Sustainable Nutrition

A Blackmores Institute Literature Review
on the impact of Climate Change on
Nutritional and Natural Medicine

Contents

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Sustainable Nutrition

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01/ Introduction

The release of the United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report last month was a timely reminder for the complementary healthcare industry to acknowledge and understand the impact climate change will have on natural medicine.

The report highlights the exposure of 1,000,000 species threatened with extinction and the need to protect and restore nature.

This Blackmores Institute literature review explores how climate change will influence:

- Human health and nutritional needs and potentially increase requirements for supplementary nutrients
- The need to build a resilient, sustainable supply chain protecting future access to nutrients from natural sources
- The responsibility to mitigate global warming by managing our emissions

Blackmores Group is proactive in addressing the changing natural environment. Our founder Maurice Blackmore understood that you can't have healthy people without a healthy planet.

We advocate for businesses and government to take strong action to address global warming and climate change through better management of emissions, a commitment to sustainable sourcing and constant monitoring of adaptation within our supply chain.

In doing this, we are guided by a strong north star – the United Nations Sustainable Development Goals, which address the biggest challenges we face as a global community. We are committed to making a positive contribution and I'm pleased to share this special report to better understand the key issues as we protect one of the earth's most powerful resources – natural medicine.

The best of health,

Dr Lesley Braun,
Director, Blackmores Institute

Literature Review Summary

- The earth's surface is warming at an unnatural rate, mainly due to human-driven activities
- The negative effects of climate change have already been observed in both terrestrial and marine ecosystems
- Extinction rates among plants and animals are accelerating, especially among those species with a narrow geographical range
- The effects on marine life have already been observed and are expected to increase. These effects will be felt all the way along the marine food chain and will impact the human populations that rely on them as a food source
- Marine sources of omega-3 fatty acids are vulnerable and conservation should be prioritised
- It is certain that the nutritional content of staple food sources, such as crop plants, will be compromised, affecting levels of protein, calcium, magnesium, iron and zinc
- Human activities have already impacted on the nutritional content of fruits and vegetables, resulting in declines in levels of protein, calcium, phosphorus, iron, vitamin B6 and vitamin C
- Medicinal plants with a narrow geographical range face extinction
- It is still uncertain as to how climate change will affect secondary metabolite or active ingredient production by medicinal plants, and whether or not their therapeutic effects or potency will be altered
- Action is required now across industry to better understand climate change and to collaborate on conservation programs
- Blackmores has developed a framework to inform their sustainability strategy to ensure the protection of natural resources
- In sharing this information, we're encouraging industry to be proactive and to engage in projects that help to mitigate the effects of climate change

> "Understanding the resilience of our natural ingredients empowers us to protect them for future generations."

02/ Context

Climate scientists in peer-reviewed papers agree that human activity has accelerated global warming. Since industrialisation in 1750, the Earth's temperature has increased by 1.0°C and is estimated to increase by another 0.5°C by 2030.

12 years

Global temperatures are increasing at such an accelerated rate that we have less than 12 years until the damage to our planet cannot be reversed.

2-3 °C

At current rates, scientists estimate that by 2100, global temperatures will be at least 2-3°C higher than they are today.

Ocean warming, together with increased UVB radiation and CO_2 levels will have a dramatic impact on ocean chemistry and marine life. Any temperature rise impacts the types of plants that grow, which animals will survive and thrive and therefore disrupts the delicate balance of nature.

These multiple changes will compromise our food security, water supply, stability of coastlines, putting human health at risk.

25%

25% of medications currently prescribed in the developed world are derived from wild sources.

80%

80% of people in developing countries totally depend on herbal medicine for their primary healthcare.

Understanding the resilience of our natural ingredients empowers us to protect them for future generations.

03/ Overview

What is climate change?

Climate change refers to changes in climatic factors such as temperature, precipitation and wind over extended periods of time. Changes in earth's orbit, volcanic eruptions, variations in solar radiation, movement of crustal plates and natural changes in greenhouse gases have continued to shape the earth's climate over billions of years, as have weather conditions such as the El Niño-Southern Oscillation (ENSO) effect.[1]

'Global warming' is used to describe how increases in temperature can affect global climate. Historical fluctuations in earth's temperature have been identified, but there is evidence that since the start of the industrial era, anthropogenic (human) activities have further contributed to the expected rate of change of the earth's surface and atmospheric composition, resulting in a net increase in the global mean temperature. Simply put, the earth is getting warmer. This is mainly due to ocean warming which dominates the heating rates and accounts for around 93% of the effect, while melting ice, warming of the continents and warming of the atmosphere accounts for the rest. During the 20th century, the earth warmed by approximately 0.7°C and most of this occurred over the last three decades.[2]

03

An imbalance of factors

There are correlations between anthropogenically-driven emissions and global warming from greenhouse gases. Industrialisation, deforestation and pollution have greatly increased atmospheric amounts of water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and carbon monoxide (CO) creating greenhouse gases that help trap heat near the earth's surface.[2] At the same time, several natural and anthropogenically-driven climate-cooling activities are also at play. Natural aerosol emissions from large-scale biomass burning and volcanic activity lead to cloud formations that reflect sunlight and absorb sunlight radiation, leading to a cooling effect on the earth surface.[1] Taking all these factors into account, the balance tips over and results in the earth's surface warming. There is consensus that its temperature is predicted to increase by as much as 2-3°C by the end of this century.[2]

Taking action

Global and local government scientific panels have been set up to investigate the effects of global warming on climate change, and to identify ways to mitigate its effects. The Intergovernmental Panel on Climate Change[2] (IPCC) is one such group. In Australia, the National Environmental Science Program (NESP) was set up to understand and plan for climatic changes.[3] At a United Nations Framework Convention for Climate Change (UNFCCC) in Paris in 2016, an agreement was reached to reduce greenhouse gas emissions and provide financial assistance to developing countries affected by changes in climate.[4] In October 2018, the IPCC reiterated the need to limit global warming to 1.5°C to help mitigate the effects of climate change.[2]

But several questions remain: Is it enough? What can we do to slow or even reverse the change? And, how can we be better prepared for the future?

Global warming is a reality and any strategy to mitigate its effects needs to take into account environmental, industrial, agricultural, nutritional and food safety and security factors in order to ensure survival of the planet's diverse ecosystems.

Given the innate interrelationships that exist in the ecosystem, the impact of changes to climate will be significant.

PURPOSE OF THIS REPORT

This report outlines the predicted impacts of climate change on global ecosystems and food chains, on the nutrient composition of foods and implications for human health and nutrition.
It also discusses what climate change means for the natural medicines industry and the roles and responsibilities of industry in helping to mitigate its effects.

We hope that in growing understanding about Climate Change, we will inspire action to address its impacts.

04/ The Impact of Climate Change on Ecosystems and Biodiversity

Global warming is expected to impact both terrestrial and marine ecosystems. Survival of plant and animal species will depend on their ability to adapt under new environmental conditions, new geographical locations and new ecosystems quickly and effectively.[2] Under global warming, changes in extreme weather and the frequency and severity of climate events are expected to increase. Heat waves, droughts, rising sea levels, heavy precipitation, floods, hurricanes, severe weather events will add to the environmental stress on global ecosystems.[2]

The effects on terrestrial biodiversity

As the planet warms, the risk of significant loss of biodiversity will also increase.[5] With a possible global temperature increase of 2-3°C. 18% of insect, 16% of plant and 8% of vertebrate species may lose their geographical range, leading to species losses.[2] Unfortunately, there is already evidence that the climate is changing more rapidly than some species can adapt.[5]

The loss of insects will have major ramifications across both plant and animal life, adversely affecting ecosystem functioning. Insects play a central role in a variety of processes, including pollination, herbivory and decomposition of plants and animals in the soil, nutrient cycling and providing a food source for higher vertebrates such as birds, mammals and amphibians. For example, 80% of wild plants are estimated to depend on insects for pollination, while 60% of birds rely on insects as a food source.[5]

Impacts on Plants: The effects of global warming on plant species can already be seen around the globe. In the northern hemisphere, plant species are steadily shifting northwards and to higher altitudes where conditions are more favourable for their growth.[6] Higher altitude conditions can only support plant species to a certain point after which the species face extinction. Changes in plant phenology including advanced budding, flowering and fruiting have also been reported.[6] These processes have impacted on pollination practises and invertebrate ecosystems associated with these plant species.

Drought is another risk factor impacting the viability of plants. The increased global risk of drought due to climate change threatens to expand desertification, especially in sub-Saharan African, Southern Africa and North America, endangering the survival of endemic plant species which must live within a narrow geographical range.[7]

Global warming has also increased the risk of other biodiversity-related threats such as fires, extreme weather events, spread of invasive species, pests and diseases.[6] Increased flooding due to a rise in sea level combined with increased rainfall and likely changes to monsoonal patterns, place the southeast Asian region in a vulnerable position and will significantly impact on food production.

Warming of the alpine regions of Asia threatens the survival of endemic plants living in these regions. According to the IPCC, the Himalayas are likely to experience some of the most drastic climate changes in the world outside of the polar regions, with temperatures predicted to increase by 5-6% and rainfall to increase by 20-30% by the end of the century.[8]

Impact on Fauna: The effects of global warming on animal species have been observed in several ecosystems including rain forests and the polar regions (both Arctic and Antarctic).[2] The geographical range of several animal and invertebrate species has changed, especially in the higher latitudes with species moving north and to higher altitudes.[2] Fauna phenology has also changed with life events such as emergence from hibernation, amphibian calling and mating, spring bird migration, egg-laying and appearance of butterflies all occurring earlier.[9] Animal species most at risk of survival are endemic species with narrow geographical ranges and rain forest, alpine and polar species.[6]

04

Impact on Marine Biodiversity: Global warming of 2-3°C is predicted to impact on both phytoplankton biomass and fish numbers.[2] Certain areas may benefit from temperatures increases – such as those in the higher latitudes. Fish are predicted to migrate from lower to higher latitude waters which may better support their survival, causing a change to the ecosystems in those areas.[2]

Phytoplankton and single-cell algae levels will dramatically decrease due to the toxic effects of increases in both UVB radiation and CO_2 levels. The consequences of this will be felt all the way through the marine food chain, affecting marine life on every level.[29]

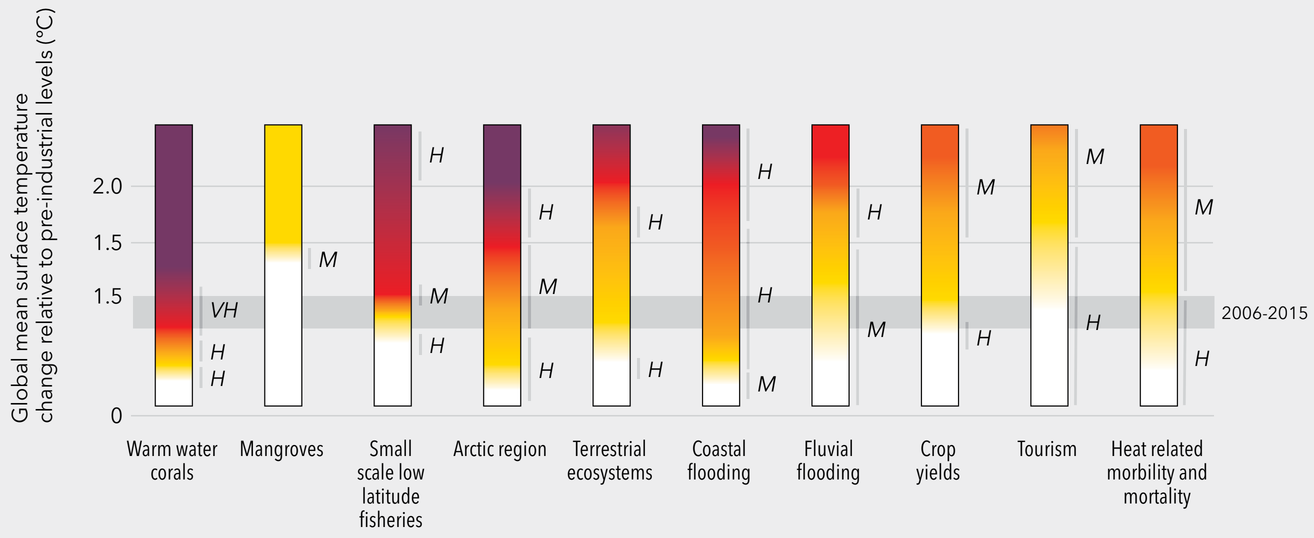
Non-or less-mobile ecosystems such as kelp forests and coral reefs are projected to experience high species losses. There is multiple evidence to suggest that 70-90% of coral reefs that exist today in tropical areas will disappear with global warming of 2-3°C.[1] Tropical waters of the lower latitudes are predicted to experience changes to their ocean chemistry including increased hypoxia and acidification, due to increased CO_2 absorption.[2] The reduction in fish species and numbers will impact on fishing practises and human access to food in those regions.[2]

04/ The Impact of Climate Change on Ecosystems and Biodiversity

> Global warming is a reality and any strategy to mitigate its effects needs to take into account environmental, industrial, agricultural, nutritional and food safety and security factors in order to ensure survival of the planet's diverse ecosystems.

04

Impacts and risks for selected natural, managed and human systems



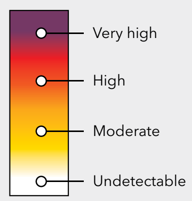
Purple
Indicates very high risks of severe impact/risks and the presence of significant irreversibly of the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.

Red
Indicates severe and widespread impacts/risks.

Yellow
Indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.

White
Indicates that no impacts are detectable and attributable to climate change.

Confidence level for transition: *L*=Low, *M*=Medium, *H*=High and *VH*=Very high



Source: IPCC 2018

04

05/ Factors that will Impact Access to Nutrients

Climate change due to increases in atmospheric CO_2 and global warming is predicted to impact on global agricultural production, food security and human health and nutrition, however, the extent to which this will happen is still not clear.[11] Historical data and projected models have helped to elucidate on the implications of climate change on human nutrition.[11] This section looks at those factors that have, and continue to have, a major impact on food security and human nutrition.

Reduced biodiversity, reduced food variety

Loss of habitat through the clearing of forest, grassland, and wetlands results in a loss of both plant and animal species, some of which are key food sources. Their loss decreases dietary diversity for some of the most vulnerable populations who rely on foraging and hunting for food.[12] Extensive use of agrochemicals to control weeds and other pests also causes species loss.[13]

Many varieties of crops have also been lost due to a focus on maximising productivity of select crops to the detriment of others. As a consequence, national food supplies are becoming increasingly homogeneous and dependent on a couple of truly "global crops," including major cereals and oil crops[14]. Current agricultural practices are moving further toward intensified monocultures, which increase grain yields in the short term but limit dietary and biological diversity.[14-16] Approximately 200 plant species and five animal species supply most of the foods consumed at the global level.[17] Wheat, rice, and maize alone contribute roughly 56% of the global dietary energy supply derived from plants.[18]

Soil quality and micronutrient levels are dropping

The earth has lost half of its topsoil over the past 150 years. Increased demand for agricultural products has led to deforestation and grassland clearing. Poor agricultural practises have exposed the fragile topsoil to erosion, nutrient depletion and increased salinity. This has led to increased pollution and sedimentation in rivers, clogging waterways and impacting on aquatic ecosystems.[19] Soil quality has also been declining due to intensive monoculture as well as heavy fertiliser, pesticide and herbicide use.[12]

It is critical to recognise that soil quality is a key factor affecting the micronutrient content of crops.[20] Several studies have shown a decrease in crop micronutrients over the past century. Between 1950 and 1999, there were declines in protein, calcium, phosphorus, iron, riboflavin, and vitamin C in 43 different fruits and vegetables.[21] Between 1930 and 1980, there were decreases of 9% in calcium, 22% in iron, and 14% in potassium in 20 different vegetables.[22] Declines in micronutrient content are not caused solely by soil quality; changes in cultivated varieties, anomalies in measurement, changes in the food system, and changes in agricultural practices are all likely contributing factors .[21-22] Therefore, there exists a clear link between soil quality and micronutrient content that needs to be addressed.

As climate changes, so will the geographic range of commercial crops change. Geographical areas that were once suitable for growth of a certain species, may no longer support their growth. According to research, the proposed solution for this will be simple – select and grow species that are suited to a certain type of climate. However, it is not only the growth conditions of the plant that need to be considered, but also the nutrition of the plant. Climate change will affect the cycling of chemicals in the soil and rhizosphere biology, impacting the availability of nutrients for plant growth and the nutrition of the plant itself.[23]

Increasing soil nutrients can have unwanted effects

Currently, nutrient-deficient or poor soils undergo intense fertilisation to improve their nutrient quality. The production of fertilisers is energy-intensive and contributes to the greenhouse gas load in the atmosphere.[23]

> "It is critical to recognise that soil quality is a key factor affecting the micronutrient content of crops.[20]
>
> It's a conundrum that the poor nutrient levels in soils are likely to be addressed with growing use of energy-intensive and emissions-intensive fertilisers which will inevitably exacerbate global warming."

An increase in atmospheric CO_2 is expected to benefit crop growth and crop yield in the short term. However, increased temperatures will lead to changes in soil microbial physiology thus altering the cycling of nutrients and affect the availability of nutrients for crop growth. Increases in CO_2 decrease the uptake of nitrogen by crop plants resulting in reduced nutrient uptake and lower concentrations of nitrogen and protein in the leaves and seeds. Increasing the soil's nitrogen supply may help to overcome this, however, this needs to be done in a sustainable way.[23]

Studies on staple crops plants such as wheat, rice, soybean and barley, grown under models of increased atmospheric CO_2 conditions predicted for the middle of this century, show lowered levels of calcium, magnesium, phosphorus, potassium, sulphur, cobalt, zinc, iron, copper, manganese, nickel, selenium, silicon and protein in different studies.[24-27] The predicted effects on plant crops, such as maize, sugar cane, millet and sorghum, are not yet known.

Studies on Indian wheat crops grown under conditions of increased atmospheric CO_2 and increased temperature, predicted for the early second half of this century, showed that there could be a possible 9-24% decline in zinc, iron and protein concentrations in the grains as well as a reduced crop yield. The study also showed that phytic acid levels of the grain reduce micronutrient absorption in the gut, thereby further reducing the availability of nutrients.[28]

Population groups who depend on these staple crops as their main food source will become more vulnerable to nutrient deficiencies, particularly protein, zinc and iron. The proposed solutions are to increase nitrogen feed to the crops, breed suitable species or food fortification – all non-sustainable and environmentally controversial approaches. If fertiliser use is the only solution, then the NutrUE (biomass produced per unit nutrients used) would need to be addressed to minimise greenhouse gas emissions.[23]

While crop plants are expected to increase growth under conditions of elevated CO_2 in the short-term, the added effect of elevated temperature will negatively impact the plant's ability to take up nutrients, compromising its protein and micronutrient composition.

06/ Reduced Marine Sources of Nutrients and Essential Fatty Acids

In accordance with the predicted effects of climate change on marine ecosystems, the availability of essential nutrients that are currently obtained from marine sources is likely to be affected.

The importance of omega-3 PUFAs for human health

Omega-3 polyunsaturated fatty acids (PUFAs) are a group of essential fatty acids that cannot be synthesised de novo by humans and need to be obtained through the diet, with marine sources being ideal. PUFAs are required for normal growth and development in humans and modulate many important biochemical processes of relevance in many human health conditions, such as inflammation. As a result, PUFAs have been the focus of intense research activity for their crucial role in disease management and prevention. Research shows that adequate intakes of omega-3 PUFAs, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), optimise health and prevent disease.[30]

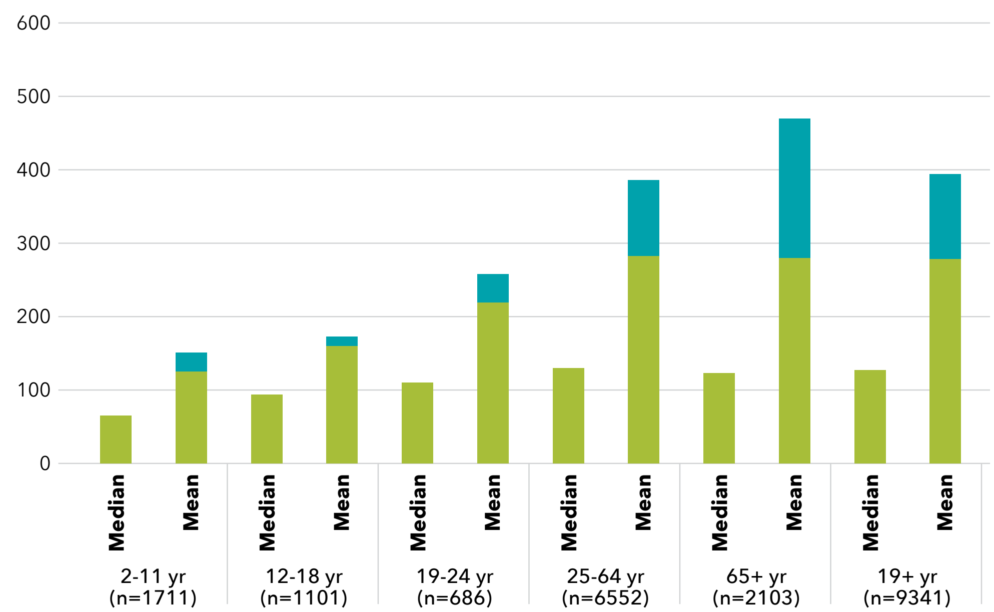
There is a considerable difference in blood levels of omega-3 PUFAs in individuals in different regions around the world. True global blood levels are difficult to identify due to lack of data from many regions however what is available indicates that most regions are low in omega-3 PUFAs.[31] The typical Western diet is low in omega-3 PUFAs but high in omega-6 PUFAs, resulting in a higher omega-6 to omega-3 ratio.[32] Such a ratio is thought to be associated with the modern prevalence of cardiovascular disease, cancer, diabetes, obesity and neurodegenerative disease, affecting millions of people worldwide.[32,33]

In Australia, consumption of omega-3 PUFAs is below recommended intakes according to the results of an analysis from the 2011-2012 National Nutrition and Physical Activity Survey.[34] The survey showed that 20% of Australians are not meeting their daily recommended intake (430mg/day for female adults and 610 mg/day for male adults) and groups that showed higher than normal intakes were largely due to omega-3 supplements.[34]

The Australian National Health and Medical Research Council (NHMRC) recommends that individuals consume two to three serves of fish per week in order to get their recommended daily intake of omega-3 PUFAs. Alternatively, a fish oil supplement is recommended for those individuals unable to meet this intake.

Marine phytoplankton and single-cell algae are the main producers of omega-3 PUFAs in the marine food chain and represent the basis of the aquatic food chain for all marine life.[35] Humans obtain PUFAs through multiple levels of this food web: from microalgae which are directly used for food products, animal feed and dietary supplements; from fish, which consume phytoplankton, and from livestock, which are fed meal produced from various organisms in the food chain.[29]

Australian n-3 LCPUFA intakes (mg/day) from food and supplements



Comparison of the median and mean omega-3 PUFA intakes from food and supplements per age category.

Source: Meyer BJ. Australians are not Meeting the Recommended Intakes for Omega-3 Long Chain Polyunsaturated Fatty Acids: Results of an Analysis from the 2011-2012 National Nutrition and Physical Activity Survey. Nutrients. 2016 Feb 24;8(3):111.

Climate change is predicted to negatively impact on phytoplankton and single-cell algae survival in two ways: an increase in UVB radiation will inhibit photosynthesis, damage cellular DNA and reduce cellular ATP (energy) production. These effects on cellular metabolism will greatly reduce the capacity to produce long chain PUFAs such as omega-3.[30] In addition, an increase in CO_2 levels decreases omega-3 production in algal cells, but increases omega-6 and 9.[30]

Sustainability of krill and calamari oil

According to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) krill numbers in the Antarctic and Southern Ocean remain at healthy levels and depend on the levels of sea ice. While they are concerned about climate change and global warming, they state that "there is no actual evidence of any reduction in sea-ice around the whole of the Antarctic".[36-37]

Because krill and calamari are part of the marine food chain which is entirely dependent on the survival of plankton and single-cell algae, it is reasonable to surmise that both krill and calamari numbers will be affected under conditions of global warming, and that in future years both krill oil and calamari oil may not be considered to be a sustainable source of omega-3 PUFAs.

Alternative sustainable sources of omega-3 PUFAs

Under the current climate change model, global fish stocks are predicted to decline and may not be a long-term and sustainable source of omega-3 PUFAs. This means that alternative sources of omega-3 are required, if these fatty acids cannot be obtained from the diet.

Cultivated microalgae provide a more sustainable solution to the concern around the future supply of omega-3 PUFAs for human health.[38]

Additional benefits of microalgae include:

- Microalgae grow rapidly, reducing the potential for heavy metal and toxic chemical accumulation from the environment
- The omega-3 content can be easily separated from other algal lipids. These lipids have the potential to be used as biofuels
- The remaining algal biomass can be used as feed for both livestock, freeing up arable land for food production[38]

Land plants such as flaxseed are also rich sources of omega-3, 6 and 9 PUFAs. The form of omega-3 in flaxseed is called alpha linolenic acid (ALA). While the body is able to convert ALA to the more beneficial EPA and DHA fatty acids, conversion is relatively slow and so marine sources of EPA and DHA are the preferred sources of these omega-3 PUFAs.[30]

07/ The Impact of Climate Change on Medicinal Plants

Medicinal and aromatic plants, like all other plants, are not immune to the effects of global warming and loss of habitat due to human activities.[39] Medicinal plants are a valuable source of new drugs with over 25% of medications currently prescribed in the developed world being derived from wild sources. It is estimated that 80% of people in developing countries totally depend on herbal medicine for their primary healthcare.[40] The use of medicinal plants is growing rapidly with an increasing demand for herbal medicines, natural health products and secondary metabolites from medicinal plants. It is estimated that plant species loss is 100 to 1,000 times higher than the expected natural extinction rate and the earth is losing at least one potential new drug every two years.[40]

> "Preservation of medicinal herbs must be a priority given 80% of people in developing countries totally depend on traditional herbs as their primary form of healthcare."

07

According to the International Union for the Conservation of Nature (IUCN) and World Wide Fund for Nature (WWF), 50,000 – 80,000 plants are used as therapeutic agents worldwide, representing over 10% of all plant species. Of these, nearly 15,000 species are faced with extinction due to loss of habitat and overharvesting, and 20% of their wild resources have already been exhausted with increasing human population and plant consumption.[40] In areas where wild collection and cultivation of medicinal plants is controlled, inefficient and incorrect management resulting in loss of species can spell economic disaster for communities who depend on these industries.[40]

The distribution of medicinal plants is not uniform across the world. China and India account for the largest use of these plants, followed by Colombia, South Africa and the United States.[40] Certain plant families not only have higher numbers of medicinal species, but also have a larger number of threatened species than others.[40] Rare species, species with narrow geographical ranges (endemic species) and species with specialised reproductivity are most vulnerable to rapid extinction. While overexploitation, indiscriminate collection, uncontrolled deforestation and habitat destruction all contribute to species rarity, climatic factors such as global warming are also threatening the survival of medicinal plants and their properties.[40]

Medicinal plants in the Arctic region:

The Arctic and alpine regions of Europe, Asia and South America are experiencing some of the most rapid changes from global warming. Changes to plant distribution have already been observed in these areas.[39] In the Arctic, endemic plants have little competition and have adapted strategies to survive under adverse conditions. An increase in temperature makes the terrain favourable for the growth of other plant species, and with this comes the risk of infestation and disease. Endemic species will be forced to migrate further north to more favourable growth areas.[39]

As an example, the traditional medicinal plant *Rhodiola rosea* (rhodiola) grows in the arctic regions of Asia, Europe and North America. It has been traditionally used to treat fatigue, depression, infections and support the immune system and heart. Largely due to supportive research, there is an increased global demand for this medicinal plant which has led to cultivation projects in Canada, economically benefitting the local Inuit communities. *Rhodiola rosea* grows along the seashore in Canada and is at risk of extinction from global warming in two ways: invasion of their natural habitat with new plant species leading to competition for resources, and flooding of the coastline during to rising sea levels.[39]

Medicinal plants in alpine regions:

Some cold-adapted medicinal plant species have begun migrating to higher altitudes in alpine regions.[41] The full impact of this movement is not yet fully known however, medicinal plants such as *Artemesia genipi* and *Primula glutinosa* that inhabit the upper alpine zones, may be faced with extinction more rapidly due to global warming.[42]

The eastern Himalayas is a region rich in high-altitude endemic plants that are valued for their useful (predominantly medicinal) properties. These plants account for approximately 62% of all plant species in the region and are important for traditional Eastern medicine systems. Over-harvest and the additional threats imposed by climate change threaten the existence of many species. For example, *Saussurea laniceps* (snow lotus) is a plant that has been used traditionally to treat high blood pressure and female conditions. This plant is at risk of extinction from both climate change and over-harvesting. Unfortunately, repeated attempts to cultivate it have been unsuccessful, most likely due to the highly fastidious requirements of such Himalayan alpine plants.[8]

Medicinal plants on islands and in rainforests:

Islands and other low-lying areas are at risk of inundation and flooding due to rising sea levels under global warming.[43] However, research indicates that common medicinal plants, used in the Pacific islands for example, are fast-growing, highly adaptable and saltwater and wind resistant, making them resilient to most of the predicted impacts of climate change.[39] There is limited research on the effects of climate change on rainforest medicinal plant species.

> "Species survival of medicinal plants as a result of the impacts of climate change is only part of the story, we need to understand the effects on the phytochemical compounds that make them efficacious."

07

Changing phytochemical properties of medicinal plants

Secondary metabolites are important phytochemical compounds found in plants that contribute to their medicinal properties. The effects of an increase in atmospheric CO_2 levels on medicinal plants have been studied in controlled environments. Studies on the response of plant secondary metabolites to light irradiation, temperature change, soil water, soil salinity and soil fertility have also been studied for many important plant species.[44]

The effects of elevated CO_2 on plant quality and secondary metabolites

In controlled environments, experiments have shown beneficial effects of elevated CO_2 on productivity and quality of various products and constituents of medicinal plants.

Examples: Impact on plant roots and foliage

Spearmint (*Mentha spicata* L.), thyme (*Thymus vulgaris* L.) and water mint (*Mentha aquatica* L.) showed increases in fresh leaf, root and shoot weight of under ultra-high CO_2 levels compared to high CO_2 levels and ambient air.[45]

Lemon basil (*Ocimum basilicum* L.), oregano (*Origanum vulgare* L.), peppermint (*Mentha piperita*), spearmint (*Mentha spicata* L.) and thyme (*Thymus vulgaris* L.) shoots showed increased fresh weight and leaf and root numbers in cultures grown under elevated CO_2 levels compared with cultures grown on the same media under ambient air.[45]

> "While elevated CO_2 may increase secondary metabolite production, there is no certainty as to how plants will adapt to the added effect of increased temperature or the impact on potency."

Examples: Impact of elevated CO_2 on plant quality

Tomato: Tripling atmospheric CO_2 concentration increased vitamin C content in tomato by 7% and significantly increased vitamin A.[46]

Sour Orange: In sour orange crop, atmospheric CO_2 enrichment by 75% increased vitamin C concentration by 15% compared to the control.[47]

Foxglove (*Digitalis lanata*): Tripling the air's CO_2 content increased the concentration of the cardiac glycoside digoxin by 11% under well-watered and 14% under water-stress conditions.[48]

St. Johns' wort (*Hypericum perforatum*): In CO_2-enriched chambers, net photosynthetic rates of the plants were 124% greater than those of the plants growing in ambient air, and their dry weights were 107% greater. CO_2 at 1000 ppm increased plant concentrations of hypericin and pseudohypericin by just over 100%.[49]

Ginger (*Zingiber officinale*): Two different varieties exposed to different CO_2 concentrations (400 and 800 ppm). High photosynthesis and plant biomass were observed at 800 ppm CO_2. Elevated CO_2 concentration resulted in increased water use efficiency. Total flavonoids, total phenolics, total soluble carbohydrates, starch and plant biomass increased significantly in all parts of the ginger varieties under elevated CO_2.[50]

07

The effects of temperature, soil water, soil salinity and soil fertility on plant secondary metabolites

Arctic and some alpine plants produce secondary metabolites in larger quantities under stressed conditions. Under conditions of increased temperature, secondary metabolite yield may be lower, and its medicinal effect may be reduced.[39] Conversely, other medicinal plants may find themselves in geographical locations that don't favour their growth. Under such stressed conditions, part of the adaptation process may be to produce larger quantities of secondary metabolites and change the action of these compounds. Phytochemical changes may also affect the way in which plants combat pests and diseases, favouring the production of one group of secondary metabolites over another.[39]

The effects of temperature increase on secondary metabolite production in plants are not yet fully understood but generally, an increase in temperature has the potential to enhance all secondary metabolites in all plant species.[44]

Examples: Impact of elevated temperature on plant secondary metabolites

The modulation of temperature appears to affect alkaloid accumulation, with higher temperatures being more conducive to their production. This has been demonstrated for *Papaver somniferum, Lupinus angustifolus. Cyanea acuminata, Cantharis roseus* and several other medicinally-important species.[44] Conversely, the production of phenolic compounds was shown to increase with a decrease in temperature. The phenolic compound (genistein, daidzein, genistin) content of *Glycine max* (soybean) increased under experimental conditions of low temperature.[51]

Temperature increase (35°C) reduced the total anthocyanin content of *Vitis vinifera* cv. Cabernet Sauvignon to less than half of that in the control berries, as a result of anthocyanin degradation and the inhibition of anthocyanin biosynthetic genes transcription.[54] Conversely, temperature decrease increased the anthocyanin content of the leaf sheaths of *Zea mays* (corn).[55]

The above examples highlight the diverse response of plants to the effects of temperature change. What is still unknown is whether or not the changes to secondary metabolite production in plants is merely a heat-shock response which will dissipate through adaptation. In order to maintain the therapeutic efficacy and ensure the safety of medicinal plants under future conditions of climate change, it may be necessary to grow them under controlled conditions, or to select cultivars in which secondary metabolite content can be ensured.[55,56] While these approaches may secure the safety and efficacy of pharmaceutically-important plants, it is a less than desirable solution for 80% of the world's population who rely on medicinal and aromatic plants as medicine.

> "Investment in medicinal plant conservation programs will ensure the protection of therapeutic herbs from the effects of climate change and will also grow understanding of their active compounds – which has the potential to deliver future innovation in natural medicine."

07

07/ The Impact of Climate Change on Medicinal Plants

07

Proposed solutions for the conservation and sustainable use of medicinal plants

The conservation and sustainable use of traditional plants have been well studied.[40] Conservation strategies include *in situ* conservation (in natural reserves and wild nurseries) and *ex situ* conservation (in botanical gardens and seed banks). While wild-sourced species are more desirable, the advantage of cultivated plants is that growing conditions can be better controlled leading to more predictable yields and stable secondary metabolite production. It also removes doubts over plant quality, authenticity and origin.

Good agricultural practises (GAP) have also been developed for medicinal plants to regulate production, ensure quality and facilitate standardisation of herbal medicines. In China, authorities have promoted GAP for commonly used herbal medicines in regions where those plants are traditionally cultivated.[40] In India, farmers have developed strategies to respond to changing weather patterns within their regions, particularly for the cultivation of medicinal plants in arid and semi-arid regions.[40]

Organic farming provides an integrated, humane and economically and environmentally sustainable farming system for medicinal plants. It relies on farm-derived renewable resources to maintain biological processes and ecological habitats.[40] The use of organic fertilisers contributes to soil health and nutrient composition and may improve the yield of secondary metabolites and volatile oils from medicinal plants.[40]

Sustainable use of medicinal herbs is important, especially for those that are slow-growing or whose yields are limited, in order to protect them from extinction.[40] In general, good harvesting practises need to be developed for different medicinal herb species. Root and whole-plant harvesting are more destructive to medicinal plants than harvesting aerial parts such as leaves, buds or flowers. Instances where aerial parts can be used in place of root or whole-plant harvests, are a more sustainable alternative.[40]

Supporting and sourcing sustainable resources

The following are examples of initiatives that provide safe and sustainable sources of medicinal plants:

Fair Wild Standard and International Standard for the Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP) under CITES: The Fair Wild Standard was set up by the Fair Wild Foundation in Switzerland in 2008. It applies to wild plant collection enterprises wishing to demonstrate their commitment to sustainable collection, social responsibility and fair trade principles. The purpose of the Fair Wild Standard is to ensure the continued use and long-term survival of wild species and populations in their habitats, while respecting traditions and cultures, and supporting the livelihoods of all stakeholders, in particular collectors and workers.

The standard assesses the harvest and trade of wild plants, fungi and lichen against various ecological, social and economic requirements. It helps support efforts to ensure resources are managed, harvested and traded sustainably, providing benefits to rural producers. One of its aims is to assist in facilitating the recommendations of the International Standard for the Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP), a project under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Sustainable Herbs Program: Set up through the American Botanical Council, the Sustainable Herbs Program seeks to ensure the safety, quality and sustainability of medicinal plants within the herbal medicine industry. It monitors the entire supply chain – from growers through to consumers. It supports sustainable organic and regenerative growing initiatives.

Botanic Gardens Conservation International (BCGI) Initiative: The BGCI was established in the U.K. in 1987. It supports the development and implementation of the Global Strategy for Plant Conservation (GSPC) at a global, regional, national, and local level. It works directly with members and other plant conservation organisations, carrying out threat assessments, seed conservation, ecological restoration, plant health and education projects around the world. It is one of the largest initiatives for the conservation of threatened plant species.

> This literature review highlights some of the consequences of Climate Change on people and the natural environment. It informs the need for the natural medicines industry to be vigilant and proactive in understanding the impact on the ingredients we use and changes to the nutritional needs of people.

Blackmores has reported a

12% annual reduction in greenhouse gas emissions

and is focused on a transition to cleaner energy sources

Blackmores diverts more than

70% of waste from landfill

Sustainable procurement has delivered packaging efficiencies

eliminating 50 metric tonnes of paper board from waste streams

Blackmores Group has more than

1.5 million education touchpoints

with consumers, retailers and health professionals each year

Blackmores has been the foundation

partner in a global fishery improvement project

to progress sustainable aquaculture, address marine environmental issues, and protect access to marine oils for generations to come

08/ Blackmores Group approach to address the impact of Climate Change

Blackmores Group has taken a strong position to address:

MITIGATION

Our actions to slow the acceleration of global warming including a reduction of emissions and lessening our impact of our operations.

ADAPTATION

Building resilience into our business model and supply chain to adapt to the changing physical world and changing markets as a result of climate change with a focus on the protection and conservation of nature.

We take responsibility for our impact by progressing four Sustainability Goals

1 Tread Lightly

- Favour cleaner and renewable energy sources
- Reduce greenhouse emissions intensity in the supply chain and manufacturing
- Reduce waste from our operations
- Progress sustainable packaging solutions

2 Source Responsibly

- Adopt sustainable procurement frameworks
- Support sustainable growth and cultivation projects
- Invest in projects to ensure the survival and protection of medicinal plants
- Support sustainable marine, plant and food resources

3 Lead the Change

- Provide transparent reporting on the impact of our operations
- Share knowledge on sustainable nutrition
- Partner with others to make a difference

4 Improve Wellbeing

- Make a positive contribution to people in the communities in which we operate
- Invest in natural health research and education
- Improve people's lives through access to better nutrition

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Blackmores Institute is the academic and professional arm of the Blackmores Group, established to support and drive an evidence-based approach to natural medicine.

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