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海底熱泉的資源保護
Protection of the Hydrothermal Vent Resource

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龜山島位於台灣東北方宜蘭東北海灣之中，因外貌酷似烏龜而得名。此島主要由兩座火山體組成，其附近海底有硫氣孔噴發使海面漂浮硫磺而呈現黃褐色，周遭海床的沉積物也多為硫磺砂，部分噴口的周遭還可發現壘球般大小的硫磺球，而從熱泉噴口收集的氣體主要是二氧化碳。中山大學陳鎮東教授繼1999年4月發現龜山島海底熱泉後(郭，2001; Chen et al., 2005)，2000年8月又發現此處有30~40個海底熱泉噴口，都只距龜山島數十公尺，水深也僅約十公尺，其中最大的熱泉噴口直徑約四公尺、高十公尺 (陳，2001)。在其它較淺 (< 300 m)海底處像是日本橘灣；巴布新幾內亞新不列顛；紐西蘭亞努阿圖；美國加州亞速群島；冰島Kolbeinsey島；義大利烏爾卡諾島與希臘米羅島附近，亦發現有淺層海底熱泉(Brinkhoff et al., 1999; Caccamo et al., 2000; Nunoura et al., 2002) 。跟淺海熱泉相對的深海熱泉，像是大西洋與印度洋中洋脊的海底熱泉的深度大約在2,300-2,400公尺左右（Moussard et al., 2004；Takai et al., 2004）。

Located at the cove of Yilan, northeast Taiwan, Turtle Island gets its name from its resemblance to a sea turtle. This island is the formation of two volcanoes, and sulfur vents are found at the surrounding seafloor shooting out sulfur particles that make the seawater slightly yellowish brown. Most of the sedimentation found at the seafloor is sulfate grains, and sulfur spheres as the size of softball are found at the surrounding of some of the vents. The gas collected at the vents is mainly CO_2. After the discovery of the Turtle Island thermal vents (Kuo, 2001; Chen et al., 2005), Chen Cheng-tung, Prof. of National Sun Yat-sen University found a group of 30-40 thermal vents next to the island in August 2000. All of these vents are only a few dozen meters away from the island at the depth of approximately 10m. The largest one is approximately 4m in diameter and 10m tall (Chen, 2001). Hydrothermal vents are at the bottom of shallow sea (< 300 m) around the world, such as Tachibanawan, Japan; New Britain, Papua New Guinea; Vanuatu, New Zealand; the Azores Island, CA. U.S.A; Kolbeinsey Island, Iceland; Volcano, Italy and Milos, Greece (Brinkhoff et al., 1999; Caccamo et al., 2000; Nunoura et al., 2002). Contrary to those of shallow sea, the deep sea hydrothermal vents found along the mid-ocean ridges of the Atlantic and the Indian Ocean are located mostly at the depth of 2,300-2,400m (Moussard et al., 2004; Takai et al., 2004).

海底熱泉不斷地噴出礦物質對地球地質化學的循環與平衡是很重要。這些噴出物對海洋的生產力或是區域海水的熱的傳輸也有影響。少數的淺層海底熱泉噴口處的生態系或是多樣性曾被深入的研究。依現有的資料顯示，不論這些淺海熱泉是在被曝露的海岸地區，是在有遮蔽的火山口或是海底洞穴，淺海熱泉區可孕含多種的矽藻與大型藻，且底生動物多樣性很高 (Morri et al., 1999)。但相對地，深海熱泉噴口處的生態系則特有的後生動物較多，生物量較高(Desbruyères and Almeida, 2000)。多種獨特的淺海熱泉生態系已被認定為物種多樣性的熱點 (hot spot)。另外海底熱泉內富含嗜熱與極嗜熱細菌與古生菌（Archaea），這些嗜熱菌的酵素從分子生物學的研究上到食品的製造上、織品或化學工業上都有一些特殊的用途(Nucci et al., 1993)。舉個例來說， DNA聚合物，在世界各地分子生物學的研究上是不可或缺的。此酵素最早就是從一個陸地熱泉分離出的高溫菌Thermus aquaticus中來的，現在可從不同嗜熱菌生產。推估此酵素的一年市場販賣量約有5億美金。其他熱泉生物對"高熱"或是其他"極端"環境因子如放射性的適應，對高金屬濃度的適應可以應用在DNA修復機制或是污染環境的生物復育的研究。由最近的研究報告可知，噴泉中或噴泉口周圍的確有許多特殊的基因(Blaustein, 2010)，它們應用在生物技術方面的潛力也無法計數。

The minerals that keep shooting out of these underwater vents are crucial to the geochemical cycle and balance of the Earth. These substances have influence to the productivity of the ocean or the thermal transmission of the regional waters. The ecosystems or biodiversity of a few of these shallow hydrothermal vents have been studied extensively. According to the data at hand, the hydrothermal vents are capable of sustaining a variety of diatoms and large algae no matter these vents are located at exposed coastal waters or sheltered volcanic vents or underwater caves, and there is a good diversity of bottom-dwelling animals (Morri et al., 1999). As a comparison, however, there are more specialized metazoans in the ecosystem of deep sea thermal vents, and the number of animals is greater as well (Desbruyères and Almeida, 2000). The diverse and unique shallow water hydrothermal vent ecosystem is now considered a "hot spot" for species diversity. In addition, a rich quantity of thermophlic and extremely thermophlic bacteria and Archaea is found at the hydrothermal vents. These thermophlic bacteria have their special contribution to molecular biological research, food production, and textile or chemical industry (Nucci et al., 1993). For example, DNA polymerase is an indispensible part of molecular biologic studies around the world. This enzyme was first found in a strain separated from a landlocked thermal vent called Thermus aquaticus. Now, it is produced from various thermophilc strains. It is estimated that these bacteria can produce approximately 500 million US dollars worth of market profits. The remarkable adaptability of thermal vent species to "great heat" or other "extreme" environments such as radioactivity and high metal concentration can be used in DNA repair mechanism or biologic restoration studies for environmental pollutions. The latest studies report that researchers did find many special genes in and around the hydrothermal vents (Blaustein, 2010), and the potential of their applications in biotechnology is unlimited.

海底熱泉是屬於稀有且脆弱的生態系，熱泉的噴口或是噴口周圍的環境較其他海底環境通常是較短暫的，因此存在較久的海底熱泉噴口就變得非常稀有。有證據顯示存在較久，較大的熱泉噴口處有較多的生物多樣性 (Juniper and Tunnicliffe, 1997; Tunnicliffe et al., 1998)。長期未遭破壞的 "mother population" 對維持噴口生態系多樣性是很重要。噴口壽命受其特殊的生地化環境以及特殊的背景而有不同的穩定性。雖然淺海熱泉噴口處的特有生物較少，但能適應非常特殊環境的原核生物與底棲生物仍與周遭的生態系有著非常複雜的相互關係。

也因人類較易接近淺海熱泉加上淺海熱泉獨特的科學價值、教育價值與經濟價值，一些淺海熱泉已面臨過度的科學研究、生物探勘或是採礦活動的威脅(Tunicliffe, 1990; Sarrazin et al., 1997; Desbruyères et al., 2006; UNCLOS, art.143(1))。雖然學術研究或是生物探勘不像是其他方面的探勘，一般對棲地的破壞不大，不過大量採集熱泉水對熱泉的結構或是其中微生物的分佈會不會有影響？仍有待評估。生物多樣性的降低或是棲地的完整性的破壞程度多少是可以接受？"永續利用" 是科學研究與生態循環之最終目的，拿取生物多樣性中的一個成員的方式可能依地區特性及每個案件不同而不同，需將族群、空間分佈，或是生活史的特性進行全盤的考量(UNCLOS, art.143(1)) 。

Hydrothermal vents are rare and fragile ecosystems. The environment in or around the vents lasts shorter than other marine environments. Therefore, it is very rare for a hydrothermal vent to survive over time. Evidence shows that the larger thermal vents that have existed for a long time tend to have a greater biodiversity (Juniper and Tunnicliffe, 1997; Tunnicliffe et al., 1998). The "mother population" that has existed for a long time without being compromised is very important to maintain the biodiversity of the vent ecosystem. The stability of a vent's life cycle depends on the special biogeochemical environment and background. Despite the smaller number of specialized species at the shallow water hydrothermal vents, the prokaryotas and bottom-dwelling species that highly adaptive to extremely specialized environment have a tremendously complicated relationship with the surrounding ecosystem.

However, also because the shallow vents are accessible to human being and they are highly unique in scientific, educational and economic values, some of the shallow hydrothermal vents are under the threat of too much scientific studies, biologic exploration or even mining activities (Tunicliffe, 1990; Sarrazin et al., 1997; Desbruyères et al., 2006; UNCLOS, art.143 (1)). Scientific studies or biological exploration may be as destructive to the habitats as other explorations, but is there any impact of collection of thermal vent species in large quantity to the structure of the vents or the distribution of microorganisms within? That still remains to be seen. How much is acceptable for the decrease of biodiversity or the destruction to the completeness of habitats? The "sustainable use" is the ultimate goal for scientific studies and the ecologic cycles. The way to take out one of the members in an ecosystem differs from region to region and from case to case. It is necessary to have a comprehensive consideration for the populations, spatial distribution or the characteristics of the life history (UNCLOS, art.143 (1)).

生物多樣性保護將是21世紀最重要的全球問題之一，也是永續發展的基礎。根據研究估計，如果全球性生物多樣性的減少趨勢問題仍沒被改善，到2050年時，全球將近有四分之一以上的物種可能從地球上消失。這將對人類的生存和福祉造成嚴重的影響。

於2000年國際InterRidge專題討論會，重申簽署聯合國公約海洋法（the United Nations Convention on the law of the Sea；UNCLOS）以及生物多樣性公約（Convention of Biological Diversity，CBD）的國家，有義務保護與保存海洋環境中稀有或是脆弱的生態系及其生物多樣性，或是永續利用其中的資源。為了信守對UNCLOS與CBD的承諾，這些國家必須了解海底熱泉區的生物群聚，並規範在海底熱泉的活動，減少或是去除對熱泉生物多樣性的影響(Desbruyères et al., 2006)。

The protection of biodiversity is one of the most important issues in the 21st century, as well as the foundation of the sustainable development. According to various studies, if the decrease of global biodiversity keeps deteriorating, it is likely that more than a quarter of species may disappear from the face of the Earth forever by the year of 2050. This will be a profound impact to the very existence and welfare of mankind.

The 2000 InterRidge conference reaffirmed that the singing bodies of the United Nations Convention on the law of the Sea (UNCLOS) and the Convention of Biological Diversity (CBD) are obligated to protect and preserve the rare or fragile ecosystems in marine environments in order to protect their biodiversity or use their resource in a sustainable way. To commit to UNCLOS and CBD, these bodies need to understand the biologic population at the hydrothermal vents and specify that the impact of the activities conducted at these vents to the biodiversity of the thermal vents shall be reduced or minimized (Desbruyères et al., 2006).

UNCLOS與CBD也指出在特定國家的行政管轄內，海洋科學家或是生物勘探者必須事前取得該國管理單位的許可，才能接近熱泉區進行海洋科學研究活動或是遺傳資源的調查 (CBDd. Arts. 7©, 8(1))。已有一些國家建立公共政策以及負責單位來管理熱泉中自然生物多樣性資源的利用以及生物勘探的核可，像是在哥斯達黎加由INBio來管理生物多樣性資源；從美國黃石公園進行熱泉水或是生物的採樣也須事前申請核可；深海探勘研究ODP Leg193航程上，新幾內亞BioNet就派觀察員上船參與 (InterRidge Workshop, 2000)。此可說明，這類的探勘或是研究航程，研究者須與管理單位簽訂一資源利用同意書，使得這樣獨特的生態環境能受到保護與規範。

It is also specified in UNCLOS and CBD that with in the jurisdiction of a specific country, marine scientists or biologic explorers have to acquire the permit from that country's competent authority before they can access the thermal vents for marine scientific studies or genetic resource survey (CBDd. Arts. 7©, 8(1)). Some of the countries have established public policies and competent authorities for the management of the use of the natural biodiversity resources at these vents and the permit for biologic exploration. For example in Costa Rica, the INBio is in charge of the management of biodiversity resource. Also, a permit is required to collect water or biologic samples in the Yellowstone National Park. During the voyage of the ODP Leg193 for deep sea exploration, the BioNet of New Guinea had some observers on board for the survey (InterRidge Workshop, 2000). It is clear that the researchers on a voyage of exploration or study like these have to sign an agreement of resource use with the management authority in order to protect the unique ecology and specify these activities.

保護龜山島海底熱泉，保護其中的生物以及基因的多樣性對經濟上或是生態方面的涵義是不容否認的。不過到現在，我們的政府對龜山島海底熱泉未做任何的管理與規範，任由國內外學者大量的取樣與探勘。龜山島熱泉區許多的物種多屬於固著性生物或是只有局限的活動力，每次大量採取海水或是生物對噴口生態系會有甚麼影響，雖還沒有研究報告可供參考，不過在特殊棲地生存的生物物種需要更小心的管理，確保它們的多樣性。

It is necessary to protection the hydrothermal vents at Turtle Island. The implication of protecting the biodiversity and genetic diversity within is undeniable in terms of economy or ecology. However up to now, the government has done nothing to these vents of Turtle Island in neither management nor specification, and these vents are left exposed to large quantity of sample collecting and exploring activities conducted by scientists from all over the world. A lot of species found at the vents of Turtle Island are sedentary or have limited mobility. There is no scientific report about what impact the large quantity of water or biological sample collecting will have on the vent ecology, but it requires more careful management for the biological species living a specialized habitat in order to ensure their diversity.

因龜山島噴口處的棲地環境與其中或是周遭的生物多樣性仍不是很清楚，我建議先由政府或是法人組織對龜山島海底熱泉生態系進行"環境衝擊評估"，了解噴口附近棲地是否已受干擾？多少噴口已喪失？喪失的百分比是多少？找出或是確認海底已受影響的生物這些資訊對評估人類活動對生物物種生存的影響有很大的幫助，並殷切期盼政府單位能快速且有效地建立龜山島海底熱泉區的管理方法與目標。

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As it is still unclear about what the habitat around the vents of Turtle Island or the surrounding biodiversity looks like, it is recommended that the government or a private foundation take an initiative to conduct an "environmental impact assessment" on the ecosystem of the Turtle Island's hydrothermal vents, as to find out whether the habitats surrounding the vents are disturbed, how many vents are lost, and what the percentage of loss is. It is necessary to identify or confirm the species at the bottom of sea that are already exposed to impacts. This information helps a lot in the evaluation of the influence of human activities to the existence of biological species. I strongly urge and hope the government to establish the management rules and goals for the hydrothermal vents at Turtle Island rapidly and effectively.

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