Should we be frightened of bracken? A review of the evidence

Deborah Wilson, Liam J Donaldson, Ovnair Sepai

Abstract
Objective—To assess the risk to human health of the plant bracken (Pteridium sp).

Design—An evaluation of studies of human and animal populations exposed to bracken, together with a review of expert reports and advice to the public.

Main results—Bracken induced disease has been demonstrated in animals in both laboratory and field studies. Depending on the species, diseases in animals associated with the plant have included: cancers of the alimentary and urogenital tract, lung and breast; haematuria; retinal degeneration; and, thiamine deficiency. Potential exposure of human populations is through: food either directly (people in some parts of the world eat bracken as a traditional dish) or indirectly by consuming animals fed on bracken; milk; water; inhalation and ingestion of spores; and insect vectors. Four studies of human populations (two analytical and two observational) failed to assess adequately confounding factors and other sources of bias, so that conclusions about a risk to human health from bracken cannot firmly be drawn. Establishing exposure is also extremely difficult in populations (such as the United Kingdom) where direct consumption of bracken is rare.

Conclusion—Bracken is a common plant worldwide. It is toxic to many animal species and to several organ systems. There is no tumour (or other disease) that is pathognomonic of exposure in animals, though cancers of the alimentary and urogenital tract seem to be the most commonly associated. It is not possible to extrapolate from animal models to humans. Studies of human populations, do not establish a clear risk of bracken to human health, largely because of methodological problems. Testing the evidence against traditional criteria of causality only fulfils the criterion of biological plausibility. Despite this, current public information implies a serious risk to human health from bracken, and increasing media coverage of the subject is likely to lead to greater public concern. Further epidemiological studies are required.

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Human health? Headlines such as “Curse of the killer bracken” and a warning on the British Broadcasting Corporation’s Countryfile programme to avoid bracken or use masks during the sporing season are capable of causing considerable public alarm about this issue. The Bracken Advisory Commission’s leaflet on risks associated with bracken provides helpful advice about avoiding sheep ticks in bracken, but also states that “it is highly advisable to keep well away from it. When it is sporing, avoid being downwind of it,” and comments on “the cancer threat posed by inhaling bracken spores.”

In the light of this range of practical advice to the public that implies that there are dangers, is there evidence that bracken presents a threat to human health?

Background
The fern, bracken (Pteridium sp) is an ancient plant that grows in abundance worldwide except in very cold or dry conditions. Many interest groups have focused their attention on bracken, either because of the belief that as a plant mass it is interesting or because of concerns about its ability to have deleterious effects on animals, human activities and even, human health. An International Bracken Group was established in 1985. Table 1 shows the potential range of interest in bracken by expert bodies.

The area of land covered by bracken is difficult to assess and calculations are often imprecise. Estimates of bracken encroachment are also problematic. Aerial photography and land survey are the most commonly used methods. Bracken invades land when the conditions are favourable, typically land that is underused or woodlands in decline. Such conditions may be because of: replacement of cattle by sheep; overgrazing; woodland clearance; drainage of moorland and rough pasture; cessation of bracken cutting; and, farming “set-aside” policies. Global warming may also accelerate encroachment of bracken onto highlands.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Potential range of expert interests in bracken</th>
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<tr>
<td>Biological sciences — zoology, botany, genetics, taxonomy, toxicity, carcinogenicity, spore studies</td>
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<tr>
<td>Earth sciences — geography, geology, climate change, soil studies</td>
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<tr>
<td>Environmental health — risk to animals and humans</td>
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<tr>
<td>Social sciences — change in land use, economic and cultural changes, cultural history</td>
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<tr>
<td>Rural sciences — agricultural systems, forests and bracken, agricultural economics, land use, bracken control</td>
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<td>Medical and veterinary services</td>
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<tr>
<td>Government — Ministry of Agriculture Fisheries and Food (MAFF), Department of Health, Department of the Environment</td>
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<td>Health and Safety Executive</td>
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Should walkers and agricultural workers be warned to avoid bracken covered areas in the sporing season or wear facemask protection? Is there good evidence that bracken damages...
Table 2  Diseases in animals associated with bracken

<table>
<thead>
<tr>
<th>Disease</th>
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<tr>
<td>Induced thiamine deficiency in horses and pigs</td>
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<tr>
<td>Acute poisoning (causing bone marrow dysplasia) and enzootic haematuria in cattle and sheep</td>
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<tr>
<td>Cancers of urogenital and alimentary tract in cattle</td>
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<tr>
<td>Bladder tumours in guinea pigs</td>
</tr>
<tr>
<td>Progressive retinal degeneration (bright blindness) in sheep</td>
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<tr>
<td>Ileal adenocarcinomas in rats fed on bracken</td>
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<tr>
<td>Interaction of papillomavirus and bracken consumption associated with cancer of the alimentary canal in cattle</td>
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<tr>
<td>Bracken as an important habitat for sheep ticks (Ixodes ricinus) in the UK</td>
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<tr>
<td>Bracken may act as an immunosuppressant that activates latent papillomavirus causing premalignant bladder lesions in cows, then acts as co-carcinogen with the virus to progress to cancer</td>
</tr>
<tr>
<td>100% of mice fed on bracken fern for three months developed pulmonary tumours compared with 7% of controls</td>
</tr>
<tr>
<td>37% of mice fed on milk from bracken fed cows developed pulmonary tumours and 27% of female mice developed mammary tumours, compared with 7% and 0% in controls</td>
</tr>
<tr>
<td>A calf fed on milk from a bracken fed cow showed evidence of severe immunosuppression</td>
</tr>
<tr>
<td>Mice fed on spores developed significantly more mammary tumours than controls and also more gastric tumours and leukaemia. Ingestion of fresh spores, not dried, was associated with gastric tumours</td>
</tr>
<tr>
<td>Approximately one third of the offspring of mice who had ingested milk from bracken fed cows developed pulmonary tumours and/or mammary tumours. This suggests that a carcinogen may have passed to the offspring during gestation or lactation in their mothers</td>
</tr>
</tbody>
</table>

Effects on animal health

Bracken carcinogenicity in animals was first demonstrated in 1965. Subsequent studies (in the field and laboratory) have associated the ingestion of bracken (or its extracts) with diseases and cancers of many sites in many animal species. Rats, guinea pigs, sheep, cattle, hamsters, quails, toads have all developed tumours after the ingestion of bracken or its extracts. Table 2 illustrates some of the animal diseases that have been associated with the consumption of bracken or its extracts.

Possible toxic agents in bracken

Crude bracken extracts have been found to be positive in the Ames mutagenicity assay but only after bioactivation with liver microsomal systems. Several agents within bracken have been investigated for evidence of carcinogenicity, including quercetin, shikimic acid, and ptaquiloside. The toxic constituents have not been unequivocally identified. Studies are being carried out to determine the chemical nature of the toxin. These studies have revealed that many of the constituents of bracken have low cytotoxic activity and therefore are not directly linked to the aetiology of acute fern poisoning. The International Agency for Research into Cancer (IARC) reported in the late 1980s that, although there is sufficient evidence for the carcinogenicity of bracken in animals, there is inadequate evidence for it to be regarded as a human carcinogen.

Ptaquiloside is a toxin isolated from bracken, which has been described as almost certainly the major carcinogen in bracken fern by Smith and Seawright. The Dutch Expert Committee on Occupational Standards state that ptaquiloside is or should be considered as carcinogenic to humans. As ptaquiloside can be potentially transferred to humans via milk, it is necessary to monitor the grazing habits of dairy herds. Japanese workers have looked at the clastogenic effects of ptaquiloside and conclude that the carcinogenic potency may result from these clastogenic effects. The spectrum of DNA damage caused by ptaquiloside resembles that of classic alkylating agents.

Shikimic acid and Cyclohexane carboxylate (a metabolite of shikimic acid) show little evidence of carcinogenicity from animal studies and inadequate evidence for carcinogenicity in humans. They are not mutagenic in the Ames assay. Although shikimic acid is unlikely to be a carcinogenic initiating agent, it may act as a carcinogen promoting agent in the bracken fern.

Quercetin has been found to be non-genotoxic and is not thought to play a part in the carcinogenicity of the bracken fern.

Povey et al administered bracken spores and bracken extracts to mice to investigate whether such exposure leads to the formation of DNA adducts. DNA isolated from the upper intestinal tract and liver was digested to 3’ nucleosides. Adducts were extracted and analysed using documented methods. Bracken induced DNA adducts were detected and it may be possible to apply these methods to determine human exposure. These studies also
showed that DNA reactive compounds were released slowly from spores. These bracken induced DNA adducts may have arisen from ptaquiloside and their formation may result in the carcinogenic action of ptaquiloside. As with all biological monitoring techniques, it is necessary to synthesise the putative carcinogens before it is possible to definitively identify their mode of action.

Boiling bracken fronds in alkaline conditions seems to render them less harmful, presumably by inactivating some of the toxic agent(s). The Japanese boil fronds in water and soda ash, this process would reduce the carcinogenicity before eating.37

Possible pathways of bracken through humans
Figure 1 shows theoretical pathways between bracken and humans.

FOOD
Bracken is not traditionally part of the British diet, but in Japan and some areas of South America the fronds are eaten.38 Bracken rhizomes were a traditional food of Maori and Aborigines.39 Some observational studies have found an association between consumption of bracken and human stomach and oesophageal cancers. Daily intake of bracken in Japan was associated with increased risk of oesophageal cancer (2.1-fold in men and 3.7-fold in women).40 The risk of eating meat from animals fed on bracken is unstudied and unknown.

MILK
Ptaquiloside has been found in milk from bracken fed cows41 and drinking such milk has been associated with cancers in animals.25 However, it is thought that dilution resulting from the bulk processing of milk would make any risk from milk in the UK quite remote. This route of exposure may be more relevant in small, geographically remote rural communities, such as parts of Costa Rica.42

WATER
There is no evidence that water contaminated by bracken causes human disease despite the fact that it has been shown that some toxic compounds in bracken are water soluble and therefore could possibly leach into water sources.43

INHALATION AND INGESTION OF SPORES
As spores have been found to be carcinogenic in mice,17 there is a theoretical risk that inhalation and subsequent ingestion could be carcinogenic in humans. There have been no studies of the effects of exposure of animals to airborne spores, only direct ingestion of spores. The study by Povey et al36 shows that, in mice, spores administered by gavage produce DNA adducts. The significance of these adducts needs further investigation.

SKIN
There have been no studies of the effects of bracken on humans or animals resulting from direct skin contact. This route would seem an unlikely cause of disease.

TERATOGENICITY
There is some evidence that mice whose mothers had been fed milk from bracken fed cows developed more pulmonary and mammary tumours than controls.25
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**Insect Vectors of Disease**

Bracken is an important habitat for sheep ticks (*Ixodes ricinus*) in the UK, which are the major vector for Lyme disease caused by *Borrelia burgdorferi.*

**Studies on Human Health**

Much of the speculation about harmful effects of bracken on human health is based on its effects in animals. However, studies exploring the relation between bracken and human health have concentrated on stomach and oesophageal cancer. Stomach cancer incidence is highest in Japan, Central and South America. Within the United Kingdom, the highest incidence is in North Wales. Incidence is also higher in the north than the south and in western areas compared with eastern areas of Britain. Other risk factors associated with gastric cancer include blood group A, atrophic gastritis and, pernicious anaemia, cigarette smoking, dietary factors (such as spicy foods and nitrate consumption), and lower social class. It appears to be commoner in coal miners and some chemical workers. Residents from areas with a high incidence of stomach cancer seem to maintain this risk after migration, but their children do not, suggesting an environmental factor in the etiology. Like many cancers, stomach cancer is probably multifactorial.

In common with many environmental exposures, bracken exposure is very difficult to measure. Studies estimate exposure using: past or present residence or occupation in a bracken rich area; recall of past or recent buttermilk consumption in a bracken rich area; history of eating bracken. The few studies looking directly at associations between bracken and human disease are discussed below.

A case-control study was prompted by the high incidence of gastric cancer in North Wales. It was part of a larger study of gastric cancer. A questionnaire elicited intake of various foods, particularly those containing retinol, salt, β-carotene, and vitamin C. No clear hypothesis regarding bracken formed part of the study’s aims. One hundred and one histologically confirmed gastric cancer cases were compared with 77 cancer controls and 202 non-cancer controls. All patients were residents of Gwynedd, Wales and were recruited from three local hospitals. Controls were not eating any special diet, nor were they suspected of having peptic ulceration. Cases and controls were matched for age, sex, and social class. The 101 cases represented just over one third of all stomach cancers. Selection, recall, and observer bias were all potential problems of this study and the methods and analysis are difficult to follow. The study appears not to consider cigarette smoking or other known risk factors for stomach cancer.

Buckley et al compared standardized mortality ratios and incidence rates (1974–1988) for stomach and oesophageal cancer from the cancer registry for the 34 districts in Gwynedd to 1968 survey maps of bracken, deep and shallow peat and areas with non-mains water supply. There was no apparent hypothesis, but the study assumed that these factors may be associated with stomach cancer. No spatial correlation was found. Multiple regression analysis considering only rural districts and combining all carcinogen sources found some statistically significant correlations that are difficult to interpret as the analyses are poorly described. The authors concluded that there existed a positive correlation between bracken and stomach cancer for men and women and with oesophageal cancer for men alone. The study did not seem to take account of how long the cases had lived in the area assigned to them or to analyse confounding factors such as smoking or social class.

A large prospective study in Japan found that eating bracken significantly increased the risk of oesophageal cancer, but only when combined with drinking hot gruel tea (chagayu).

Specific age incidence rates of cervical, gastric, and oesophageal cancers in people born in bracken infested and bracken free areas in Costa Rica were compared by Villalobos-Salazar et al. Incidence data were extracted from the National Cancer Registry. “Bracken—

**Key Points**

- Bracken is carcinogenic in many animal species.
- Humans may be exposed to bracken by the inhalation and subsequent ingestion of bracken spores.
- Measuring human exposure to bracken is difficult—in the future monitoring of bracken induced DNA adducts may be helpful in determining exposure.
- There is no confirmed association between exposure to bracken and human disease.
- The possibility of a risk to human health from bracken warrants further research, perhaps focusing on outdoor workers.
infested” and “bracken-free” were defined according to height above sea level, a method validated in a previous study. The authors did not present any tests of statistical significance but reported that the age-standardised incidence of gastric and oesophageal cancer in women and all persons born in bracken infested areas were at least twice that of those born in bracken free areas.

No studies of the health effects of bracken on forestry and other outdoor workers regularly occupationally exposed to inhalation and ingestion of bracken spores appear to have been performed.

Assessing the evidence
Using the so called “criteria for causality” the quality of the evidence of an association between bracken and human cancer can be explored.

Strength of association—a strong association between a factor and a disease is less likely to occur by chance or error than a weak one. In animals, the strength of association between bracken consumption and cancers is high, but in humans the strength of association is approximately double that of controls. In animals, the strength of association between a factor and a disease is less likely to occur by chance or error than a weak one. In humans the strength of association is high, but reported that the age-standardised incidence of gastric and oesophageal cancer in women and all persons born in bracken infested areas were at least twice that of those born in bracken free areas.

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Experimental evidence—natural experiments may give clues to whether an association is causal. Remote areas where people live an isolated life among the bracken and drink milk from bracken fed cattle could provide a type of natural experiment, but with no local control group.

Assessment of the evidence

Strength of association—a strong association between a factor and a disease is less likely to occur by chance or error than a weak one. In animals, the strength of association between bracken consumption and cancers is high, but in humans the strength of association is approximately double that of controls. In animals, the strength of association between a factor and a disease is less likely to occur by chance or error than a weak one. In humans the strength of association is high, but reported that the age-standardised incidence of gastric and oesophageal cancer in women and all persons born in bracken infested areas were at least twice that of those born in bracken free areas.

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most exposed to bracken in the United Kingdom could be defined, this could offer further research opportunities.

The possibility of a risk to human health from bracken warrants further research, especially in light of the plant’s apparent increase. Analytical studies, using a carefully considered measure of bracken exposure are required to clarify this risk. A case-control study of gastric cancer would be the next logical step.

Conflicts of interest: none.

Funding: none.

2 Countryfile. BBC1, 28 August 1994.
33 theatre.
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