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Traditional Medicines in a Global Economy: Resource Sustainability and Resilience in the Traditional Tibetan Medical Practice of Ingredient Substitution

Denise M. Glover[1]

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Abstract
I discuss the long-standing practice of ingredient substitution in traditional Tibetan medicine as an adaptive resource management strategy that has enabled resilience in the larger socio-ecological world of medicinal resources, cultural knowledge, and ecological stewardship. Given that there are increasing pressures on and threats to the natural resources utilized in Tibetan (and other) traditional medicines, this flexible strategy should be supported and further accommodated in the growing industry of medicine production. Current industrialized pharmaceutical standardization suffers from a rigidity that partially threatens a sustainable resource management strategy. The theoretical orientation I utilize draws from Resilience Theory literature and discusses adaptive cycles, panarchy, and rigidity traps in the sphere of traditional Tibetan medical knowledge, medicine production, and resource management.

Keywords Resilience · Medicine production · Pharmacological substitution · Resource management · Tibet · China

Introduction

Nearing the end of the second decade of substantial growth in the traditional medicines industry in China, which relies almost exclusively on naturally sourced ingredients, concerns about the sustainability of natural resources it utilizes are increasing. Rapid expansion in any part of an interconnected social-ecological system can be problematic, in that stability already established within the system can be disturbed. Yet according to a variety of systems-theories, particularly those explored in the works of Resilience Theory scholars (Holling 1973, 2001; Allen and Starr 1982; Berkes and Folke 1998; Gunderson and Holling 2002a; Walker *et al.* 2006), complex systems do not remain in states of equilibrium in perpetuity. Change and fluctuation are integral to complex systems. However, to understand the sustainability of a complex system, it is important to establish the extent to which sudden shifts and disturbances can be endured without the entire system collapsing. Resilience is the ability of a system to adjust to sudden changes—such as rapid expansion. We are still only beginning to understand how rapid expansion of the traditional medicines industry in China in a globalizing medicines market and increasing environmental changes due to climate change are affecting the larger complex socio-ecological system of human-plant-industry. A key issue is that baseline understandings related to resource strain are not well established. Are we at a crisis moment, or on the verge of such a moment, in terms of the environments in which many of these natural resources occur, or in terms of the species populations themselves? With the exception of endangered species, we do not have a full enough picture, in part because the resources used in traditional medicines in China are quite widely dispersed. But it is clear that increased medicine production and thus extensive harvesting and over-harvesting, along with other factors such as climate change, are increasing the possibility of a future state of disequilibrium (Craig and Glover 2011; Saxer 2013; Kloos 2017; Kloos *et al.* 2020).

I focus here on the cultural practice of ingredient substitution (T: tshab) in Tibetan medicine formulation as an adaptive strategy utilized historically and currently in times of resource scarcity, and how this practice fits in to a larger structure of human and ecological interactions. Rather than considering medicinal ingredient substitution as a kind of "inferior" or "undeveloped" practice, as it is sometimes in pharmacological literature, I argue that it can be more fully understood as an effective resource management strategy, developed over

✉ Denise M. Glover
dglover@pugetsound.edu

[1] Department of Sociology and Anthropology, University of Puget Sound, Tacoma, WA, USA

generations in response to previous resource crises, that has sustained traditional Tibetan medicine as well as the resource ecology on which the system depends. Most current models of standardization in medicine production do not easily allow for changing of formulas based on availability of resources, in large part due to strict protocols with biological species identification and chemical profiling, what Gunderson and Holling (2002a) term a "rigidity trap." I argue that the medications standardization process should be adjusted to allow for flexibility of resource use to avoid a precipitous collapse of resources and/or to respond to pre-collapse fluctuations in resource availability. Furthermore, support for non-industrialized Tibetan medicine production (see Blaikie 2009; Kloos 2017; Hofer 2018) should be a priority for conservationists, as there are natural limits to resource availability in this small-scale type of production compared to industrialized production with near unlimited growth.

The Revival of Tibetan Medicine

A decade after the economic reforms that began in the late 1970s, traditional Tibetan medicine in the People's Republic of China (PRC) began receiving important governmental support. Hospitals, production facilities, and university departments of Tibetan medicine were established in Tibetan areas of the PRC, including the Tibet Autonomous Region (TAR), Qinghai, Sichuan, Gansu, and Yunnan Provinces, as well as in Beijing, where a hospital of Tibetan medicine was built in 1992 (Huang 2006, cited in Saxer 2013: 35). After the 1992 fourteenth Communist Party Congress when a "socialist-market economy" was proclaimed as China's future, production of medications was widened significantly from only for hospitals to include a pharmaceutical industry. Encouragement of private businesses spurred interest in transforming state-run production facilities into private (or in some cases, semi-private) ones. While several of the key players in the contemporary industry (e.g., Cheezheng/Qizheng in Lanzhou, established in 1993, and Jiumei Tibetan medicine Co. Ltd. in Xining, established in 1999) were privately founded, the majority of current businesses in the industry "were established from the nexus of a government-run hospital or medical college during the 1990s" (Saxer 2013: 37). In May 2015, support for the private economic sector was emphasized at the Central United Front Work Conference, with special attention paid to the TAR; reports highlight the fact that 96% of "market players" in the TAR are in the private sector (China Tibet Online June 2, 2015).

The economic encouragement of private industry worked in tandem with the state's long-standing interest in promoting traditional medicines as important resources for decentralized and relatively inexpensive public health care. Such an orientation has varied since the founding of the PRC, but even Mao Zedong was in favor of supporting some aspects of Chinese medicine, although not through decentralization, when he declared in 1955 that "our motherland's medicine is a great treasure house" (quoted in Farquhar 1995: 251). From Mao's point of view, this was especially pertinent for improving public health, and he envisioned a newly improved health care system that combined what was useful from both Chinese traditional medicine and western biomedicine; this resulted in the creation of the barefoot doctor movement and, to some degree, the creation of what is called in western-language literature Traditional Chinese Medicine (TCM). China's long-term connection, since the 1970s although renewed with new vigor since 2001, to the World Health Organization forges an increasing emphasis toward on-the-ground, in-situ, existing traditional medical systems as key resources for public health and universal health care. The WHO released its first Traditional Medicine Strategy report in 2002 (the strategy for 2002–2005) and its most recent strategy report in 2014 (for 2014–2023); both reports particularly emphasize the importance of utilizing traditional and complementary medicines to achieve universal health care coverage during the twenty-first century.

The protection and promotion of ethnic medical systems (*minzu yiyao* 民族医药) in the PRC has been encoded in a variety of laws. Article 21 of the Constitution of the PRC (1982) claims that the state develops and promotes traditional medicines (*fazhan woguo chuantong yiyao* 发展我国传统医药). Likewise, Article 3 of the Drug Administration Law of the State Food and Drug Administration asserts that the state develops traditional medicinal drugs (*chuantong yao* 传统药) with the aim of prevention and treatment of diseases. Most explicitly, protection and promotion of ethnic medicines is guaranteed in the *Minzu quyu zizhi fa* 民族区域自治法 (sometimes translated as the Regional Ethnic Autonomy Law, or the Nationality Areas Autonomy Law) of 1984, where Article 40 states that local authorities (within autonomous areas) will help to develop (*fazhan* 发展) the traditional medical systems of ethnic/nationality groups (*minzu chuantong yiyao* 民族传统医药).

Significant in terms of symbolic power, the Tibetan medical classic *The Four Tantras* (T: Rgyud bshi) is now recognized on the Chinese National Archives Documentary Heritage list (*Zhongguo dang'an wenxian yichan guojia ji minglu* 中国档案文献遗产国家级名录). Since Tibetan medicine, along with other traditions such as Mongolian and Dai medicine, is an ethnically marked knowledge system (Glover 2005), state encouragement and support of the institution of Tibetan medicine is a demonstration of the state's support of the Tibetan cultural world, and the state's larger agenda of a "Harmonious Society." This has long been a selling point of state provisioning for the relatively (now) apolitical institution of Tibetan medicine in the PRC. In essence, the CCP is hoping to promote a positive picture of state support for Tibetan culture at a time when many Tibetans and much of the world outside the PRC have concerns of cultural genocide and increased Hanification/Sinification throughout cultural Tibet. Thus, Tibetan medicine is in many ways the poster child for "positive" development in Tibetan areas of the PRC: it has entrepreneurial as well as state support, it contributes to the health care of the nation, and it indicates prosperity and growth for Tibetan culture and industry in the PRC. This is of course a narrative that one can construct from public discourse and state-sponsored publications. It is a powerful account that has the potential to influence national and international on-lookers, consumers, practitioners, and others involved in the medical industry.

Increased public interest in consumption of Tibetan medicine in China, starting perhaps with the SARS epidemic in 2003 (Craig and Adams 2008), along with increased marketing, has created an uptick in production throughout the country, with government statistics citing a 129% annual increase in the first years of the early 2000s (Saxer 2013). Granted, this is likely a small percentage of the overall pharmaceutical production in the PRC (cited at 668 billion yuan in output value in 2007—almost five times the industry output value in 1998). A 2013 report notes that China, since 2011, has become the world's third largest pharmaceutical market (Pacific Bridge Medical 2013). The same report claims that 36% of the total market share of pharmaceuticals in China is classified as Traditional Chinese Medicines (which includes Tibetan and other "ethnic" medicines). Kloos (2017) cites market reports of TCM's annual growth rate of 15% average between 2011 and 2016. Kloos *et al.* (2020: 4–5) further report that the sales value of Tibetan medications in the TAR doubled between 2003–2005, and between 2010 and 2015. Thus, total production and consumption of Tibetan medicines in China is significant. On top of this are markets for traditional Tibetan pharmaceuticals beyond the borders of the PRC (such as India, Bhutan, Mongolia, and Europe), some but not all of which utilize resources from within China.[1]

It is difficult to assess how much impact the rise in production alone has had on resources, as there are other factors that affect resource availability, including impacts of climate change. Ethnobiologist Jan Salick and colleagues (Salick *et al.* 2009) have documented the ways that climate change, particularly temperature increase, have affected plant distribution in the highland regions of the Hengduan and Himalayan Mountain ranges.[2] As Salick reported, "Alpine plants are getting pushed off of the mountaintops" (2009). Overgrazing in alpine regions is also a significant issue, and likely contributes to the decrease in suitable habitat for these plants. Several key ingredients in Tibetan medicine are on either or both of the endangered species lists, IUCN's Red List (International Union for Conversation of Nature) or CITES (Convention on International Trade of Endangered Species),[3] including *Aconitum heterophyllum* (T: bong dkar), *Nardostachys grandiflora* (T: spang spos), and some species of the genus *Meconopsis* (T: 'utpal sgnon po). Law and Salick (2005) have also hypothesized that the phenotypes of some heavily utilized plants, such as the Himalayan snow lotus, *Saussurea laniceps*, have been affected by harvesting preferences.[4] Ethnographic evidence based on my own research and that of colleagues over the course of a decade (Glover 2005; Law and Salick 2006; Ma *et al.* 2011; Saxer 2013; Kloos 2017) indicates that collectors and practitioners of Tibetan medicine agree there are decreases in the availability of certain substances (herbal and animal products)—and there is general agreement as to which resources are decreasing. Research conducted in 2008 by Ma Jianzhong of the Yunnan Academy of Forestry and colleagues in the Khawakarpo (NW Yunnan) region note that 26% (37 out of 144 species) of important Tibetan medicinal plants that grow in the region were identified by local practitioners as "endangered" (Ma *et al.* 2011). Recently, Stephan Kloos (2017) reported that practitioners from China, India, Mongolia, and Bhutan noted problems with resource availability. So, whether these decreases are due solely to increased production is not clear; however, since most ingredients in Tibetan (and Chinese) medicine are wild-sourced, increases in production will likely affect resource availability. And, for whatever reasons, the resources are recognized to be under pressure.

In China (and surrounding countries and regions such as Bhutan, Ladakh, Nepal, and India), there have been attempts at in-situ and ex-situ conservation and cultivation of medicinal plants used in various traditional medical systems. The results are quite varied. For trials in NW Yunnan, one ex-situ site saw a 68% overall survival rate for species planted at various altitudes, over the course of 1 year (Ma *et al.* 2011). In Nepal, the international NGO The Mountain Institute spearheaded a

[1] Padma, Inc. in Switzerland (a leading producer of Tibetan medicines in Europe) source most of their ingredients from outside China and about 50% from within Europe (Herbert Schwabl email communication May 4, 2020). However, Switzerland may be the exception to such low usage of PRC-sourced materials. Stephan Kloos confirmed (email May 4, 2020) that a large majority of materials used in the traditional medical system of Mongolia are imported from China. Clearly more data are needed to arrive at a definitive assessment of what and where the strain on resources is.

[2] Salick and colleagues have done similar research in other alpine environments as part of the GLORIA (Global Observation Research Initiative in Alpine Environments) Program.

[3] While the CITES list was originally compiled by IUCN, there are some slight discrepancies between the IUCN Red List and the CITES list.

[4] In this study, the researchers utilized herbarium specimens collected in the region as early as 1872 to demonstrate a marked decrease in size of the plant. They hypothesize that this is due to harvesters favoring larger-sized plants.

large-scale project cultivating *Swertia chirayita* (T: gya tig) that has been seen as largely successful: the quality of the plant is acceptable to Tibetan doctors, it has become an important cash crop in the local economy, and it has decreased demands on wild sources, which were under pressure (Saxer 2013: 103–106). Other attempts have yielded less positive results. Many of the easiest plants to cultivate are the least endangered, such as *Inula racemosa* (T: ma nu), often seen in courtyards in Tibetan homes. Some of the most endangered plant species (on IUCN's Red List or CITES list) are the most difficult to cultivate, such as *Aconitum heterophyllum, Nardostachys grandiflora,* and some species of *Meconopsis*; for some species that grow in alpine areas above 3500 m, in-situ cultivation may be the most promising for plant survival but is often the most challenging for cultivation project logistics. Limited cultivation research efforts are continuing throughout the Himalayas and surrounding areas, especially for endangered plants. In 2010, a cultivation site for three species of Tibetan medicinal herbs was established in Nyinchi in the TAR (east of Lhasa), in association with the Qizheng medical production company (Shan nan shuang). A 2013 article reports the establishment of a plantation for growing saffron in Lhoka Prefecture (south of Lhasa) in the TAR; a local science and technology company (unnamed in the article) has reportedly invested in the venture, and the price range given for the value of saffron is 500–5000 USD per pound (China Tibet Online).[5] In 2016 I visited Lhasa and was told by researchers associated with the Mentsikhang (Institute for Tibetan Medicine) that they were beginning to have success in cultivating a *Meconopsis* species in ex-situ sites, but the project was just in its infancy.[6] Despite these valiant efforts to increase the availability of many medical plants, supplies are still often insufficient. Consequently, the practice of using substitutes is becoming especially relevant and has been employed—both historically and contemporaneously—to increase overall ecological resilience.

[5] During my research in the summer 2015 in Shangrila, Yunnan Province, I met a medicinals trader selling saffron. The Hui Muslim man was from Lanzhou but had set up an import business in Lhasa and was in Yunnan working business deals to sell the goods he trades at the Prefectural Tibetan Medicine Hospital. The saffron (*Crocus sativus*) he was selling was imported from Iran, he claimed. A local doctor explained that saffron originally from Kashmir (now also grown in Iran) was much better quality (and hence preferred) than that grown domestically. While I was not able to confirm the identity of the domestically grown saffron, I suspect it might in fact be safflower, *Carthamus tinctorius.* *S*affron (*Crocus sativus*) imported from Iran appears to be less expensive (on the global market, at least) than that grown in Kashmir, at least in late 2014 and 2015 (as reported in *Business Standard* of India, Nov 27, 2014).

[6] Martin Saxer (2013: 105–106) reported that in 2009 only about 10% of the research efforts at the Mentsikhang were devoted to cultivation research.

Ingredient Substitution in Tibetan Medicine

The long-standing practice of using ingredient substitutes in Tibetan medicine is encoded in the classic twelfth century medical text *The Four Tantras* and other key medical texts. Substitutions are used for a variety of reasons, most of which revolve around the key issue of resource availability. Tibetan medical texts specify formulas, or recipes, as well as harvesting, preparation, proportions, and processing information. In some cases, due to the variability of the distribution of resources, a standard resource specified in a recipe may not be available. For instance, a plant that grows at high altitudes, such as a type of gentian, is unlikely to be available at lower-elevations, where it may be substituted by a plant with a similar pharmacological effect. This is in part reflected in the polysemy of many names for medicinal ingredients, where the Tibetan name for an ingredient may include several varieties, and may include more than one botanical species name (see below).[7] Substitutions are also sometimes made based on expense; less expensive sources may be chosen to keep the cost of production and of the final product low. Lastly, ingredients that are otherwise rare (difficult to obtain not necessarily due to location but possibly to processing or other associated costs) are often replaced with more common ones. In all cases, ingredients with similar pharmacological effects can be substituted for those specified in the texts, or in some documented cases according to local knowledge traditions that identify an ingredient as appropriate and effective. As Tibetan medicine is practiced far beyond the Himalayas and surrounding areas (for example, on the central Asian plains of Buryatia), adaptations are made in the context of local conditions and resource availability.

Generally substitutions can be made based on the taste (T: ro) and potency (T: nus pa) of an ingredient; substances with similar taste and potency will have similar pharmacological effects, so can be substituted for each other. However, as substances also have post-digestive taste and interact with other ingredients in the formula, substitutions can be challenging to identify. Some substitutions are in fact identified in the classic medical texts (and some are documented and approved by the Commission on Natural Pharmacopoeia, discussed below). The doctors with whom I have worked in southern Tibet currently utilize many of the substitutions from the medical texts. Experimentation with new substitutes is not widely encouraged, at least in state-sponsored institutions of Tibetan

[7] The discussion of correlation between scientific (mainly Linnaean) classification and "non-scientific" classification is a broad topic of interest in ethnobiology (Berlin 1992; Ellen and Reason 1979) that I discuss more fully in other publications (Glover 2005, 2018). Simply put, at certain levels of a taxonomy there are some strong correspondences (although never 100% equivalence) between the Linnaean system and non-Linnaean systems, while at other levels there are vast divergences.

medicine in the PRC. Such a conservative approach may be due in part to the extent to which authority pervades much of Tibetan culture, particularly in the written traditions such as classic Tibetan medicine where emphasis on innovation has not been primary,[8] but it is also likely due in large part to contemporary processes of standardization and validation (including good manufacturing practice (GMP)) that aim for uniformity across the medical system (see below). As Saxer (2013: 90) has claimed, "…it is fair to say that the introduction of GMP, which has been heralded as boosting the innovation of Sowa Rigpa [Tibetan medicine], may become a major obstacle for innovation and adaptation to changing circumstances." This leaves us with the paradox that while the tradition of Tibetan medicine has a mechanism for flexibility in the practice of using substitutions, current ability to use substitutions is rather limited. Additionally, while innovation is heralded as a cornerstone of market capitalism (one of the driving forces of standardization is market expansion), the innovative strategy of ingredient substitution in Tibetan medicine is stymied by the very standardization processes that are supposed to lead to market success.

Most contemporary substitutions are made to protect animals (some endangered) and endangered plants. Examples illustrating the practice of substitution include gur gum, gla rtsi, and bse ru.[9] Gur gum is generally identified as saffron, obtained from *Crocus sativus*. The market value of saffron varies tremendously. A trader in materia medica from Lhasa at the Hospital of Tibetan Medicine in Rgyalthang reported that saffron from Kashmir (kha che gur gum in Tibetan, i.e., "Kashmiri gur gum") cost more than 10,000 yuan (approximately $1500 USD) per kilo whereas gur gum from Qinghai or Gansu was only 100 yuan per kilo (Pers. Comm. 2015). My long-time consultant and friend Dr. Ma Liming told me that Kashmiri gur gum is regarded as more potent, in part because Kashmir is acknowledged as the "origin" of gur gum; plants were brought from Kashmir to Tibet for cultivation but did not thrive and are therefore considered of inferior quality—Dr. Ma stated that estimation still holds for contemporary populations. Nevertheless, the Tibetan Hospital in Rgyalthang prefers to purchase the less expensive, domestic variety. Another very common substitute for *Crocus sativus* is *Carthamus tinctorius*. Sabernig (2011:88) reports that *Carthamus tintorius* is commonly used in the hospital at Kumbum Monastery in Qinghai Province as a substitute for *Crocus sativus*: "The simple reason I was given is that huge amounts are needed. *Carthamus tintorius* L. is a plant amply growing in the area and is much cheaper than real saffron," reflecting a combination of considerations of both cost and abundance in the choices made by these medicine producers.

Gla rtsi (musk) is generally understood to be the musk of several species of musk deer (*Moschus* spp.). It has long been a key trade resource from the Tibetan Plateau to the Middle East (Akasoy and Yoeli-Tlalim 2007). Twenty years ago in Rgyalthang (current day Shangrila) in Yunnan Province when I was conducting fieldwork, gla rtsi was hardly ever used in production because it was difficult to obtain, but there was a small stash of it in the office of one of the hospital doctors for "special uses" (meaning mainly for use with special people, people in positions of power, or people otherwise deemed in grave need of the ingredient due to serious health concerns) (Pers. Comm. 1999). As of 2015, gla rtsi is no longer used in the production facility at the Rgyalthang hospital, and there appear to be no reported stashes. While musk deer have been protected under Chinese law since 1988 (Wild Animal Protection Law), enforcement has been challenging. With China's admission to the WTO in 2001, the pressure to adhere to standards of protecting endangered species is greater than it was in 1999. Most species of the genus *Moschus* are on the IUCN Red List and one is classified as vulnerable (the step before endangered), with populations declining. Although there are breeding facilities for the musk deer, one of which is in Sichuan, breeding success has been minimal (Parry-Jones and Wu 2001). Common substitutes in Tibetan medicine for gla rtsi include several plant species: *Pedicularis magalantha* (T: gla rtsi me tog—literally, "musk flower"), *Delphinium moschatum* (T: gla da ra), *Delphinium brunonianum* (T: bya rgod spos), and even gur gum (*Crocus sativus*). A recent study (Li *et al.* 2016) reports that conservationist values and practices among ethnic Tibetans (in contrast to the nearby Lisu ethnic group) may have an impact on musk deer populations in NW Yunnan Province, with population rates being five times higher in Tibetan cultural areas as compared to Lisu cultural areas. While much of this may be explained by different land usage (including presence or lack of livestock), and cultural concepts of sacred sites, as the authors claim, the role of Tibetan pharmacological practice of substitution would be interesting to explore.[10]

Sabernig (2011) calculated the amount of ingredients specified in medical texts that contain substances from four endangered species (deer musk, elephant bezoar, bear bile, and

[8] Aumeeruddy-Thomas and Lama (2008: 173–75) report that in Dolpo, Nepal, doctors of Tibetan medicine were somewhat reluctant to talk with conservationists about their knowledge of substitutions. The reasons for this are unclear, but it may be the result of a combination of disagreement among the medical practitioners themselves of how to approach substitutions, a discomfort with sharing this type of knowledge with outsider, non-medical specialists, and concern with how medical practice may or may not line up with conservationist priorities. It is also noteworthy that the authors note how at national-level workshops, practitioners generated "a list of substitutes that were acknowledged to be effective for use by the authoritative Chagpori Institute of Darjeeling" (p. 174), attesting to the power of the authoritative voice throughout the larger Tibetan cultural world.

[9] Here I purposely use Tibetan names for ingredients since the polysemy of these terms in part reflects the flexibility of the system.

[10] In Chinese medicine (to the best of my knowledge), deer musk has also traditionally been used as a medicine, and substitutions are also used, but plants are not generally seen as possible substitutes for animals.

rhinoceros horn) that have traditionally been used in Tibetan medicine. She found ranges from a mere 2% (of 190 formulas) for rhino horn to 37% (of 164 formulas) for deer musk. She also provides clear evidence that these ingredients are regularly substituted with non-endangered materials, according to their therapeutic effects. For example, cattle gallstones can be substituted for bezoar (gallstones or bile, usually from elephants), as can a compound of the silica from bamboo (or a calcium carbonate deposit, itself a substitute for bamboo silica) and gur gum, often mixed with cattle gallstones (ibid: 89). For the horn of rhinoceros (T: bse ru), horns from cattle and yak are commonly used. She notes that at the Kumbum Monastery Hospital, decisions were sometimes made based on cost but also on concerns for animal welfare: "Even though the [doctor] monks believe that bear bile is more appropriate, they prefer ox bile because it is cheaper and better in terms of preventing animal cruelty and the preservation of wildlife" (ibid: 89). Thus decisions about substitutions include philosophical and ethical considerations, some of which may be in response to recent, globalizing trends for species protection but some of which may be linked to older Buddhist ideals about non-violence toward sentient beings.

Panarchy and Resilience

Gunderson and Holling's (2002a) concept of panarchy helps us understand the nested hierarchies involved in a complex bio-socio-cultural knowledge system such as Tibetan medicine, where peoples, plants, ecosystems, and markets are interlocked. Panarchy is a conceptual framework to account for the characteristics of complex structures (biotic, economic, socio-cultural), as well as endurance and change *within* and *between* those structures at varying scales of space and time. Developed in the context of sustainability studies, Holling (1973, 2001) and Gunderson and Holling (2002a) were aiming for a heuristic that both transcended disciplinary boundaries and unified diverse levels of analysis in ecological studies, from focus on specific biota, to biotic communities, to larger human social structures, and cultural behaviors, to larger-scale ecologies and economic structures.

A key feature of a panarchy is adaptive cycles that take place within and between varying levels. These cycles include moments of rapid transformation and change (termed "revolt" in Resilience Theory) as well as moments of sustained stability ("memory"). The traditional Tibetan practice of pharmacological substitution is an example of sociocultural memory developed as an adaptation to geographic and ecological shifts encountered within the system of Tibetan medicine. Some of these shifts are well-known: adaptations to local environments with different species of plants and animals available as the tradition expanded to various regions of the Himalayas, Central Asia, and China; influence from IUCN's Red List and CITES. Others can be inferred historically from contemporary practice: decline in availability of particular resources can cause a shift to a substitute resource; canonized attention to suffering of sentient beings in Buddhist philosophy can cause an aversion to using ingredients from animals.

The adaptive cycles of a panarchy form a nested hierarchy, in which higher/upper levels of the structure both define and potentially constrain lower levels (Allen and Starr 1982); upper levels are more inclusive of lower levels, and shared features of all levels increase at upper levels. Nested hierarchies tend toward stability overall, so that disturbances at any level will usually get absorbed by the larger structure, although significant disturbances at any level may lead to total collapse if resilience is lacking. Nested hierarchies also result in repeated patterns throughout the hierarchy. For example, Holling *et al.* (1995) discuss how lumpiness (patterns of gaps and clumps) of body mass size in biota is distributed throughout a biome in direct relationship to the environmental lumpiness of that biome. This is due to self-organizing processes that the panarchy contains, such as adaptation. As they state, "…the persistence of the landscape patterns encourages adaptation to them. Thus lumpy patterns in landscapes generate lumpy categories of body size ... That is, gaps in body mass distributions of resident species of animals correlate with scale-dependent discontinuities in the geometry of vegetated landscapes" (ibid: 349–367).

For the sociocultural-ecological panarchy in which Tibetan medicine is embedded, we might conceptualize examples of key levels in the panarchy: the upper levels include the global market in traditional medicines as well as the broader cultural knowledge system identified as Tibetan medicine (T: sowa rigpa); middle levels include the ecologies in which medicinal ingredients grow/are found and the regional versions of Tibetan medicine praxis in those ecologies; and lower levels include the species of biota as well as individualized (although often lineage-based) knowledge sets and practices by specific practitioners of Tibetan medicine; a micro-level includes a chemical/molecular scale.

Resilience is the ability of a system to withstand disturbances "while retaining essentially the same function, structure, feedbacks, and therefore identity" (Walker *et al.* 2006: 13). Resilience can be discussed at several levels of the panarchy. I explore here how resilience at the level of regional and individual praxis (in the practice of substitution) interlinks with resilience of the larger ecosystem, embodied in an understanding of substitution as an adaptive resource management strategy of conservation. At another level of analysis, the molecular level, I explore how the biological plasticity of the ingredients themselves replicates a resilience that we see at higher levels in the panarchy.

First, key to understanding whether the natural resources that are utilized in traditional Chinese and Tibetan medical systems are at risk of a severe collapse or not, is the extent to which the ecosystems of these resources are resilient to disturbances. One approach in assessing this is to consider how significant parts of the systems (termed "nodes" by Scheffer *et al.* 2012) are related. For this analysis, the nodes are biological units at the level of either the species or the genus because these are the units of analysis that are the most pertinent in evolutionary biology, due to the undergirding of natural selection and a focus on adaptation. Whether over-harvesting of some species may affect other species and the larger ecosystem in which they occur may in part be dependent on what Scheffer *et al.* (2012) have identified as the heterogeneity/homogeneity and the modularity/connectivity of the nodes in the system. Generally speaking, severe and sudden collapse of a system may be more likely in systems where there is lack of heterogeneity (i.e., where there is homogeneity) and in which there is a high level of connectivity (or interdependence) among nodes in the system; such a scenario results in stability and little change, but a rigid system that is susceptible to critical transitions (crisis, or collapse) if a key node (such as a keystone species) is affected by a disturbance. Conversely, the more heterogeneous and modular (less connected, more independent or autonomous) the units in a network are, the more adaptive the system will be to gradual change over time and the less susceptible to sudden shifts or tipping points (collapse). As Scheffer *et al.* explain:

> This situation implies a trade-off between local and systemic resilience. Strong connectivity promotes local resilience, because effects of local perturbations are eliminated quickly through subsidiary inputs from the broader system…. However, as conditions change, highly connected systems may reach a tipping point where a local perturbation can cause a domino effect cascading into a systemic transition. Notably, in such connected systems, the repeated recovery from small-scale perturbations can give a false impression of resilience, masking the fact that the system may actually be approaching a tipping point for a systemic shift. (pp. 344-5)

Using this framework, the medicinal resources themselves (the nodes) utilized in the Tibetan medical system are arguably both heterogeneous and comparatively independent of each other. This is in part assured through the continued practice of substitution that has likely resulted in extensive use of resources over generations with sustainable results. The fact that the musk obtained from musk deer can be replaced with materials from a variety of plants (from the genera *Delphinium*, *Pedicularis*, *Erodium*) and that these plants all belong to different plant families attests to the heterogeneity of units in the system. The fact that these various species do not seem to be interdependent in the ecosystems in which they occur shows that the system is modular.

At a lower level of analysis, there appears to be strong evidence that the flexibility in substitution practices reflects significant features of molecular activity, both in terms of the molecular activities of the nodes (species or genera) and in terms of generated formulas, or recipes, that have been developed in the cultural knowledge system of Tibetan medicine. Schwabl and van der Valk (2019) argue that the system of Tibetan medicine has botanical plasticity. In fact, as the examples above indicate, it is more than just botanical plasticity, but arguably biological plasticity (plants substituted for animals, for example). Nonetheless, using a systems-theory analysis, Schwabl and van der Valk argue that there is functional stability in the way that Tibetan formulas work. This is due in large part to what they identify as a pleiotropic mode of action in Tibetan medicines. Since formulas are largely compounds made from various substances, they have low concentrations of single chemical compounds and "simultaneous activation of multiple network points [organs, cells, molecules]" (ibid: 212), resulting in pleiotropic activity. Such widespread effect in action has also been identified in chemistry as polypharmacology or network pharmacology, based on the concept of "biosynthetic molecular promiscuity" (Gertsch 2011: 1091), where multiple chemical receptors of an organism are simultaneously targeted by molecular activity within a naturally occurring substance, such as a plant. Gertsch (2011: 1090) hypothesizes that this may be an evolutionary advantage to the fitness of plants. Thus, this "molecular promiscuity" appears to occur at the level of the species and is enhanced by the cultural formulas or recipes of Tibetan medicine mixing multiple ingredients. In Gunderson and Holling's terms, this is an example of a repeating pattern, part of the self-organizing structure of a panarchy. We can likewise conceptualize this as a cultural adaptation to curative praxis: effective remedies tend to be those that have desired immediate effect and probably widespread effectiveness, over time and space. And perhaps the adaptive aspects of these formulas—the biological plasticity, the widespread effectiveness, and the ability to tailor remedies to social and ecological conditions—is the key to resilience of the system as well as its longevity.

Given that substitution is a readily encoded practice in Tibetan medicine, in large part in response to availability of resources, I argue this is a practice of resilience. The flexibility to respond to resource shortage (whether due to ecological, economic, or other socio-political reasons) is a built-in adaptive strategy of the system. And because the materials themselves are heterogeneous and independent (deer musk may be replaced with several different kinds of plant), per Scheffer *et al.* (2012), this may be key in the resilience of the system.[11] The practice of medicinal ingredient substitutions may also

[11] One thing that must be kept in mind is that this may all constitute what Scheffer *et al.* (2012) identify as "local resilience." In the case of local resilience, grand catastrophes can still occur.

meet the “design criterion” of Smith and Wishnie’s (2000: 501) standard for labeling a practice as conservation: those practices that we recognize as conservationist must be “designed” (for example, through cultural adaptation) to mitigate resource depletion. They propose this design feature, in combination with an effect feature (actually mitigating resource depletion), as a way of distinguishing conservationist systems from systems that result in sustainability but are not based on practices of conservation, such as small-scale resource use (that is, abundant resources with few pressures, usually due to low population numbers). Since pressures on the natural ingredients used in Tibetan medicine are clearly increasing, knowing whether the sustainability of the medical system over time was due merely to low-impact resource use, or to a system that was possibly responsive to periodic high-impact use, is important. Thus, we may also be able to consider the practice of using substitutes as a practice of conservation, resulting in sustainable resource use, in addition to resilience.

The practice of substitution is often looked upon as a “problem” in the pharmacological industry. Mosihuzzaman and Choudhary (2008: 2003), for example, frame substitutions as being the result of “similar plants/wrong identification, or the use of cheaper alternatives” and note especially cases of toxicity due to substitutions in various Asian medicines (Chinese medicine, Ayurveda) as reported in the literature. Zhang *et al.* (2012) use the newly coined term “pharmacovigilance” to argue that proper identification of ingredients is paramount to safe medicine production:

> The vast and diverse land area of China nourishes a large reservoir of TCM drugs, notably of herbal origin. However this diversity contributes to the complexity of the species used, their origins and names. Already the naming issues, including the same name for different herbs, different names for the same herb, similar name or abbreviation for totally different species, can lead to considerable confusion. (ibid: 520-21)

While acknowledging the difficulties of species identification, and also the possibilities of deleterious effects of using incorrect, possibly toxic, substances, a flexibility in use of resources is not even considered in pharmacological analyses. This is in part due to the lack of flexibility in species identification in pharmacology, but probably also to a lack of understanding of how such adaptive aspects of a cultural knowledge system like Tibetan medicine actually work. In order for flexibility in this traditional medical system to be effective, knowledge and experience of the textual medical tradition and/or local, often oral traditions, as well as clinical practices of healing and medicine production are necessary. The flexibility that ingredient substitution in Tibetan medicine generates is one that is grounded in long-term empirical investigation of efficacy, resource distribution, and sustainable resource usage. Much of this is excluded in contemporary factories using standardized protocols that do not easily allow for (or in some cases allow at all) ingredient substitution.

With the increasing standardization and industrialization of traditional medicines in China and elsewhere, the adaptive function of substitution is being challenged. Innovation of new substitutions is not generally encouraged, at least in the industrialized setting. Standardization of medicine, based on national and international laws and standards of production (like GMP), does not tolerate flexibility of resource use. Industrialized production of Tibetan and other traditional medications in China adheres to protocols established at the national level, in a top-down approach to pharmaceutical production. Such protocols began with the drug registration system for Tibetan medicine established in 1995 under the auspices of the Ministry of Health and were expanded by the Drug Administration Law of 2001, in which a new national system of drug registration was set up under the State Food and Drug Administration (SFDA). The Law of 2001 in particular followed guidelines set by the WHO and other international regulatory bodies, such as the WTO. Such standards preclude many creative, adaptive alterations, although change is not impossible. Thus, substitutions may be approved at the national level after long and careful study (under the auspices of the National Pharmacopoeia Commission), but the ability to innovate and react quickly to changing conditions is denied the practitioners themselves.[12] In essence, industrialized standardization is in many ways antithetical to the very heart of traditional Tibetan medicine production. As Gerke (2018) notes: “…Sowa Rigpa [Tibetan medicine] formulas [are] a distinctive genre… since their style is fluid and provides an underlying script for continuous change and reformulation, which inherently defies standardization” (p.180). Schwabl and Vennos of Padma Inc. (a Swiss pharmaceutical producer of Tibetan medicines) summarize the key issues encountered in the European context with standardization of Tibetan formulas:

> Once a formula is selected and presented to the authorities it remains as [a] fixed combination. This is in contrast to the practice of many Asian medical traditions, where the formula is constantly adapted to local conditions, availability of raw material and therapeutic situation. This flexibility is not well understood in the modern scientific and regulatory context, also the pharmacopoeias do not reflect this. The European (modern Western) fixation on botanical species as the only way

[12] It is also true that in China the existence of regulations does not necessarily mean they are always strictly followed, nor that the logic of regulations is necessarily flawless (Saxer 2013).

> of standardising a formula limits the repertoire of available species, whereas Tibetan Medicine has a high flexibility and can address many…challenges. (2015: 111)

Perhaps somewhat ironically, industrialized standardization may also have a bearing on the efficacy of the medicines thus produced, as Blaikie (2015: 17) explains: "Industrializing production…necessitates the sacrifice of pharmacological fine-tuning and results in generalized medicines whose efficacy may be compromised for certain individuals and under certain environmental conditions." Such an influence may prove harmful to the medical knowledge system itself, as efficacy is undoubtedly linked to consumer choice and the integrity of the system as a healing art. Lastly, it seems plausible to argue that as standardization of Tibetan formulas becomes more widespread (related to increased marketization, nationally and globally) there is the potential for added resource strain. In fact, heterogeneity and independence are key aspects of resilience even in the medicinal marketplace; as ingredients for medicinal formulas become less varied, less flexible, and more homogenous (as do the formulas themselves), there is more vulnerability and less resilience should there be resource collapse of one or more ingredients. The practice of substitution needs to be continually adapting lest the substitutions themselves become the scarce resources. Two main considerations for dealing with the rigidity trap that standardization brings, in terms of Tibetan medicine production, are to allow for substitutions in the manufacturing of Tibetan medicines in the industrial setting (and likewise to encourage innovation in finding new substitutions), and to support small-scale, non-industrial producers of Tibetan medicine, whose formulas are variable, "often adapt[ed]…to local climatic conditions, taking into account altitude, temperature and humidity…[and] adjusting for different phases of [an illness] or for patients with differing constitutions" (Blaikie 2015: 16; see also Blaikie 2009). The latter option likely falls outside the realm of regulated medicine, and is therefore not open to policy recommendations.

Conclusion

The most important considerations in the intertwining of human and ecological systems revolve around the adaptive capacity that is a key component of sustainability. This means cultural knowledge systems that are adaptive, and resource management that is likewise adaptive to ecological pressures and disturbances. Just as biological kinds adapt to local ecologies, and adjust in discontinuous, "lumpy" patterns of body size (Holling *et al.* 1995), for example, adaptation at the cultural level is a repeating pattern that helps stabilize the larger biocultural social structure. The practice of ingredient substitution itself is a fairly stable cultural practice, but it encourages an approach to resource distribution and conservation that allows for variation through space and time. As industrialized production of Tibetan medicine proceeds in China according to standards set by national agencies in response to international standards, concerns with adaptability are left wanting, generally discarded for the rigidity traps of efficiency and standardization. As Gunderson and Holling argue, this approach entails risks:

> The cost of efficiency is a loss in flexibility. Increasing dependence on existing structures and processes renders the system vulnerable to any disturbance that can release its tightly knit capital. Such a system is increasingly stable, but over a decreasing range of conditions. The transition from the conversation to the release phase can happen in a heartbeat. (Gunderson and Holling 2002b: 7)

Ingredient substitution as practiced in traditional Tibetan medicine forms significant institutional memory that is beneficial to the sustained and flexible use of resources. This practice may very importantly be helpful in encountering any future crises, especially in the context of increasing climate change and resource overuse. And since it is difficult to determine a precise onset of a potential collapse of resources, it seems prudent to nurture adaptive and resilient responses that may benefit the larger ecosystem as well as more contained human systems of knowledge generation and production. This requires adjustments in allowing the traditional resource management strategy of substitution in Tibetan medicine to be practiced, supported, and expanded upon in the industrial and non-industrial settings in which it occurs in China.

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Compliance with Ethical Standards

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