Crop Protection Compendium - *Pteridium aquilinum* (L.) Kuhn

Pierre Binggeli 2005

NAMES AND TAXONOMY

Preferred scientific name

Pteridium aquilinum (L.) Kuhn

Taxonomic position

Domain: Eukaryota
Kingdom: Viridiplantae
Phylum: Pteridophyta
Class: Pteridopsida
Order: Myrtales
Family: Dennstaedtiaceae

Other scientific names

Pteris aquilina L.
Pteridium esculentum (Forst.) Nakai
Pteridium revolutum (Bl.) Nakai

BAYER code

PTEAQ (*Pteridium aquilinum*)
PTERE (*Pteridium revolutum*)

Common names

English:
bracken
bracken fern
French:
fougère
Belgium:
adelaarsvaren
Brazil:
feio
feto
pluma grande
samambaia
Canada:
American bracken
American brake
brake
eastern bracken
fougère d'aigle
fougère impériale
fougère-aigle commune
fougère-aigle de l'est
fougère-aigle de l'ouest
fougère-paille
fouère à l'aigle
grande fougère de l'ouest
grande fougère
hog brake
pasture brake
polypode à feuilles recourbée
pteridium aquilin
ptéride aigle-impériale
ptéride aigle
ptéridie aigle-impériale
ptéridie d'aigle
ptéridie latiuscule
ptéridium des aigles
ptéridium large
ptéridium à ailes d'aigles
ptéris aigle-impériale
western bracken
Denmark:
ornebregne
El Salvador:
crespillo
Fiji:
mata
qato
qato cuva
quato
Finland:
sananjalka
Germany:
Farnkraut
Guinea:
gbologola
gbowolowoulou
kossé
koumto
sankan
Indonesia:
pakis jemblung
Italy:
felse aquilina
Japan:
warabi
Korea, Republic of:
kosari
Madagascar:
apanga
Norway:
einstape
Philippines:
pakong buwaya
Puerto Rico:
felpa
South Africa:
adelaarsvaring
brake
eagle fern
hog-pasture brake
hombewe
muvanguluvha
pasture brake
ukozani
Thailand:
kut kin
USA:
eastern brakenfern
southern bracken
tailed bracken
western brackenfern
Zambia:
luputu

Notes on taxonomy and nomenclature

The genus *Pteridium* (Dennstaedtiaceae) comprises a few relatively stable morphotypes which are at least partially interfertile. Tryon (1941) recognized a single species with two sub-species, containing 12 varieties, and this scheme has been used throughout the world until recent taxonomic advances have made by using both morphometric analysis and DNA fingerprinting. Thomson (2000) reported that morphometric comparisons of frond material grown under standard environmental conditions and DNA fingerprinting by arbitrarily primed PCR were used to assess taxonomic groupings and relationships in the cosmopolitan bracken ferns of 11 of these varieties, excluding var. feei from Central America. This work resolved groupings corresponding to the varieties, var. *africanum*, var. *arachnoideum*, var. *esculentum*, var. *latiusculum* and var. *revolutum* from each other. The molecular analysis carried out by Thomson (2000) appeared to elucidate the genetic relationships and some origins of the various varieties studied, concluding that these results were consistent with those from the morphometric analysis, and that the varieties might best be raised in rank to species level. However, apart from some work in Australia in particular, the literature does not reflect the changes suggested by Thomson (2000), and indeed in many instances, such as for publications relating to Africa, the plant is simply referred to as *P. aquilinum*. Correspondingly, this datasheet employs the all-embracing *P. aquilinum* concept.

HOST RANGE

Notes on host range

P. aquilinum affect grasslands, forestry plantations, and some cultivated areas.

HABITAT

Species of the genus *Pteridium* are seriously weedy in marginal land in many parts of the world, such as in the UK where *P. aquilinum* is particularly a problem in the uplands. In North America, *Pteridium* spp. occur readily in dry to wet forest margins and openings, peatbogs, logged areas and dry meadows from coastal to sub-alpine zones (Douglas et al., 1991). In the UK, it affects not only rough grasslands but also significantly impacts heather moorland (Birnie et al., 2000) but is also found in woodlands, wastelands, riverbanks and cliffs (Grime et al., 1988). In central Cameroon it is commonly found at the forest savanna boundary and is often associated with the invasive *Chromolaena odorata* (Youta-Happi, 1998). In much of the tropics, *Pteridium* spp. is common in some mountain areas and will become more dominant where fire occurs (D'Antonio et al., 2000; Wesche et al., 2000). *P. aquilinum* is found in a variety of sites in sun to partial shade and on soils that range from deep and rich to hard-packed or sandy. It is one of the first plants to colonize logged or cleared areas though it seldom persists in cultivated areas.

Habitat descriptors
Serious weed in: managed forests; natural forests
Principal weed in: natural grasslands
Weed in (importance not known) in: managed grasslands; agricultural land; wastelands

GEOGRAPHIC DISTRIBUTION

Notes on distribution

This group of closely related subspecies probably has the largest world distribution of any plant taxa, occurring in much of the temperate and tropical regions on all continents as well as mainly oceanic islands. It can become extremely widespread and cover large parts of the landscape, for example, 8% of the area of Scotland, UK. However, there is much regional variation in the recognized types of cover (continuous versus discontinuous) (Birnie et al., 2000). Whether the species is weedy or invasive in each of the countries when known to occur is debatable, and as such has been left as 'unknown' in the Distribution table. It may, however, be considered invasive in at least some of these countries by using any of the definitions, and as such is classified as an invasive species in the Risk and Impacts table.

Distribution List

Europe			
Albania	widespread	native	Tutin et al., 1964
Andorra	widespread	native	Tutin et al., 1964
Austria	widespread	native	Tutin et al., 1964
Belarus	widespread	native	Tutin et al., 1964
Belgium	widespread	native	Tutin et al., 1964
Bosnia and Herzegovina	widespread	native	Tutin et al., 1964
Bulgaria	widespread	native	Tutin et al., 1964
Croatia	widespread	native	Tutin et al., 1964
Cyprus	widespread	native	Tutin et al., 1964
Czech Republic	widespread	native	Tutin et al., 1964
Denmark	widespread	native	Tutin et al., 1964
Estonia	widespread	native	Tutin et al., 1964
Finland	widespread	native	Tutin et al., 1964
Former Yugoslavia	widespread	native	Tutin et al., 1964
France	widespread	native	Tutin et al., 1964
Corsica	widespread	native	Tutin et al., 1964
Germany	widespread	native	Tutin et al., 1964
Gibraltar	widespread	native	Tutin et al., 1964
Greece	widespread	native	Tutin et al., 1964
Hungary	widespread	native	Tutin et al., 1964
Ireland	widespread	native	Tutin et al., 1964
Italy	widespread	native	Tutin et al., 1964
Latvia	widespread	native	Tutin et al., 1964
Liechtenstein	widespread	native	Tutin et al., 1964
Lithuania	widespread	native	Tutin et al., 1964
Luxembourg	widespread	native	Tutin et al., 1964
Macedonia	widespread	native	Tutin et al., 1964
Malta	widespread	native	Tutin et al., 1964

Moldova	widespread	native	Tutin et al., 1964
Monaco	widespread	native	Tutin et al., 1964
Netherlands	widespread	native	Tutin et al., 1964
Norway	widespread	native	Tutin et al., 1964
Poland	widespread	native	Tutin et al., 1964
Portugal	widespread	native	Tutin et al., 1964
Azores	widespread	native	Tutin et al., 1964
Madeira	widespread	native	Tutin et al., 1964
Romania	widespread	native	Tutin et al., 1964
[Russian Federation]			
Central Russia	widespread	native	Tutin et al., 1964
Eastern Siberia	widespread	native	Tutin et al., 1964
Northern Russia	widespread	native	Tutin et al., 1964
Russian Far East	widespread	native	Tutin et al., 1964
Southern Russia	widespread	native	Tutin et al., 1964
Western Siberia	widespread	native	Tutin et al., 1964
San Marino	widespread	native	Tutin et al., 1964
[Serbia and Montenegro]			
Serbia	widespread	native	Tutin et al., 1964
Slovakia	widespread	native	Tutin et al., 1964
Slovenia	widespread	native	Tutin et al., 1964
Spain	widespread	native	Tutin et al., 1964
Balearic Islands	widespread	native	Tutin et al., 1964
Canary Islands	widespread	native	Tutin et al., 1964
Sweden	widespread	native	Tutin et al., 1964
Switzerland	widespread	native	Tutin et al., 1964
Ukraine	widespread	native	Tutin et al., 1964
United Kingdom	widespread	native	Tutin et al., 1964
Channel Islands	widespread	native	Tutin et al., 1964
Asia			
Afghanistan	present	native	Holm et al., 1979
Bhutan	present	native	Parker, 1992
China	widespread	native	Flora of China, 2003
Anhui	present	native	Flora of China, 2003
Fujian	present	native	Flora of China, 2003
Gansu	present	native	Flora of China, 2003
Guangdong	present	native	Flora of China, 2003
Guangxi	present	native	Flora of China, 2003
Guizhou	present	native	Flora of China, 2003
Hainan	present	native	Flora of China, 2003
Hebei	present	native	Flora of China, 2003
Heilongjiang	present	native	Flora of China, 2003
Henan	present	native	Flora of China, 2003

Hong Kong	present	native	Flora of China, 2003
Hubei	present	native	Flora of China, 2003
Hunan	present	native	Flora of China, 2003
Jiangsu	present	native	Flora of China, 2003
Jiangxi	present	native	Flora of China, 2003
Jilin	present	native	Flora of China, 2003
Liaoning	present	native	Flora of China, 2003
Macao	present	native	Flora of China, 2003
Nei Menggu	present	native	Flora of China, 2003
Ningxia	present	native	Flora of China, 2003
Qinghai	present	native	Flora of China, 2003
Shaanxi	present	native	Flora of China, 2003
Shandong	present	native	Flora of China, 2003
Shanghai	present	native	Flora of China, 2003
Shanxi	present	native	Flora of China, 2003
Sichuan	present	native	Flora of China, 2003
Taiwan	present	native	Flora of China, 2003
Xinjiang	present	native	Flora of China, 2003
Yunnan	present	native	Flora of China, 2003
Zhejiang	present	native	Flora of China, 2003
India	widespread	native	Holm et al., 1979
Indonesia	present	native	Holm et al., 1979
Iran	present	native	Holm et al., 1979
Iraq	present	native	Holm et al., 1979
Israel	present	native	Holm et al., 1979
Japan	widespread	native	Guo et al., 2003
Korea, DPR	present	native	USDA-ARS, 2003
Korea, Republic of	present	native	USDA-ARS, 2003
Pakistan	present	native	Holm et al., 1979
Philippines	widespread	native	Kowal, 1966
Sri Lanka	present	native	Holm et al., 1979
Thailand	present	native	Holm et al., 1979
Turkey	present	native	Holm et al., 1979
Vietnam	present	native	Missouri Botanical Garden, 2003
Africa			
Burundi	localized	native	Hemp, 2002
Cameroon	present	native	Youta-Happi, 1998
Congo Democratic Republic	present	native	Holm et al., 1979
Equatorial Guinea	present	native	Adams, 1957
Ethiopia	present	native	Holm et al., 1979
Gabon	present	native	Missouri Botanical Garden, 2003
Ghana	present	native	Holm et al., 1979
Guinea	present	native	Carrière, 2000

Kenya	localized	native	Hemp, 2002
Madagascar	present	native	Bloesch et al., 2002
Malawi	widespread	native	Lemon, 1968
Mauritius	present	native	Vaughan & Wiehe, 1937
Rwanda	localized	native	Hemp, 2002
Sao Tome and Principe	present	native	Adams, 1957
Sierra Leone	present	native	Missouri Botanical Garden, 2003
South Africa	widespread	native	Bromilow, 1995
Sudan	localized	native	Jackson, 1956
Tanzania	localized	native	Hemp, 2000
Uganda	present	native	Sekercioglu, 2002
Zambia	present	native	Lawton, 1978
Zimbabwe	present	native	Holm et al., 1979
Central America & Caribbean			
Bahamas	present	introduced invasive	Kairo et al., 2003
Belize	present	native	Missouri Botanical Garden, 2003
Bermuda	present	native	Thomson & Alonso-Amelot, 2002
Costa Rica	present	native	Thomson & Alonso-Amelot, 2002
Cuba	localized	native	Seifriz, 1943
El Salvador	present	native	Holm et al., 1979
Guatemala	present	native	Thomson & Alonso-Amelot, 2002
Honduras	present	native	Thomson & Alonso-Amelot, 2002
Jamaica	present	introduced invasive	Kairo et al., 2003
Nicaragua	present	native	Missouri Botanical Garden, 2003
Panama	present	native	Missouri Botanical Garden, 2003
Puerto Rico	present	native	Missouri Botanical Garden, 2003
Trinidad and Tobago	present	native	Beard, 1953
North America			
[Canada]			
Alberta	present	native	Darbyshire, 2003
British Columbia	present	native	Darbyshire, 2003
Manitoba	present	native	Darbyshire, 2003
New Brunswick	present	native	Darbyshire, 2003
Newfoundland	present	native	Darbyshire, 2003
Nova Scotia	present	native	Darbyshire, 2003
Ontario	present	native	Darbyshire, 2003
Prince Edward Island	present	native	Darbyshire, 2003
Quebec	present	native	Darbyshire, 2003
Mexico	present	native	Crane, 1990
Saint Pierre and Miquelon	present	native	Darbyshire, 2003
[USA]			
Alabama	present	native	Crane, 1990
Alaska	present	native	Crane, 1990

Arizona	present	native	Crane, 1990
Arkansas	present	native	Crane, 1990
California	present	native	Crane, 1990
Colorado	present	native	Crane, 1990
Connecticut	present	native	Crane, 1990
Delaware	present	native	Crane, 1990
Florida	present	native	Crane, 1990
Georgia (USA)	present	native	Crane, 1990
Hawaii	present	native	Crane, 1990
Idaho	present	native	Crane, 1990
Illinois	present	native	Crane, 1990
Indiana	present	native	Crane, 1990
Iowa	present	native	Crane, 1990
Kansas	present	native	Crane, 1990
Kentucky	present	native	Crane, 1990
Louisiana	present	native	Crane, 1990
Maine	present	native	Crane, 1990
Maryland	present	native	Crane, 1990
Massachusetts	present	native	Crane, 1990
Michigan	present	native	Crane, 1990
Minnesota	present	native	Crane, 1990
Mississippi	present	native	Crane, 1990
Missouri	present	native	Crane, 1990
Montana	present	native	Crane, 1990
Nebraska	present	native	Crane, 1990
Nevada	present	native	Crane, 1990
New Hampshire	present	native	Crane, 1990
New Jersey	present	native	Crane, 1990
New Mexico	present	native	Crane, 1990
New York	present	native	Crane, 1990
North Carolina	present	native	Crane, 1990
North Dakota	present	native	Crane, 1990
Ohio	present	native	Crane, 1990
Oklahoma	present	native	Crane, 1990
Oregon	present	native	Crane, 1990
Pennsylvania	present	native	Crane, 1990
Rhode Island	present	native	Crane, 1990
South Carolina	present	native	Crane, 1990
South Dakota	present	native	Crane, 1990
Tennessee	present	native	Crane, 1990
Texas	present	native	Crane, 1990
Utah	present	native	Crane, 1990
Vermont	present	native	Crane, 1990

Virginia	present	native	Crane, 1990
Washington	present	native	Crane, 1990
West Virginia	present	native	Crane, 1990
Wisconsin	present	native	Crane, 1990
Wyoming	present	native	Crane, 1990
South America			
Argentina	present	native	Thomson & Alonso-Amelot, 2002
Bolivia	present	native	Thomson & Alonso-Amelot, 2002
Brazil	widespread	native	Lorenzi, 1982
Acre	present	native	Lorenzi, 1982
Alagoas	present	native	Lorenzi, 1982
Amapa	present	native	Lorenzi, 1982
Amazonas	present	native	Lorenzi, 1982
Bahia	present	native	Lorenzi, 1982
Ceara	present	native	Lorenzi, 1982
Espirito Santo	present	native	Lorenzi, 1982
Fernando de Noronha	present	native	Lorenzi, 1982
Goias	present	native	Lorenzi, 1982
Maranhao	present	native	Lorenzi, 1982
Matto Grosso	present	native	Lorenzi, 1982
Minas Gerais	present	native	Lorenzi, 1982
Paraiba	present	native	Lorenzi, 1982
Parana	present	native	Lorenzi, 1982
Pará	present	native	Lorenzi, 1982
Pernambuco	present	native	Lorenzi, 1982
Piauí	present	native	Lorenzi, 1982
Rio Grande do Norte	present	native	Lorenzi, 1982
Rio Grande do Sul	present	native	Lorenzi, 1982
Rio de Janeiro	present	native	Lorenzi, 1982
Rondonia	present	native	Lorenzi, 1982
Santa Catarina	present	native	Lorenzi, 1982
Sao Paulo	present	native	Lorenzi, 1982
Sergipe	present	native	Lorenzi, 1982
Tocantins	present	native	Lorenzi, 1982
Colombia	present	native	Thomson & Alonso-Amelot, 2002
Ecuador	present	native	Thomson & Alonso-Amelot, 2002
French Guiana	present	native	Thomson & Alonso-Amelot, 2002
Guyana	present	native	Thomson & Alonso-Amelot, 2002
Paraguay	present	native	Thomson & Alonso-Amelot, 2002
Peru	present	native	Thomson & Alonso-Amelot, 2002
Suriname	present	native	Thomson & Alonso-Amelot, 2002
Uruguay	present	native	Thomson & Alonso-Amelot, 2002
Venezuela	present	native	Thomson & Alonso-Amelot, 2002

Oceania			
[Australia]			
Tasmania	widespread	native	Anon., 2003
Fiji	present	native	Parham, 1958
New Zealand	widespread	native	Holm et al., 1979
Norfolk Island	localized	native	Braggins, 1996

HISTORY OF INTRODUCTION AND SPREAD

Little is known about the potential dispersal of the species but it is unlikely to have been intentionally moved by humans and if it has it would have been restricted to a few regions of the world. It is likely that some movement of the plant (rhizome) has happened via movement of soil. The only report of the species being exotic is from Jamaica and the Bahamas, and it would appear that it is only invasive in the former location (Kairo et al., 2003).

BIOLOGY AND ECOLOGY

Genetics

The chromosome number of *P. aquilinum* var. *aquilinum* is 2n=104 with a nuclear DNA amount of 12.8 pg (Grime et al., 1988). In his taxonomic re-assessment of the genus Thomson (2000) concluded that the DNA evidence suggested that morphotypes in *Pteridium* were "determined by specific qualitative and quantitative combinations of a limited number of highly conserved, additively assorted, genomic elements". It exhibits polymorphism for cyanogenesis (Grime et al., 1988). Morphological and morphometric analysis by Thomson (2000) elucidated some genetic relationships between varieties, including the distinguishing of an additional grouping of Atlantic Island (Azores, Madeira) and European brackens as an '*aquilinum* complex' including var. *aquilinum* and a number of morphotypes recognised by C.N. Page and others at various taxonomic levels (near *atlanticum*, *fulvum*, *pinetorum*, *osmundaceum*). Also, he confirmed that var. *yarrabense* was a tetraploid hybrid (2n=208) of var. *esculentum* and var. *revolutum*, that at least those accessions of var. *caudatum* examined were tetraploid hybrids (2n=208) involving var. arachnoideum as one progenitor, and that the closest relatives of var. *decompositum* were var. *latiusculum* and var. *revolutum*; and provided evidence of close genomic relationships between var. *latiusculum*, var. *pseudocaudatum* and var. *pubescens* in North America. Thomson (2000) suggested that Tryon's varieties *africanum*, *aquilinum*, *arachnoideum*, *decompositum*, *esculentum*, *latiusculum* and *revolutum* might best be treated as species; *pseudocaudatum* and *pubescens* as varieties within l*atiusculum*; *yarrabense* and *caudatum* (at least in part) as hybrids. Thomson and Alonso-Amelot (2002) have dealt with the taxonomic status and relationships of *Pteridium caudatum* in Central and South America. However, this datasheet does not separate the species as described by Thomson (2000) and covers all varieties within the over-arching *P. aquilinum*.

Physiology and Phenology

In temperate climates, fronds emerge from late spring onwards and persist until the autumn. Spores ripen in August to September and are shed in August to October in the UK. Under experimental conditions half of the spores take 4 days to germinate and germination is to some extent inhibited by darkness, and the prothallus will grow better in unshaded habitats (Grime et al., 1988). In Western Europe the shoots are copper brown during the

dormant season and the fronds will be still standing for much of the winter and only gradually break up. The fronds will grow after the winter season whereas in tropical regions this will tend to occur after fires. Wynn et al. (2000) demonstrated significant differences in response to light and temperature regimes between four genotypes grown under experimental conditions. There is much variation in both the total dry mass per unit area (1.8-5.1 kg/m²) and the total rhizome dry mass (0.24-0.42 kg/m²).

Pteridium spp. are to a large extent fire-resistant as the rhizomes send up new shoots after the old ones are burnt. In tropical regions the species is often referred to as a typical postfire successional species (Wesche et al., 2000) and after fire may form so-called 'bracken savannas' (Beard, 1953). However, in Sudan, it is absent from the most fiercely burnt hillsides (Jackson, 1956). In Hawaii, where it is uncommon, it is one of the few seasonal sub-montane native species to increase in burned compared to unburned areas (D'Antonio et al., 2000). Similarly, in much of the temperate zones it is known to be fire-responsive (Cwynar, 1987; Skre et al., 1998). Indigenous peoples such as the Maoris in New Zealand would appear to have been responsible for the increase of the fern through their use of fire (Germann and Holland, 2001).

Reproductive Biology

Up to 30 million spores may be produced by a single frond and spore production tends to be greater in open habitats. Spores are wind-dispersed. Viable spores are often found in abundance within a soil profile, and a buried spore bank is suspected. Spores may remain viable for up to 10 years. Natural regeneration from spores may occur in spring and is mainly restricted to areas of disturbed or burnt ground. Expansion of established clones will be chiefly vegetative (Grime et al., 1988).

Environmental Requirements

Pteridium spp. are commonly found at varying altitudes. In the UK, *P. aquilinum* is found from sea level to 590 m but is more abundant in the uplands (Grime et al., 1988). In the Imatong Mountains of Sudan its altitudinal range is 1800-2600 m (Jackson, 1956) and up to 3200 m in Colombia (Missouri Botanical Garden, 2003). It prefers acid soil, tolerating soil pH of 3.0-7.6. However, in the UK, it is most frequent and abundant below pH 4.5 and particularly on deep soils. It is found on a range of shaded and unshaded habitats but grows best on productive brown-earths and more open habitats. Young shoots are very sensitive to frost and trampling by large mammals (Grime et al., 1988).

Associations

The roots bear vesicular-arbuscular mycorrhiza (Grime et al., 1988). The extrafloral nectaries of young fronds provide food for ants and these may rid the plant of insect predators (Tempel, 1983; Grime et al., 1988). In Western Europe herbivory by large mammals such as deer, results in a reduction in many palatable species and with the expansion of *P. aquilinum* (Lameire et al., 2000; Kirby, 2001). In the UK, vegetational change from arable land to woodland over 100 years resulted in the unexpectedly disappearance of *P. aquilinum* once the woodland had become established (Harmer et al., 2001). Often there is little vegetation under the canopy of *P. aquilinum*, just a carpet of its litter. The plant is also considered to be allelopathic (Grime et al., 1988).

Climatic amplitude (estimates)
- Altitude range: 0 - 3200 m
- Rainfall regime: summer; bimodal
- Dry season duration: 0 - 6 months

- Mean annual temperature: 9 - 29ºC

Soil descriptors
- Soil texture: light; medium; heavy
- Soil drainage: free; impeded
- Soil reaction: very acid; acid; neutral
- Special soil tolerances: shallow; infertile

MEANS OF MOVEMENT AND DISPERSAL

Although *P. aquilinum* is considered to be heavily defended from mammalian and insect predators (Grime et al., 1988), many insects have been recorded on the plant (Crane, 1990) though their effects on growth and survival are not known. A number of insects attacking *P. aquilinum* were identified from the UK (Lawton, 1976) New Mexico, USA (Lawton, 1982) and Brazil (Martins et al., 1995), some of which were investigated as potential biological control agents. Lawson (1976) lists 40 species of arthropods feeding on *P. aquilinum* in the UK and notes seasonal changes in relation to the plant's defense mechanisms against herbivory.

NATURAL ENEMIES

Although *P. aquilinum* is considered to be heavily defended from mammalian and insect predators (Grime et al., 1988), many insects have been recorded on the plant (Crane, 1990) though their effects on growth and survival are not known. A number of insects attacking *P. aquilinum* were identified from the UK (Lawton, 1976) New Mexico, USA (Lawton, 1982) and Brazil (Martins et al., 1995), some of which were investigated as potential biological control agents. Lawson (1976) lists 40 species of arthropods feeding on *P. aquilinum* in the UK and notes seasonal changes in relation to the plant's defense mechanisms against herbivory.

Natural enemies listed in the database

The list of natural enemies has been reviewed by a biocontrol specialist and is limited to those that have a major impact on pest numbers or have been used in biological control attempts; generalists and crop pests are excluded. For further information and reference sources, see About the data. Additional natural enemy records derived from data mining are presented as a separate list.

Natural enemies reviewed by biocontrol specialist	
Natural enemy	**Pest stage attacked**
Herbivores:	
Aneugmenus padi	Leaves
Chirosia histricina	Leaves
Conservula cinisigna	Leaves
Dasineura filicina	Leaves
Ditropis pteridis	Leaves
Eupteryx maigudoi	Leaves
Panotima angularis	Leaves
Additional natural enemies (source - data mining)	
Natural enemy	**Pest stage attacked**
Pathogens:	
Ascochyta aquilina	

Ascochyta necans
Phoma aquilina
Septoria aquilina
Herbivores:
Strongylogaster lineata

IMPACT

Economic impact

When mature and tough, fronds of *P. aquilinum* are poisonous to horses and cattle. The rhizomes are five times more toxic than the leaves, but are seldom eaten. Sheep have been poisoned experimentally, but natural poisoning is not common. The poison is cumulative over about 1 month for horses and 1-4 months for cattle before symptoms appear. Horses are usually poisoned by eating large amounts of contaminated hay, containing over 20% *P. aquilinum*, whereas cattle are poisoned by consuming an amount of green or dried leaves approximately equal to the animal's weight. In the UK, it is a weed of grasslands and forestry and is increasing in the uplands and is difficult to eradicate (Grime et al., 1988). It affects farmers in many parts of the world, with lost opportunity costs associated with the invasion of productive grazing land, veterinary costs associated with poisoning and tumours, ticks and associated disease problems and direct bracken control costs. In forestry plantations, control is often required during the establishment phase (Pakeman et al., 2003).

Environmental impact

In terms of conservation, *P. aquilinum* often has little biodiversity interest and in Britain it has generally replaced habitats of greater importance (Pakeman et al., 2003).

Social impact

The plant is toxic to livestock and humans (Grime et al., 1988; Crane, 1990). The impact on human health is difficult to quantify, but Pakeman et al. (2003) consider that it could be locally important. There is unproven speculation that drinking water taken from catchments that are predominantly covered with *P. aquilinum* may contain carcinogens or other toxins that are harmful to human health.

Impact on biodiversity

In Europe there is some evidence that a decrease in species richness over time may be due to competitive exclusion by *P. aquilinum* (Lameire et al., 2000).

Summary of impact

Negative impact on: biodiversity; crop production; livestock production; forestry production; rare or protected species

PHYTOSANITARY SIGNIFICANCE

P. aquilinum is cosmopolitan in its distribution and there appears to be only a limited risk of further introduction.

SUMMARY OF INVASIVENESS

P. aquilinum is a cosmopolitan weed that readily spreads into pasture and marginal areas and is favoured by fire and soil acidity. Its presence reduces land productivity and adversely affects biodiversity. The plant is little affected by animals because of its toxicity. *P. aquilinum* is difficult to control particularly because of its ability to sprout from an extensive network of underground rhizomes and has large reserves of carbohydrate.

Risk and Impact Factors

- invasive in its native range: yes
- proved to be invasive outside its native range: yes
- highly adaptable to different environments: yes
- high reproductive potential: yes
- highly mobile locally: no
- its propagules remain viable for more than one year: yes
- tolerates cultivation, browsing pressure, mutilation, fire etc.: yes
- competitive in crops or pasture: yes
- affects ecosystem: yes
- adversely affects natural communities: yes
- adversely affects community structure: yes
- adversely affect human health: yes
- has sociological impacts on recreational patterns, aesthetics, property values: yes
- harmful to animals: yes
- produces spines, thorns or burrs: no
- host or vector of pests or diseases: no
- likely to be accidentally transported internationally: no
- likely to be deliberately transported internationally: no
- difficult to identify or detect as a commodity contaminant: no
- difficult to identify or detect in the field: no
- difficult or costly to control: yes

MORPHOLOGY

Plant type: herbaceous; vegetatively propagated; perennial.

P. aquilinum is a polycarpic geophyte; a perennial fern which reproduces by spores and widely creeping, branching underground stems, sometimes forming colonies. The fronds arise directly from a deep underground rhizome that is much subdivided. The large compound leaves (fronds) are 0.3-1.3 m high, and 15-45 cm long, whereas both fertile and sterile fronds may reach a height of up to 2 m in the UK and can be much smaller under sub-optimal conditions. The leaf stalk, usually mistaken for the stem, actually is attached to the rhizome under the ground. The triangular deciduous leaves turn brown and die after the first autumn frosts in temperate climates, and the new ones arise each spring from the rhizomes. The leaf is divided into numerous segments (leaflets), each of which may be again divided or redivided, with the lowest segments three times compound. The clusters of spore cases densely line the inrolled edges of the underside of the leaves. The sporangium is aggregated into sori on the underside of the frond. Young fronds produce extrafloral nectaries (Grime et al., 1988; Duc et al., 2003).

SIMILARITIES TO OTHER SPECIES

Whereas the genus *Pteridium* is readily distinguished from other fern taxa, separation of the various species/subspecies within the genus is difficult (Thomson, 2000).

CONTROL

Cultural Control

The plant is susceptible to damage by the trampling of fronds by large mammals, but this does little to control the plant. Frequent liming (to increase soil pH) and fertilizer applications used in upland grassland improvement also have the additional benefit of reducing infestations of *P. aquilinum*, as it is a plant of infertile acid soils. Reseeding with preferable forage grasses or herbaceous species also appears to reduce the cover of *P. aquilinum*, such as has been achieved with *Festuca rubra* and *Vicia cassubica* in Bulgaria (Petrov and Marrs, 2000).

Mechanical Control

Duc et al. (2000) have considered the mechanical control of *P. aquilinum* in the UK by cutting it once or twice a year, which reduced the total dry mass per unit area by approximately 60% after 5 years. Any mechanical treatment must be conducted over a number of years if it is to have any noticeable effect (Marrs et al., 2000). Also timing of the cuts is very important, for example the optimal time is in the autumn, before *P. aquilinum* has transferred its nutrient reserves from the above-ground parts back down to the rhizomes for the dormant winter period.

Chemical Control

Control by herbicide is generally difficult. Asulam has been the main chemical used in control programmes in the UK since the early 1970s, primarily because it is licensed for aerial spraying. Of other chemicals that have been tried, only glyphosate has been used in some situations where *P. aquilinum* is one of a number of weeds to be controlled. In recent years, aerial spraying using helicopters has been carried out on around 5000-8000 ha per year. However, only about 25% of sites sprayed with asulam show long-term suppression of bracken whilst the remaining sites normally revert back to complete *P. aquilinum* cover within 5-10 years. Therefore appropriate follow-up treatment is essential, such as knapsack or vehicle-based spot spraying of missed areas or regenerating fronds (Pakeman et al., 2003). In Bulgaria, glyphosate applied to a permanent meadow infested with *P. aquilinum* reduced the infestation but it rapidly recovered where no follow-up operations were carried out, and was more successful when carried out in combination with a follow-up weed wiping application of glyphosate (Petrov and Marrs, 2000). Metsulfuronmethyl and glyphosate-trimesium are recommended for use on *P. esculentum* in Tasmania (Anon., 2003).

Biological Control

In the UK, where *P. aquilinum* is a major weed of pasture in particular, studies on biological control were initiated in the 1970s. Lawson (1976) identified 40 arthropod species feeding on *P. aquilinum*, but noted their inability to prevent spread of infestations owing to the impact of native natural enemies of the arthropods. Lawton (1988) summarized the situation in the UK and discussed the requirements for successful biological control agents, emphasising the need for agents of the same subspecies of the weed, comparable climates,

and for agents which would be free from attack ny native natural enemies. South Africa appeared to provide the best likelihood of finding such agents, and Lawson (1988) listed arthropods associated with *P. aquilinum* there, from hitherto unpublished observations. Two defoliating moths, *Panotina angularis* and *Conservula cinisigna* and an unidentified eriophyid mite were considered promising. The moths were imported into quarantine in the UK, screened and found to be host specific (Fowler et al., 1989). However, the programme was abandoned because of the costs of field testing and doubts over the wisdom of using biological control to manage a native weed (Cruttwell McFadyen, 1998). Comparative studies on the arthropod fauna of *P. aquilinum* on other continents; New Mexico, USA (Lawton, 1982) and Brazil (Martins et al., 1995) have also been made.

Integrated Control

Duc et al. (2000) reviewed the responses of fronds to control treatments in Great Britain and noted great variability even within a small geographical area. Follow-up application of herbicide several years after the start of a control programme enhanced the efficacy of all treatments. To develop a control strategy in the UK, Duc et al. (2003) stated the following factors must be considered: that rhizome mass differs between sites and in response to control treatments; cutting twice per year is generally most effective; where cutting is impossible, herbicide treatment should be applied. and the weather may affect rhizome mass, with wet years being detrimental. Also a combination of mechanical and chemical methods may be more effective under some conditions. Pakeman et al. (2003) have pointed out that *P. aquilinum* control has to be seen as part of a much larger land use/management strategy and they suggest a variety of control scenarios and restoration practices.

USES

In New Zealand, the Maori ate the starchy, below-ground parts of the fern and used fire as an aid for hunting and to promote regrowth of this edible resource (Germann and Holland, 2001). Faust (2002) has reviewed the ethnobotany of the species in the Yucatan Peninsula. In early spring, the young unrolled leaves and tender leaf stalks may also be cooked as a vegetable, and are consumed in Thailand and Japan, even though they contain carcinogens (USDA-ARS, 2003). In the UK, it used to have some economic importance as a source of fuel, thatch, bedding, compost, food and potash (Grime et al., 1988). It is occasionally used for sheep bedding in Wales to this day, though in small amounts to avoid poisoning of stock from consumption, due to beliefs concerning its possible ethnoveterinary effects. Potential uses of *P. aquilinum* in organic agriculture in the UK are being considered (Donnelly et al., 2002) and it is being promoted as a component of peat-free growing media (Pitman and Webber, 1998). There are numerous uses in folkloric medicine (USDA-ARS, 2003).

PESTS

Pests listed in the database

Minor host of:
Gibberella avenacea (Fusarium blight), *Heterobasidion abietinum* , *Heterobasidion annosum* , *Peridroma saucia* (pearly underwing moth)

Wild host of:
Rhododendron ponticum (rhododendron)

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During the growing season the fronds are dark green and may reach a height of up to 2 m.

Bracken takes months to break up during the dormant season when the fronds have dried. Under some climatic conditions it becomes a fire hazard.

Bracken covering marginal land in Ireland (Murlough Bay - Fair Head). Under oceanic conditions, areas of bracken are readily seen in winter when the fronds turn reddish-brown.

Monotypic clumps in winter, growing up to the shoreline.

On marginal grazing land bracken produces monotypic clumps (dark green patches). In extreme cases it may dominate all the ground vegetation.