used. The choice of the method used to assess dioxin risk can, for instance, significantly affect estimates. One could argue that the CPF used here (i.e. 9,700) is too low. That which has been used by the US EPA is considerably higher (i.e., 156,000) and may even be increased by this agency once their reassessment of dioxin exposure and human health effects is complete. Nonetheless, even the use of a CPF of 156,000 would have resulted in cancer risk estimates not greater than that predicted for CHD due to a change in diet (i.e., three and 14 cancers per 10,000 for the upper 95th percentiles for a mixed diet in Powell River and Gold River, respectively).

Further, the approach taken here is more conservative than the method used by Health Canada to assess dioxin risk. The use of a CPF calculated using a linearized form of the multistage model assumes linearity between dose and response in the low dose range. In contrast, Health Canada uses a safety factor approach which assumes the existence of a threshold level (Feeley and Grant 1993). By applying a safety factor of 100 to a NOEL of 1,000 pg TCDD/kg per day, Health Canada has established a tolerable daily intake of no more than 10 pg TEQ/kg per day. Risks can not be quantified using this approach, which makes it difficult to make risk comparisons and management decisions which are readily standardized according to definitive, probabilistic risk levels.

Additionally, it was assumed that individuals would automatically replace shellfish with equal amounts of beef, chicken and pork if a fishery closure or consumption advisory is in place. This, of course, may not be the case in reality. People may, for instance, eat greater amounts of fishery resources from other non-contaminated areas. If such areas are further away from aboriginal communities, however, this may be problematic for some. Unlike non-aboriginal fishermen, First Nation peoples tend to harvest in areas close to their communities. For instance, it was estimated that aboriginal peoples in Ontario travel an average distance of only 26.3 km to fish

(E.A.G.L.E Project 1996). Non-aboriginal fishermen, in contrast, travel an average distance of 119 km. In light of this, it would not be unreasonable to assume that at least some First Nation peoples would reduce their consumption of country foods if they live in an area that is impacted by pollution. The choice to replace shellfish with equal amounts of chicken, beef and pork may have in fact resulted in an underestimation of CHD risks. An analysis of the actual diets consumed by survey respondents suggests that even higher fat store-bought foods may be chosen by many as alternatives. Specifically, eggs, hamburger, luncheon meats and wieners were among the top five favorite meats consumed by survey participants (i.e. g/day consumed).

The results of the diet survey used is another source of uncertainty in terms of both the estimated dioxin and CHD risks. As mentioned previously, a traditionally important local fishery for the Band members who participated in the survey, has been affected by pollution problems including dioxin contamination since the 1970s. This is likely to have caused a reduction in shellfish consumption and may not be representative of country food consumption patterns elsewhere. There is some survey data available on other aboriginal communities but it is either is restricted to fish consumption or is reported in such a form to protect the First Nation under study which makes it difficult for use by others. Further study on shellfish consumption patterns and the reporting or release of data with First Nation approval is needed to allow for scientific reproducibility and validation. If the consumption rates reported here are lower than for other First Nation peoples, we can expect that the actual risks of both dioxin contamination and that associated with a change in diet would be greater.

There are also other human health risks associated with both dietary changes and dioxin exposure that were not considered in the analysis which may be more insidious and effect greater numbers of exposed peoples. In particular, the potential for dioxin and furan exposure to induce a number of immunological, reproductive, neurological or developmental toxic effects (e.g., Davis and Safe 1988, Olson *et al.* 1990, DeVito *et al.* 1992) may warrant the need for protective measures which force a reduced consumption of contaminated foods.

It should also be stressed that there are a number of benefits associated with the harvesting and consumption of fish and shellfish. The physical health of First Nations peoples is closely intertwined with their social and cultural well-being (Elliot and Foster 1995, Read 1995, E.A.G.L.E Project 1996). This, in turn, is strongly connected to their relationship with the environment. Although the socio-cultural benefits of shellfish harvesting are not easily measured in quantifiable terms, their consideration is important. Country food harvesting in general involves certain traditional values, practices and customs which are culturally significant. Further, by supplementing the diet with resources available from the local environment, the costs of market foods can be off-set (Health Canada 1994). Although such socio-cultural and economic factors did not receive attention in this study, they should not be ignored in management decisions. As such factors are not easily estimated, and the methods which have been developed to quantify them involve a great deal of subjectivity, aboriginal peoples need to be involved in the assessment of risks and benefits and their comparison.

Conclusions

The results of this analysis suggest that the risk management activities undertaken by the Government of Canada to protect Canadians from the risks of consuming dioxin-contaminated shellfish may have served to create countervailing risks for aboriginal peoples in coastal areas. Specifically, a possible dietary change induced by fishery closures and consumption advisories may have caused the cancer risk to be substituted with a coronary disease risk that is at least as great. While a variety of limitations may serve to reduce the accuracy of results and the appropriateness of making risk comparisons, this should not detract from the main conclusion of this study; that is, the need for risk regulators and managers to think beyond the direct risks of concern and to be culturally sensitive in their decision-making. In light of the study results, it is recommended that decision-making processes regarding the use of fishery closures and advisories should consider the potential risks of such management actions.

Ultimately, the choice of management options, however, involves subjective decisions regarding risk tradeoffs and acceptable risk. Aboriginal peoples should thus be involved in the formulation of future fishery risk management activities. With their involvement, risk management decisions that unnecessarily or unfavorably impact the harvesting and consumption of country foods may be avoided in the future.

Acknowledgements

We would like to thank the First Nations Band in BC which granted us access to data from the diet survey, without which this study would not have been possible. We would further like to thank the reviewers for their valuable comments regarding this paper.

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