生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	紅樹林使沿海水域變得平靜 (Mangrove forests calm coastal water)
生物系統 LIVING SYSTEM	紅樹林 (Mangrove forests)
功能類別 FUNCTIONS	#獲取、吸收、或過濾固體 #調節水文流動 #控制沖蝕和沉積 #Capture, absorb, or filter solids #Regulate hydrological flows #Control erosion and sediment
作用機制標題	紅樹林的根透過吸收海浪的能量來保護海岸線 (Roots of red mangrove forests protect coastal shorelines by absorbing energy from waves)
生物系統/作用機制 示意圖	     

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

氣候變遷對全球濱海地區 (coastal area) 帶來更強烈和密集的風暴。強烈的風暴潮 (storm surge) 和其它各種巨浪 (large wave)，帶來大量的能量。當海浪沖刷到海岸，可以造成強烈的沖蝕作用 (erosion)、建築物的重大損害，甚至人命損失。而紅樹林可以保護海岸線免於強力海浪的破壞。紅樹林多層的架構幫助減緩及分散海浪能量，因此海浪的威力在抵達海岸前會被減弱。

紅樹林沼澤 (mangrove swamp)這些密集的生態系 (ecosystem) 出現在熱帶與亞熱帶的海岸水域。它們主要由根部形狀獨特的樹木和灌木所組成。舉例來說，「支持根 (prop root)」或「支柱根 (stilt root)」，看起來像是很多隻腳從樹幹基部分岔出來，把樹固定在土壤中。其它物種則有「膝根 (knee root)」，像是從土壤冒出彎曲著的膝蓋。它們固定樹體之外，更能幫助處於缺氧土壤中的主根 (main root) 吸收更多氧氣。第三種根呈細長手指狀，且從植株附邊凸出地表。它們稱為呼吸根 (pneumatophores)，也有助於氣體交換。海浪以高速衝擊到紅樹林，會遇到密集而纏結的障礙物，隨著海浪被路徑中的障礙切成小塊，能量會慢慢地流失。科學家發現，海浪只要進入紅樹林 100 公尺，就會損失大約三分之二的能量。海浪越深入紅樹林，能量就會流失得越多。特殊的根部構造對海水產生更多摩擦力 (friction) 和阻力 (drag)，當海浪最後抵達海岸邊時，通常都已經變成了溫和的小水波。

當然，海浪慢下來的程度取決於它的高度。因為紅樹林的障礙物接近地面，所以對更高、更強力的海浪效果可能不是很好。然而，紅樹林的樹冠層對於迎面而來的海浪，也有著和根部相同的效果。高度能觸及樹冠層的海浪，會被樹冠層厚實的樹幹、蔓延的樹枝，和大量的樹葉所瓦解並消散，就像較淺的海浪一樣。總括來說，高密度的紅樹林生態系和樹冠層對於保護海岸線群集 (community) 免於風暴摧殘非常有利。

Climate change is bringing stronger and more intense storms to coastal areas across the world. Powerful storm surges and other types of large waves carry enormous amounts of energy. When they wash up on a shoreline, they can cause rapid erosion, major damage to buildings, and loss of human life. Mangrove forests can protect shorelines from damage by powerful waves. The forests' layered architecture helps to slow down and scatter wave energy so that it loses power before it reaches the shore.

Also called mangrove swamps, these dense ecosystems occur in tropical and sub-tropical coastal waters. They are dominated by tree and shrub species that have unusual root shapes. For example, "prop roots," or "stilt roots," look like multiple legs branching out from the base of the tree trunk, anchoring the tree in the soil. Other species have "knee roots" emerging like bent knees from the soil. They anchor the tree and also help the main roots, nestled in oxygen poor soils, to get oxygen. A third type of roots are tall finger-shaped growths poking out of the soil near the main plant. These are called pneumatophores, and also aid in gas exchange. A wave rolling into a mangrove forest at high speed is met by a dense tangle of obstacles and it loses more and more energy as it gets sliced up by all the hurdles in its path. Scientists found that a wave can lose up to two-thirds of its energy after moving just 100 meters into a mangrove forest. The further it travels through the mangrove forest, the more energy it loses. The special root structures create so much friction and drag on the water that when the wave finally reaches the shoreline it has often been reduced to a gentle ripple.

How much the wave slows down depends on how high it is, of course. Because the obstacles of the mangrove forest are close to the ground, they might not have as much of an effect on higher, more powerful waves. The forest canopy, however, can have the same type of effect as the mangrove roots on an incoming wave. Waves that are high enough to reach the height of the canopy – with its thick trunks, sprawling branches, and numerous leaves – get broken up and dissipated much the same way that shallow waves do. Overall, the dense mangrove ecosystem and forest canopy can be very beneficial to shoreline communities by helping to protect them during storms.

文獻引用 (REFERENCES)

「所有的數據都顯示紅樹林可以在相對較短的距離內降低風浪 (wind wave) 和湧浪 (swell wave) 的高度：海浪高度可以在進入紅樹林 100 公尺後降低 13%到 66%。當海浪開始通過紅樹林，最高的每單位距離海浪高度下降率會發生在紅樹林邊緣附近。許多紅樹林的特徵會依距離而影響海浪高度的下降率，特別是樹的實體結構 (physical structure)。當海浪經過越高密度的障礙物，會更快速地減弱。淺水域中長有氣生根的紅樹林能更迅速地減弱海浪強度。在更深的水域中，海浪可能直接在氣生根上通過，但較低矮的樹枝也能起類似作用。」(McIver et al. 2012: 3)

"All evidence suggests that mangroves can reduce the height of wind and swell waves over relatively short distances: wave height can be reduced by between 13 and 66% over 100 m of mangroves. The highest rate of wave height reduction per unit distance occurs near the mangrove edge, as waves begin their passage through the mangroves. A number of characteristics of mangroves affect the rate of reduction of wave height with distance, most notably the physical structure of the trees. Waves are most rapidly reduced when they pass through a greater density of obstacles. Mangroves with aerial roots will attenuate [weaken] waves in shallow water more rapidly than those without. At greater water depths, waves may pass above aerial roots, but the lower branches can perform a similar function." (McIver et al. 2012: 3)

參考文獻清單與連結 (REFERENCE LIST)

McIvor, A. L., I. Möller, T. Spencer, and M. Spalding. (2014). *Reduction of wind and swell waves by mangroves*. The Wetlands International and Nature Conservancy. Retrieved from: https://www.nature.org/media/oceansandcoasts/mangroves-for-coastal-defence.pdf

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