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Sino-Russian cooperation on the sustainable utilization of Arctic biological resources: modernizing traditional knowledge

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Abstract Considering the effects of global warming, humans need to face the possibility of an ice-free Arctic during summer. Russia spans Eurasia and occupies more Arctic lands than any other country. This vast area has a great variety of species, and the geography and environment of the Arctic have endowed these species with unique and valuable properties. All the world's ancient nations have their traditional knowledge. The indigenous traditional knowledge of the Arctic and the knowledge embedded in traditional Chinese medicine are part of the world's time-honored wisdom. Some of this ancient lore cannot be verified by modern scientific methods, but the methods are effective in practice, triggering further exploration and innovation. Russian Arctic indigenous people have a long history of using the Arctic biological resources. The use of therapeutic materials in traditional Chinese medicine has many similarities with the use of Arctic biological resources by indigenous peoples. Both types of traditional knowledge can inspire new approaches to the development of the Arctic biological resources. China and Russia are among the world's largest countries, and it is important that they cooperate in developing the Arctic biological resources. The development of sustainable use of these resources, while updating traditional knowledge, is an urgently needed investment that requires an innovative approach.

Keywords **Arctic, biological resources, sustainable development, traditional knowledge**

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1 Introduction

Due to their natural environment, Arctic species have unique characteristics that make them effective in curing serious diseases or otherwise serving a role in human healthcare. The potential uses of Arctic organisms are not yet fully understood. Russia's Yamal-Nenets Arctic Science Center has a long history of research on the beneficial effects of Arctic biological resources on the human body, and some results have been applied in healthcare for astronauts, athletes, and scientific expedition members. Given the effects of global climate change, increasing biological resources are becoming available in the ice-free Arctic. The book "Nordic Path of Arctic Cooperation" states that to "understand the vulnerability and resilience of

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the Arctic environment and society and support the Arctic sustainable development" is a priority for Arctic research over the next decade (Henningen and Yang, 2019). Because biological resources are renewable, the use of Arctic resources is not only closely related to the "sustainable development of the Arctic", but also offers promising human use applications.

2 Modernization of traditional knowledge

Traditional knowledge can encompass traditional literature, art or scientific works, performances, inventions, scientific discoveries, design, signs, names and symbols, and privileged information. Tradition develops from creative advances in the fields of industry, science, literature, and art. "Tradition-based" refers to the following characteristics of knowledge systems. The categories of traditional knowledge can include: agricultural knowledge, scientific knowledge, technical knowledge, ecological knowledge, medical knowledge (including related medicines and therapies), knowledge related to biodiversity, folk art expressed as artworks, linguistic elements (such as names, geographical indications and symbols), and other cultural properties (Zhang, 2005). From this definition, it can be seen that the categories of traditional knowledge related to ecological knowledge, medical knowledge (including related drugs and treatments), and biodiversity-related knowledge are all closely related to biological resources. Indeed, traditional knowledge is always evolving with environmental change, so the modernization of traditional knowledge is a continuous process.

Mazzocchi (2006) states in a report that the importance of this traditional knowledge for the protection of biodiversity and the achievement of sustainable development is slowly being recognized internationally. Rai (2007) says in an article on northeast India that: "Traditional management practices will play an important role in managing natural resources. There is a need to preserve and revive these indigenous knowledge systems, and it is also imperative to popularize them among the youth before they are gradually and finally lost with time."

Arctic indigenous knowledge and Chinese medicine both belong in the category of traditional knowledge and have many similarities and commonalities. If we compare the two, traditional Chinese medicine has a longer textual heritage, and the traditional knowledge of the Arctic indigenous people has a more urgent need for exploration at the present time.

2.1 Traditional knowledge of Arctic indigenes

Due to global warming, indigenous knowledge is becoming a hot topic in academia. The book "Scientists and Global Governance" (Yang et al., 2018) defines the traditional knowledge of Arctic indigenes and explains that "indigenous traditional knowledge is a continuously accumulating knowledge system", and the evolution of its practice and belief is achieved through the adaptation process and the intergenerational transfer of culture. Although the knowledge systems of Arctic indigenous groups differ greatly owing to history, culture, traditions, regions, and languages, the unique knowledge they have developed is based on a deep understanding of climate, ice and snow, natural resources, hunting, and travel. This has helped them survive in the harsh climate for generations. The definition explains that the knowledge system is dynamic and has developed over time, that is to say, the modernization of indigenous traditional knowledge is an inherent attribute, and indigenous people achieve intergenerational transfer through modernization of traditional knowledge. The definition also states that the main content of indigenous knowledge "is the relationship between organisms (including humans) and their relationship with the environment". This point indicates that the traditional knowledge of Arctic indigenous people is closely related to the sustainable development of the Arctic. Therefore, this definition covers the content, accumulation, and services of indigenous traditional knowledge.

"Researching Arctic Indigenous Study" (Pan, 2012) states: "In the past 20 years, the knowledge of Arctic indigenous people has been increasingly valued; In the entire Arctic region, the enthusiasm for using indigenous knowledge is growing, but there exists a gap of how to get this knowledge properly." This passage points out the current predicament of Arctic indigenous research. At present, the research on Arctic indigenous people is not sufficient. Arctic indigenous peoples have multiple nationalities and are distributed in different countries. The existence of multiple languages has created barriers to understanding, which require to be overcome. Moreover, Arctic indigenous traditional knowledge is passed from orally between the Arctic indigenous people, and this means scientific researchers must constantly dig, sort, verify, write it up, and translate it into practical methodologies.

2.2 Traditional Chinese medicine knowledge

Traditional Chinese medicine (TCM) is not only a body of traditional knowledge but also has a close relationship with the utilization of biological resources. The raw materials of TCM are derived (mostly) from biological resources. For example, the classic 16th century text, "Compendium of Materia Medica" by Li (2016), published by Beijing United Publishing Company in 2016, first introduces the properties of animals and plants and their habitats, and then introduces the pharmacological effects. The preface to the modern version states: "'Compendium of Materia Medica' has not only contributed significantly to the development of Chinese pharmacology, but also contributed to the development of world medicine, botany, zoology, mineralogy, and chemistry."

The basis for the efficacy of TCM is naturally grown

biological resources. In recent years, due to mass production through artificial cultivation and the widespread use of chemical fertilizers, the curative power of Chinese medicinal materials has been adversely affected. Now there is a saying that "Chinese traditional medicine will be ended by Chinese medicinal materials". Comparatively, naturally grown medicinal materials from the Arctic have outstanding value. The "Traditional Chinese Medicine Regulations of the People's Republic of China", issued in 2003, proposed standardization of TCM technology, proceduralization, systemization of education and training, and professionalization of personnel to standardize the path of modernization of TCM traditional knowledge, protection and promotion (The State Council, the People's Republic of China, 2008).

Arctic indigenous lore and traditional Chinese medical knowledge represent the traditional knowledge of ancient people in two different regions of the world. So far, research on how to link the two in relation to biological resource use has not been carried out. Some researchers in the Russian Arctic began to study the use of local biological resources as long as 300 years ago. Such research activities have explored the traditional knowledge of the indigenous people, and some of the processing methods for herbal medicines in the Arctic are similar to those used in TCM. TCM has a more ancient written heritage and works such as "Qianjinfang (also known as Great Herbal Medicine)" (Sun, 1993) and "Compendium of Materia Medica" introduced the use of biological resources from different aspects. The combination of Arctic indigenous traditional knowledge with traditional Chinese medical practice is not only a requirement for the modernization of traditional knowledge, but also an opportunity for the use of Arctic biological resources.

3 Biological resources in the Russian Arctic

3.1 Animals

3.1.1 Mammals

Mammals in the Arctic are classified as marine and terrestrial. Marine mammals include whales, seals, sea lions, and walruses. The number of marine mammal species in the Arctic has increased due to the effects of climate change. The Arctic functions as a permanent habitat for some species, and a seasonal habitat for many more. For example, there are three types of whales that have inhabited the Arctic for many years: narwhal *Monodon monoceros*, beluga *Delphinapterus leucas*, and bowhead whale *Balaena mysticetus*. However, there are now additional 19 species of cetaceans in the Arctic: Northern right whale *Eubalaena glacialis*, Northern bottlenose whale *Hyperoodon ampullatus*, White-beaked dolphin *Lagenorhynchus albirostris*, Long-finned pilot whale *Globicephala melas*, Atlantic white-sided dolphin *Lagenorhynchus acutus*, North Pacific right whales *Eubalaena japonica*, Gray whale *Eschrichtius robustus*, Baird's beaked whale *Berardius bairdii*, Stejneger's beaked whale *Berardius stejnegeri*, Cuvier's beaked whale *Ziphius cavirostris*, Dall's porpoise *Phocoenoides dalli*, Harbor porpoise *Phocoena*, Sperm whale *Physeter catodon*, Blue whale *Balaenoptera musculus*, Fin whale *Balaenoptera physalus*, Sei whale *Balaenoptera borealis*, Minke whale *Balaenoptera acutorostrata*, Humpback whale *Megaptera novaeangliae*, and Killer whale *Orcinus orca* (Laidre and Regehr, 2018).

Terrestrial mammals in the Russian Arctic include polar bears, reindeer, Arctic foxes, white wolves, and musk oxen. Polar bears are at the top of the Arctic food chain, mainly relying on seals, walruses, and sea lions for sustenance. Due to changes in the Arctic climate and the consequent reduction in ice floes, polar bears may need to swim long distances to obtain food. This shift seriously affects the predation success of polar bears, leading to a decline in their numbers. Reindeer represent the largest group of Arctic mammals; the Yamal-Nenets region alone has more than 800000 reindeer (Russian News Agency, 2017).

3.1.2 Fishes

More than 600 species of fishes have been recorded in Arctic waters (Zeller et al., 2011). Freshwater fishes caught by the indigenous people in the Russian Arctic consist of various species including great white salmon *Coregonus nasus*, northern whitefish *Coregonus peled*, European whitefish *Coregonus albula*, trout *Salvelinus alpinus*, pike *Esox lucius*, needlefish *Gymnocephalus cernuus*, freshwater cod *Lota lota*, and whitefish *Coregonus pidschian* (Figure 1). These fishes, which frequent the estuary areas of the Arctic Ocean, have high nutritional value (Lobanov and Andponov, 2017).

3.1.3 Birds

The increase in temperature due to climate change has resulted in more birds, mostly migratory species, occurring in the Arctic. In the Russian Arctic, the birds observed include the Red-throated Loon *Gavia stellata*, Black-throated Loon *Gavia arctica*, Yellow-billed loon *Gavia adamsii*, Dark-bellied Brant *Branta bernicla*, Greater White-fronted goose *Anser albifrons*, Taiga Bean goose *Anser fabalis*, Northern Pintail *Anas acuta*, Long-tailed duck *Clangula hyemalis*, King eider *Somateria spectabilis*, Steller's Eider *Polysticta stelleri*, Red-breasted Merganser *Mergus serrator*, White-tailed Eagle *Haliaeetus albicilla*, Gyrfalcon *Falco rusticolus*, Willow Ptarmigan *Lagopus lagopus*, Rock Ptarmigan *Lagopus mutus*, Grey Plover *Pluvialis squatarola*, Pacific Golden Plover *Pluvialis fulva*, European Golden Plover *Pluvialis apricaria*, Common Ringed Plover *Charadrius hiaticula*, Eurasian Dotterel *Eudromias morinellus*, Spotted Redshank *Tringa erythropus*, Red-necked

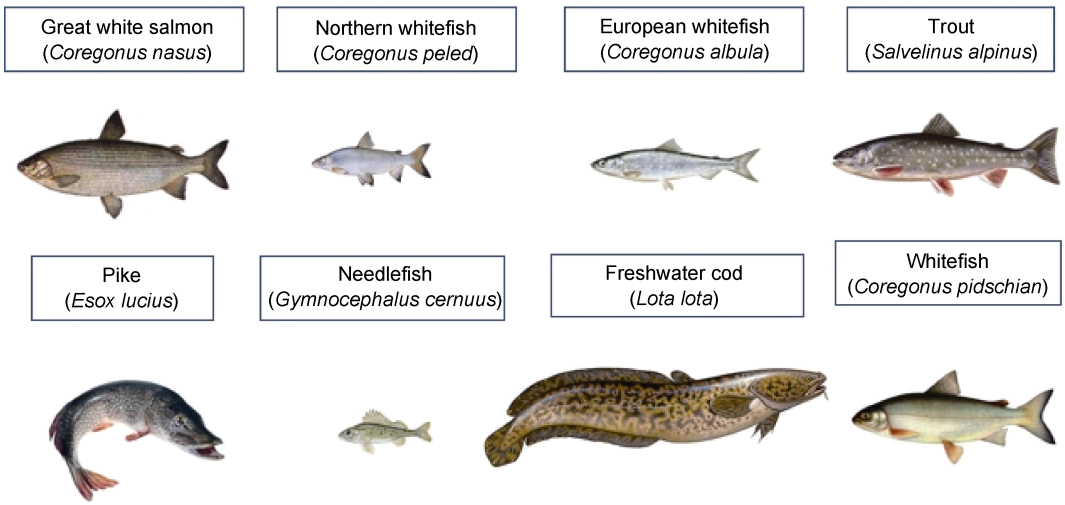

Figure 1 Freshwater fishes in Russian Arctic.

Phalarope *Phalaropus lobatus*, Ruff *Philomachus pugna*, Little Stint *Calidris minuta*, Dunlin *Calidris alpina*, Purple Sandpiper *Calidris maritima*, Pectoral Sandpiper *Calidris melanotos*, Red Knot *Calidris canutus*, Jack Snipe *Lymnocryptes minimus*, Bar-tailed Godwit *Limosa lapponica*, Pomarine Skua *Stercorarius pomarinus*, Arctic Skua *Stercorarius parasiticus*, Little Gull *Larus minutus*, Glaucous Gull *Larus hyperboreus*, Arctic Tern *Sterna paradisaea*, Snowy Owl *Nyctea scandiaca*, Horned Lark *Eremophila alpestris*, Red-throated Pipit *Anthus cervinus*, White Wagtail *Motacilla alba*, Willow Warbler *Phylloscopus trochilus*, Fieldfare *Turdus pilaris*, Lapland Longspur *Calcarius lapponicus*, Whooper Swan *Cygnus cygnus*, Bewick's *Swan Cygnus bewickii*, Common Scoter *Melanitta nigra*, Peregrine Falcon *Falco peregrinus*, Wood Sandpiper *Tringa Glareola*, Pintail Snipe *Gallinago stenura*, Long-tailed Jaeger *Stercorarius longicaudus*, Ivory Gull *Pagophila eburnea*, Short-eared Owl *Asio flammeus*, Hooded Crow *Corvus cornix*, and Bluethroat *Luscinia svecica* (Emelchenko and Nizovtsev, 2017). The frequency of occurrence and number of species of Arctic migratory birds has been increasing due to the warming climate.

3.2 Plants

Arctic plants and animals are exposed to extreme conditions. Their presence in this harsh environment demonstrates the amazing adaptations of these organisms to Arctic conditions (*i.e*., cold, polar magnetic storms, polar days, and night light suppression). The plants in the Russian Arctic fall into the following five categories (Ivanov, 2016).

3.2.1 Trees

There are not many trees in the Russian Arctic. Due to the cold, tall trees form a "tree line" over 1 m high near the polar circle (there are no trees north of the tree line). Common trees in the Russian Arctic include Tundra white birch *Betula nana*, Siberian elderberry *Sambucus sibirica*, Siberian spruce *Picea obovata*, Siberian pine *Pinus sibirica*, Siberian larch *Larix sibirica*, Siberian fir *Abies sibirica*, Siberian ash *Sorbus sibirica*, ordinary pine *Pinus silvestris*, fragrant poplar *Populus suaveolens*, and common bird cherry *Prunus padus.*

3.2.2 Shrubs

Arctic shrubs include many berries, some of which are effective in preventing cardiovascular and cerebrovascular diseases such as hypertension. Arctic shrubs have higher medicinal value than the same species in other regions. These shrubs include Marsh Labrador tea *Ledum palustre*, Chinese pistache *Pistacia chinensis*, hawthorn *Crataegus dahurica*, Altai honeysuckle *Lonicera altaica*, marsh cranberry *Oxycoccus palustris*, Siberian liana *Atragene sibirica*, raspberry sakhalin *Rubus matsumuranus*, Siberian juniper *Juniperus sibirica*, Single delight *Moneses uniflora*, sidebells wintergreen *Orthilia secunda*, Kuril tea *Pentaphylloides fruticosa*, Nordic currant *Ribes glabellu*, European black currant *Ribes nigrum*, meadow sweet *Spiraea salicifolia*, Mongol thyme *Thymus mongolicus*, bear berry *Arctostaphylos uva-ursi*, Whortleberry *Vaccinium myrtillus*, black crowberry *Empetrum nigrum*, Prickly rose *Rosa acicularis*, single-seeded ephedra *Ephedra monosperma*, and many others.

3.2.3 Herbs

Herbaceous plants are more common in low and middle latitudes; however, there are Arctic herbs, which are extremely potent and powerful. These herbs include swamp calamus *Acorus calamus*, valerian *Valeriana alternifolia*, stinky cornflower *Thalictrum foetidum*, Buckbean *Menyanthes trifoliata*, *S*piked speedwell *Veronica incana*, Snowdrop windflower *Anemone sylvestris*, Siberian bamboo *Phlojodicarpus sibiricus*, Woolly geranium *Geranium pratense*, Groundcedar *Diphasiastrum complanatum*, Sweetclover *Melilotus officinalis*, Candle larkspur *Delphinium elatum*, Wild strawberry *Fragaria orientalis*, Tuberous tuber *Phlomis tuberose*, Northern sweet grass *Hierochloe odorata*, Fireweed *Chamerion*

angustifolium, Yellow marsh marigold *Caltha palustris*, Red clover *Trifolium pratense*, Arctic raspberry *Rubus arcticus*, Stone rubus *Rubus saxatilis*, Stinging nettle *Urtica dioica*, Great burnet *Sanguisorba officinalis,* Pacific silverweed *Potentilla anserina*, Wild mint *Mentha arvensis*, Dandelion *Taraxacum ceratophorum*, Swthistle *Sonchus oleraceus*, Tenacious stonecrop *Sedum aizoon*, Shepherd's purse *Capsella bursa-pastoris*, Tansy *Tanacetum vulgare*, Yellow Spring bedstraw *Galium verum*, Large plantain *Plantago major*, Common wormwood *Artemisia vulgaris*, Tarragon *Artemisia dracunculus*, Yakut wormwood *Artemisia jacutica*, Snowdrop *Pulsatilla flavescens*, Five-lobed motherwort *Leonurus quinquelobatus*, Quackgrass *Elytrigia repens*, Compact rhubarb *Rheum compactum*, Roseroot stonecrop *Rhodiola rosea*, Jacob's ladder *Polemonium coeruleum*, Knotweed *Polygonum aviculare*, Marsh cudweed *Gnaphalium uliginosum*, Caraway *Carum carvi*, Yarrow *Achillea millefolium*, Odorous chamomile *Chamomilla suaveolens*, Field horsetail *Equisetum arvense*, Horseradish *Armoracia sisymbrioides*, Hellebore root *Veratrum lobelianum*, Celandine *Chelidonium majus*, Silver spray yarrow *Achillea cartilaginea*, Garden sorrel *Rumex thyrsiflorus,* Sainfoin *Onobrychis arenari*, and others.

3.2.4 Fern

There are only a few fern species in the Arctic; the available ferns include Siberian polypody *Polypodium sibiricum*, Fragrant wood fern *Dryopteris fragrans*.

3.2.5 Mosses, lichens, and fungi

Mosses and lichens are widely distributed in the Arctic, including Witch's hair lichen *Alectoria ochroleuca*, Greygreen reindeer lichen *Cladina rangiferina*, Sphagnum *Sphagnum fuscum*, Beard lichen *Usnea longissima*, Iceland cetraria lichen *Cetraria islandica*, Chaga *Inonotus obliquus* (fungus), Clubmoss *Lycopodium clavatum.*

4 Arctic indigenes' use of biological resources and modernization of traditional knowledge

Russia spans vast territories and waters in the Arctic. The Arctic indigenous people were the first in the world to find and harvest Arctic biological resources. As early as 1669, Mr. Yepisev had already studied medicinal plants in the Arctic region of Yakutia and collected some health-enhancing herbs, described them in detail, and sent them to Moscow (Ivanov, 2016). The indigenous people of the Russian Arctic comprise multiple ethnic groups: Sami, Komi, Nenets, Khanty, Yakut, Evenki, Chukchi, and other minorities. The customs of the different groups of Russian Arctic indigenes are similar, largely because they have similar production methods. These methods are divided into four categories of activity—fishing, hunting, reindeer stocking, and plant collection—all of which have been carried out for thousands of years. These production methods constitute the livelihood of the Arctic indigenous people. The value of the biological resources of the Russian Arctic indigenous peoples can be divided into three major categories.

4.1 Edible value

Arctic biological resources are widely used by local indigenous people and the primary use is food. Figure 2 shows the fish, reindeer meat, and berries consumed by the Russian Arctic indigenes in their daily lives, a diet that has remained largely unchanged for thousands of years.

Figure 2 Daily foods of Russian Arctic indigenous people (white salmon, reindeer meat and berries).

Indigenes raise reindeer to obtain a stable source of meat. Moreover, reindeer meat and blood are considered nutritious food items. Reindeer meat is believed to prevent arteriosclerosis and high blood pressure, as well as to reduce obesity.

Fishing has been one of the major sources of sustenance for Russian Arctic indigenes for centuries. Freshwater fishes in the Arctic, such as white salmon, pike, and burbot, have extremely high nutritional value. There is a proportional relationship between fish consumption and muscle mass in the human population.

Berries are also important dietary items for the Russian Arctic indigenes. Records show that wild berries such as blueberries, marsh cranberries, bear berries, black pine balls, and others grow in the Russian Arctic indigenous area. Russia's Arctic wild berries are produced in large quantities. In addition to being used as fruits, they can also be made into bread, chocolate, jam and other foods. They have anti-aging properties, and can protect the optic nerve and regulate gastrointestinal functions (Lobanova, 2013).

The eggs of Arctic migratory birds are also collected by indigenous people for their high nutritional value.

There are few medical facilities in the Russian Arctic indigenous area, and patients are usually transported by helicopter ambulances. However, there are few patients with chronic conditions, such as cardiovascular and cerebrovascular disease, among the Arctic people. The health of the Russian Arctic indigenes benefits from their traditional dietary knowledge.

4.2 Medicinal value

Arctic creatures withstand cold, geomagnetic storms, and light suppression all year round. The distinctive environment of the Arctic results in the unique attributes of

these organisms, in some cases endowing them with high medicinal value. For example, the slow growth rates of Arctic plants give them concentrated nutrients. Modern medicine has conducted research on the traditional foods of indigenous people and found that the content of nutritional ingredients in indigenous traditional foods is extremely high.

4.2.1 Concentrated nutrients from Arctic organisms

Omega-3 fatty acids. The tissues of freshwater fishes in the Arctic contain omega-3 fatty acid levels dozens of times higher than those in fishes from southern regions. Dietary omega-3 fatty acids reduce the risk of heart attacks and strokes (Lobanov, 2016).

Saturated/polyunsaturated fatty acids. The fats of northern fish and reindeer meat have a balanced ratio of unsaturated fatty acids and saturated fatty acids, conferring high resistance of cells to free radical damage. These nutrients help reduce systemic stress, particularly the stress of high-speed thinking or decision-making in extreme conditions (Lobanov, 2016).

Amino acids. The meat and blood of reindeer and northern fish has tryptophan, tyrosine, and lysine content; these amino acids are necessary for the synthesis of neurotransmitters. Lack of these amino acids can cause depression, chronic fatigue, reduced mental performance, low hormone levels, and destruction of the reproductive system (Figure 3; Lobanov, 2016).

Figure 3 Nutritional supplements made from reindeer blood for nutritional support of astronauts, athletes, and expedition members (https://dryblood.ru/).

Trace elements. The tissues of Arctic plants and animals are rich in trace elements (Fe, Zn, Mg, and Cu), which can increase the transfer, absorption, and utilization of oxygen, thereby increasing the energy potential of cells (Lobanov, 2016).

Vitamins. Plants growing in the Arctic contain twice to 20 times more ascorbic acid than the same plants growing in temperate regions (Lobanov, 2016).

Reindeer antlers, lichens, and plants contain hormones that regulate the body's hormonal, reproductive, and immune systems, the aging process, and tumorigenesis (Lobanov, 2016).

The medicinal value of white salmon fish meat, reindeer blood, lichen moss, cedar pine needles, dwarf white birch, Arctic Ganoderma (a fungus), and other plants was discovered long ago. According to field investigations, the experimental white mice raised by Russian Arctic researchers on a diet of white salmon were 3–4 times larger than the control group raised on edible grains. Russian Arctic indigenous people have a tradition of smoking leaf tobacco and, according to local medical institutions, some patients diagnosed with lung cancer have been cured by eating local herbs. Chemical analysis has shown that some medicinal components in Arctic organisms are present in amounts several times that of the same species in low latitudes (Lobanov, 2016). Modern medicine is one of the ways to modernize traditional knowledge by studying the ingredients of Arctic indigenous traditional food and exploring its medicinal value.

4.3 Other values and uses

Arctic biological resources are also used as raw materials for household items and other products. The tents inhabited by the Nenets are sewn from reindeer skin (Figure 4). The fur and bones of Arctic animals are often used in ships, sleighs, and other transportation vehicles. Arctic animal parts can be made into construction materials with excellent antifreeze properties. For example, the hulls of boats constructed from the skins of large Arctic fish are highly resistant to the cold and wind.

From as early as the 17th century, fur from the Russian Arctic has been popular in Europe. Indeed the trade in fur from Arctic animals such as polar bears, Arctic foxes, Arctic wolves, and Arctic rabbits, as well as reindeer skin, was one of the most flourishing businesses in Europe. Two Arctic port cities, Murmansk and Arkhangelsk, have been two of Russia's top three trading cities since the 17th century, with the main transaction volume from the trade of Arctic animal fur (Yang and Luo, 2019).

5 Sino-Russian cooperation on the Arctic biological resources and modernizing traditional knowledge

5.1 Basis for cooperation

5.1.1 Advantages of China and Russia jointly developing Arctic biological resources

The advantages of Russia's involvement are reflected in the following: The extreme living conditions of animals and plants shape their adaptations for high productivity. The distance of these resources from industrial areas guarantees high purity in raw materials. The northern raw materials market is not saturated, resulting in high-profit margins and few competitors. The accumulation of scientific research, processing technology, and experience in practical

Figure 4 Nenets' tents are made of reindeer skin.

applications has accelerated the speed of project development. The outcomes show in the development of regional infrastructure (*i.e.*, airports and helipads, highways, and railway networks; and the year-round Sabetta seaport), which mean that export costs are cheaper than in other Arctic regions. The cold weather and permafrost wells provide suitable conditions for the storage of raw materials without the need to incur high energy costs.

The advantages of China's involvement are as follows. First, foods and medicines derived from Arctic biological resources have high nutritional purity and may have significant effects on the prevention and treatment of cardiovascular and cerebrovascular diseases and Alzheimer's disease. With the aging of the Chinese population, China has become the world's largest market for health products and medicines. Second, Chinese traditional medicine companies draw on thousands of years of inherited knowledge and experience with regard to the use of biological resources. The combination of Arctic biological resources and TCM could lead to considerable advancement in methods of production and use. Third, China's pharmaceutical and health-care product manufacturing enterprises have sufficient reserves of labor and capital to make considerable investments in the Russian Arctic. Finally, China's transportation and logistics industry is very well developed, and its transportation infrastructure, construction, and logistics management experience will help accelerate modernization in the Russian Arctic (Luo, 2019).

5.1.2 Basic conditions for the development of Russian Arctic biological resources

The Russian Arctic region has a large geographical span with uneven regional development. At present, the more suitable areas for cooperation are in the northwestern polar region of the Ob River Basin.

As shown in Figure 5, the west flank of the Ob River is not far from Russia's central area and is supported by the third and fourth largest cities in the country, with a solid industrial base (Novosibirsk is the third-largest city and Yekaterinburg the fourth-largest city in Russia; both are located in the upper reaches of Ob River Basin). The newly emerging industrial cities in the north are rich in oil resources, and residents in border regions enjoy high subsidies and higher wages, factors that have attracted people from the southern part of Russia and the Commonwealth of Independent States. The labor force is thus better off than in other Arctic regions. The infrastructure with regard to roads, railways, maritime transport, and air transport is relatively complete. Communication, engineering, and power facilities are in place. The population is relatively larger than in other Arctic regions of Russia. Lastly, the logistics network is well-formed.

5.2 Feasible paths

5.2.1 Government cooperation

"The Federal Law About Foreign Investments in the Russian Federation" stipulates that foreign companies must obtain the consent of the Russian government to be allowed to invest in Russia (Russian Federation, 2018). Investment in the Arctic region, as a special economic zone, must be approved by the Russian Federation government and local state governments. Hence, the development of Russian Arctic biological resources requires initial support from the government at all levels in Russia. Therefore, the establishment of cooperation between the Chinese and Russian governments is essential. The establishment of friendly government relations and a mutual visit mechanism between the business administration departments of the two governments would be conducive to the further development of Arctic cooperation.

Figure 5 Russian road and railway map (http://russia-karta.ru/region/eng_4.jpg).

5.2.2 Scientific research institution cooperation

Some of the intended objectives of this study are: to promote cooperation between China's economically developed regions and the Russian Arctic scientific research institutions, establish joint laboratories, and train and exchange scientists to facilitate cooperation for the sustainable utilization of Arctic biological resources. At present, the Arctic Science Center of Russia's Yamal-Nenets Autonomous Region and Guangdong University of Traditional Chinese Medicine, The Guangdong Provincial Hospital of Traditional Chinese Medicine, and the Scientific Research Center of Guangzhou Pharmaceutical Group are promoting cooperation and are expected to build joint laboratories.

China's scientific research institutions have already established closer ties with Arctic research institutions in Northern Europe and North America, but collaboration with the Russian Arctic science institutions, especially in the field of biological resources, has just begun. After all, the land area in the Russian Arctic Circle accounts for nearly half of the total land area of the Arctic Circle. The area has great species diversity, and the biological resources constitute a renewable resource. The potential for cooperation between China and Russia over Arctic biological resources is huge. The first step is to promote cooperation between scientific research institutions of the two countries.

The introduction of modern western medicine into China has promoted the modernization of traditional Chinese medicine. By the same token, the TCM knowledge of Arctic indigenous people can also complete the modernization process with the help of modern science. As the traditional knowledge embedded in Chinese medicine and the Arctic indigenous traditional knowledge have something in common, the two kinds of traditional knowledge can be used for reference and fusion, which will definitely create a new chapter in the use of Arctic biological resources.

5.2.3 Enterprise cooperation

Enterprises from the two countries can jointly develop processing systems for biological resources in the Russian Arctic, as well as jointly developing products and technologies for Arctic biological resources of interest to Chinese pharmaceutical companies. At present, many Chinese pharmaceutical factories, chain drug stores, and catering companies are conducting research on the biological resources in the Russian Arctic. The next step is to develop Chinese medicine products, health medicine products, and health foods using these resources. To maximize the value of Arctic biological resources, combining Chinese traditional medicine with health products in innovative ways has great commercial potential.

6 Conclusions

The Arctic indigenes have coexisted with nature for millennia and accumulated rich traditional knowledge about Arctic biological resources. Arctic indigenous traditional knowledge and the ancient science of Chinese medicine are

both parts of the world's treasure-house of traditional knowledge. The use of modern scientific and technological means to support the practice of traditional knowledge is the primary way to modernize traditional knowledge. The unique attributes of Arctic biological resources, informed by Chinese medical knowledge passed down for thousands of years, will allow exploration of the huge hidden potential of Arctic organisms. It promises the development of many medical and health products for chronic diseases, compromised health, and aging. Compared with other types of resources, biological resources are renewable and sustainable and should take priority in the sustainable development of the Arctic. Russia is the largest country in the world, and China is the country with the largest population in the world. Cooperation between China and Russia in developing Arctic biological resources and promoting the modernization of traditional knowledge will bring new opportunities to the development of the Arctic.

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Appendix：The most promising plants in the Russian Arctic (Lobanov, 2014)

1 Black crowberry (*Empetrum nigrum*)

Figure A1 Black crowberry (*Empetrum nigrum*).

(1) Unique attributes

It significantly improves mental and physical performance, the efficiency of decision making under stress, survival during extreme cooling, and accuracy and speed of hand movement coordination. It also reduces weather sensitivity. Unlike other stimulants, it does not increase blood pressure.

(2) Scope of application

- functional foods and dietary supplements; supplements for martial arts athletes, participants in team sports and figure skating, adventure tourists, and climbers;
- dietary supplements for people experiencing a highly emotional and intellectual load (managers, operators, drivers, rescuers, police, teachers, doctors, and students);
- dietary supplements for people allergic to weather changes.

(3) Raw materials: bamboo shoots and berries.

(4) Preparation method: drying, freeze-drying. Wide range of growth, at least 100 t of stock each year.

(5) Products: soft drinks, chocolate, candy, marmalade, and chewing gum.

2 Tundra white birch (*Betula nana*)

Figure A2 Tundra white birch (*Betula nana*).

(1) Unique attributes

It increases the elasticity of blood vessel walls, reduces tissue swelling, increases collagen spiraling and skin elasticity, protects cells from free radicals (slowing down aging), and improves cellular use of oxygen during exercise.

(2) Scope of application

- suitable for various beverage ingredients;
- functional foods and dietary supplements for athletes;
- consumption by patients receiving chemotherapy and antibiotics.

(3) Raw materials: leaves.

(4) Preparation method: drying.

(5) Products: soft drinks, chocolate, candy, marmalade, and chewing gum.

3 Siberian larch (*Larix sibirica*)

Figure A3 Siberian larch (*Larix sibirica*).

(1) Unique attributes

It protects cells from free radicals (slows down aging), increases resistance to intoxication with organic toxins, gives drinks a fresh flavor and extends shelf life.

(2) Scope of application

- functional foods and dietary supplements for athletes;
- consumption by patients receiving chemotherapy and antibiotics.

(3) Raw materials: tender leaves.

(4) Preparation method: drying, freeze-drying.

(5) Products: soft drinks, chocolate, candy, marmalade, and chewing gum.

4 Sphagnum（*Sphagnum fuscum*）

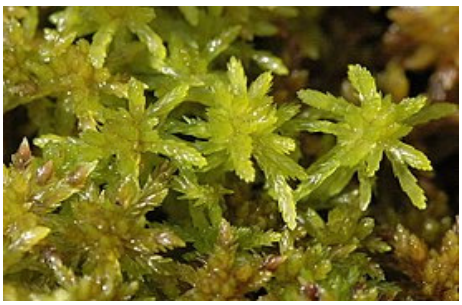

Figure A4 Sphagnum (*Sphagnum fuscum*).

(1) Unique attributes

It absorbs heavy metals, water-soluble and fat-soluble toxins, reduces the rate of glucose absorption, promotes food digestion, stores products for long periods of time, and prevents food allergies.

Unlike other adsorbents of plant origin, it does not irritate the intestinal wall. It prolongs the shelf life of products. It has a neutral taste and is suitable for inclusion in sweet, salty, spicy, bitter, and sour preparations.

(2) Scope of application

- functional foods and dietary supplements;
- high protein content in food;
- suitable for patients with impaired digestive function of the small intestine, type 2 diabetes patients, and patients who have received treatment with broad-spectrum antibiotics.

(3) Raw material: tender buds.

(4) Preparation method: drying and crushing.

(5) Products: bread, biscuits, biscuits, chocolate, candy, jam, and chewing gum.

5 Greygreen reindeer lichen (*Cladina rangiferina*)

Figure A5 Greygreen reindeer lichen (*Cladina rangiferina*).

(1) Unique attributes

It enhances immunity, promotes the treatment of chronic inflammatory processes in the lungs and bronchi, and reduces intestinal fermentation. It absorbs heavy metals and large-scale organic toxins, reduces the rate of glucose absorption, and assists food digestion without irritating the intestinal wall. It can also play a role in long-term storage of food products.

(2) Scope of application

- functional foods and dietary supplements for patients with chronic lung disease;
- digestive disorders in the small intestine；
- type 2 diabetes；
- following treatment with broad-spectrum antibiotics.

(3) Raw material: tender shoots.

(4) Preparation method: drying and crushing.

(5) Products: bread, chocolate, candy, jam, and sausages.