國際海洋資訊
International Ocean Information

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「2020臺灣海洋國際論壇」報導
A Report on the Taiwan International Ocean Forum 2020

新加坡海洋資訊
Singapore Ocean Information

海洋委員會 Ocean Affairs Council 發行

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海洋永續經營 創造關鍵競爭力！

主任委員：李仲威

臺灣四面環海，海洋生物多樣性高，並擁有良好的漁場以及海洋能源，如何永續利用海洋資源，是我國經營海洋的關鍵。海洋委員會於11月5日舉辦「2020臺灣海洋國際論壇」，探討海洋廢棄物的處理科技、海洋能源以及海洋科學研究的發展方向，在本期「專題報導」特別將論壇討論精要介紹給讀者；「資訊新知」則由國家海洋研究院海洋生態及保育研究中心同仁撰文，介紹如何利用「人工藻場」的方式進行海洋棲地復育，以達到漁業資源永續的目標。另外，在40年來降雨最少的一年，身處臺灣的我們更能感受水資源的重要性，「產業動態」本期主題介紹新加坡如何利用海水淡化，增加穩定的水源供應，其水資源之多元規劃「四大水喉」值得我們借鏡。

新加坡位處麻六甲海峽與新加坡海峽交會處，不僅是世界第 3 大煉油中心、國際航運中心、國際貿易中心和區域旅遊中心；亦是中、日、韓等貿易大國與中東、歐盟貿易的必經之地。擁有如此得天獨厚的地理位置，更要重視與他國在海域方面的合作與協調。本期介紹新加坡如何依據國際法，制定劃界規範，並與馬來西亞、印尼等鄰國進行海域協商；「國際議題」專欄則聚焦東南亞區域的海域意識（Maritime Domain Awareness, MDA）制度，介紹由通報、分享、融合3個海域資訊中心所構成的東南亞MDA體制，如何成功有效地運作，他們所建立的典範制度，可做為我國未來建立相關機制的參考。

圖說／新加坡濱海灣
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認識海洋，更因海洋而偉大——「2020臺灣海洋國際論壇」報導

採訪撰文／鍾嘉雯（台灣經濟研究院助理研究員）
陳璋玲（國立成功大學水利及海洋工程學系教授）
關鍵字／海洋廢棄物、海洋能源、海洋科學研究

海洋委員會於2020年11月5日舉辦「2020臺灣海洋國際論壇」，規劃「海洋能源研究及創新發展」、「以海洋科學方式解決海洋廢棄物問題」2大主題，期盼藉由知識與經驗的分享，接軌國際，對科學研究與海洋環境永續做出貢獻。

圖說／「2020臺灣海洋國際論壇」與會貴賓合影
圖片提供／海洋委員會

2020年11月5日，海洋委員會於高雄國賓大飯店舉辦「2020臺灣海洋國際論壇」，開幕式由海洋委員會蔡清標副主任委員致詞，在2020年聯合國發布「為永續海洋而創新」目標後，2021年起的十年，將是「聯合國海洋科學促進永續發展十年」。本次論壇安排「海洋能源研究及創新發展」、「以海洋科學方式解決海洋廢棄物問題」2大主題，期盼藉由產、官、學、研各界的共同與會發表與討論，接軌國際，構築海洋國家的未來願景。

由於嚴重特殊傳染性肺炎（COVID-19）影響，本次會議虛實整合，邀請國外學者以預錄影片、現場視訊方式發表，美國在臺協會高雄分處、澳洲辦事處、英國在台辦事處、公益財團法人日本台灣交流協會高雄事務所、國立臺灣海洋大學亦協助與支持本次活動。除了知識與經驗的分享，更向國際社會宣告我國參與海洋國際事務之決心。

圖說／海洋委員會蔡清標副主任委員致詞
圖片提供／海洋委員會

開幕式與專題演講

在開幕儀式後，歐洲海洋能源中心（European Marine Energy Centre, EMEC）營運與科技執行長Jonathan D Lindsay以預錄影片方式展開第一場演講「歐洲海洋能源研究及創新發展」。Lindsay首先分享英國海洋能發展，並表示全球暖化不僅是民眾前所未有關注的議題，更是歐洲各國優先考量的政策方向，據估計，歐洲的海洋能裝置容量預計可達100GW，占歐洲總發電量的10%。歐洲已有多國成立海洋能測試中心，並規劃多項國家級的測試計畫，目前已投入1.65億歐元的研發資金，開啓了44項專案，其中尚有19項正在進行中。未來，海洋能需要結合國家補助、銀行挹注與保險等，降低財務成本，提高商業化的可能性。

喬治亞大學Jenna Jambeck教授則演講「以海洋科學方式解決海洋廢棄物問題」主題。Jambeck於2014年與13位女性加入橫跨大西洋的eXXpedition航海考察計畫，並於2019年展開恆河調查計畫，研究恆河於雨季前後的塑膠廢棄物排放情形，與恆河流經的5國成員合作，順利取得水體採樣、空氣採樣等資料。Jambeck認為，與當地社區合作可瞭解相關脈絡，而無人機追蹤與AI辨識技術則可提升塑膠辨識度，期望未來可以擴大影響力，持續採取行動，不讓流入海洋的垃圾再增加。

圖說／「2020臺灣海洋國際論壇」主辦單位與協辦單位合影
圖片提供／海洋委員會

主題一：以海洋科學方式解決海洋廢棄物問題

主題一第1場由海洋保育署宋欣真副署長介紹「以海洋科學方式處理海洋廢棄物之機遇與挑戰」，海洋廢棄物處理已是全球關注的重要議題，而臺灣運用遙測技術及人工智慧（AI）擴大科技監控即時掌握資訊，結合地方政府及各區漁會強化源頭清理，推動高值化技術以熱裂解方式產製燃料油。未來海洋保育署也規劃相關平臺，並設計認證機制與可追蹤產品足跡的QR code，提升國人對海廢產品的認知。第2場由國立中央大學陳繼藩教授介紹「遙控無人機影像於海洋廢棄物人工智慧識別技術之探討」，其研究以AI科技進行海洋廢棄物的監測與辨識，目前可辨識地面解析度優於5公分之影像，並分成寶特瓶、保麗龍以及漁用浮球3種類型。陳教授說明，目前之AI模型期望能與相關APP結合，並鼓勵大眾參與，增加訓練資料；未來可建立開放之數據平臺，與政府、NGO團體分享，提高模型辨識之準確度。

第3場由日本九州大學磯辺篤彦教授介紹「日本海洋微塑膠研究的最新進展」，日本於2014年派遣2艘船實地調查日本週邊海域中上層的微塑膠（小於5毫米）和中塑膠（大於5毫米）濃度，結果發現研究區域內微塑膠總量為172萬件／平方公里，是北太平洋的16倍。2016年再於南冰洋進行實地考察。依據數值模型與跨洋調查結果，研究團隊推估至2066年，北太平洋西部與中部上層海洋的重量濃度將達103毫克／立方公尺，其微塑膠將對此區域的海洋生物具潛在危害。第4場由多倫多大學Chelsea M. Rochman教授越洋連線分享「立足在地、放眼全球：論及微塑膠議題，在地知識對於推動積極變革至關重要」。其研究團隊考察美、加4條河川與湖泊流域，發現微塑膠經由城市廢水排放、農業逕流和暴雨逕流3大路徑流入集水區，而安裝洗衣機過濾器、暴雨排水系統處設置植生滯留槽或雨花園、在河川支流設置海洋垃圾桶或回收輪，可有效過濾微塑膠並減少排放。Rochman認為，推動全球、區域及國家間的合作，與制定因地制宜的解決方案，缺一不可。

下午場次第5場主講人為全球幽靈漁具處理倡議（Global Ghost Gear Initiative, GGGI）Ingrid Giskes執行長，幽靈漁具的定義為遺失或丟棄的漁具，其占大型廢棄物的46～70%，少數為非法漁業所拋棄，但大多是因意外而棄置。Giskes分享在印尼推動漁具標示，在萬那杜、加拿大以低成本方式追蹤找出廢棄物熱點等案例，並表示GGGI推出全球幽靈漁具資訊平臺與多語APP，於2017年發布最佳實踐框架，期望可促進國際合作。第6場由國立臺灣大學柯佳吟副教授介紹「海洋垃圾的全球分布與清除機會」，其研究團隊進行全球性分析，認為「風」對於海洋垃圾的區域分布重組非常重要，特別是赤道地帶和北極地區，經由風阻效應跨洋區運送垃圾的結果，極地區域的海洋可能將成為垃圾匯集的區域。因此各國間進行資訊交流與合作計畫，讓社會大眾瞭解並採取行動，達成科學—政策—實踐的多面向應對，才可能確保海洋環境的保護。

第7場由美國國家海洋暨大氣總署（NOAA）Ellen Ramirez副組長介紹「強化海洋廢棄物監測能力」，Ramirez說明衛星分析部門進行氣候預測、海洋微塑膠等資訊蒐集與分析，以光波分析產出不同波長，利用多光譜、單色和全色的分析，找到海面上垃圾的匯集點，並將資料匯入光譜資料庫。但遙測、衛星技術掃描範圍有限，未來可考慮結合視覺檢測和光譜檢測，以區分塑膠和其他成分。第8場由國立高雄科技大學張國棟副教授介紹「鏈結風與洋流資訊發展海洋廢棄物漂流模擬技術及動態

地圖資訊」，張副教授說明，風與海流會帶動海漂垃圾移動，其團隊採用拉格朗日公式（Lagrangian formulation），透過海洋模擬技術，計算出海漂垃圾在海面上於不同時間的漂移動態，按照結果可思考如何因應，並引起社會大眾之關注。

圖說／「2020臺灣海洋國際論壇」以視訊方式與各國學者交流互動
圖片提供／海洋委員會

主題二：海洋能源研究及創新發展

主題二上午第1場由斯特拉斯克萊德大學Cameron Johnstone執行主任介紹「潮汐能借鏡風能知多少—如何能透過擴展渦輪機大小來減少成本」。風能以增加風機轉子直徑的方式，可將發電量從100瓩增至7,000瓩，但風機直徑不受空間限制，而潮汐渦輪機需負荷高於空氣860倍的海水密度，目前最大直徑限制在27公尺內，僅可提升至2,000瓩裝置容量（較目前示範機組多出33～50%）。Johnstone探討如何發展複雜度較低之渦輪機與最佳化尺寸。第2場由國家海洋研究院陳建宏副院長介紹「臺灣發展海洋能源條件之機遇與挑戰」，臺灣具備豐富的海洋能之潛力，但除了目前的技術瓶頸外，臺灣特有的颱風、地震對海洋能的影響亦不可小覷。陳副院長說明，在洋流能方面，目前海洋委員會補助2套自行研發的洋流能機組，正預備進行實際海域測試；在溫差能方面，臺灣東部為全球發展溫差能的最佳場域之一，工研院曾研發出5瓩的溫差能發電系統；至於波浪能，由於臺灣局部地區波能密度極高，亦有不少廠商有興趣投入。

第3場由美國能源部國家再生能源實驗室于弋翔高級研究員分享「海洋能源—波浪能技術的現況與展望」，目前愛爾蘭、丹麥、葡萄牙、瑞典、英美等海洋國家的研究單位與產業開發商已提出許多波浪能的設計與測試，但如何設計出成功的波浪能轉換器，需考量其裝置的輸出功率、建置至維護之成本，以及對環境之影響等，以符合成本效益。第4場由日本東京大學高木健教授分享「洋流渦輪機的發展近況及未來展望」，臺灣和日本皆有黑潮流經，具備洋流能潛力，高木教授介紹日本新能源產業技術綜合開發機構（NEDO）「海洋能源技術研發」計畫研發全尺度浮游式雙渦輪機系統，並進一步開發100瓩級的「海龍」洋流渦輪系統，進行拖曳試驗後成功產生了100瓩之電力。目前NEDO已進入「海洋能源發電長期示範計畫」階段，預計於2030年後開始實際應用，讓洋流能發電可運用於日本的偏遠島嶼地區。

下午場第5場由英國愛丁堡大學Markus Mueller教授分享「海洋能源電力傳輸及能源轉換研析」，其介紹電力轉換之選項與直接驅動系統，以及C-GEN技術的發展。第6場由工業技術研究院顏志偉組長分享「海洋能源相關技術設備之避颱措施」，海洋能設備在海上主要受力為波浪、海洋及風，而臺灣每年7至9月為颱風季，颱風的極端波浪將造成對海洋能設備之威脅，顏組長針對波浪發電系統進行分析，颱風季來時，波浪發電系統結構可能遭致破壞，並面臨超過運動上下死點以及浮體漏水沉沒等問題，因此提出可行的抗颱策略，才有可能發展我國之海洋能商業化系統。

第7場由美國太平洋西北國家實驗室海洋科學實驗室Andrea Copping研究負責人介紹「發展海洋能源之環境影響及經濟效益評估」，Copping透過海洋能源系統（Ocean Energy Systems）合作計畫，檢視海洋動物衝撞潮汐渦輪機、海洋能設備噪音干擾海中生物、電纜釋放出電磁場等海洋能源對環境之潛在影響，大多數影響可藉由油氣探勘、離岸風電等產業獲取資訊，少部分則需實地探查，不過相關產業之成本仍較高，目前較可能在偏鄉、離岸養殖或海洋探測等方面提供電力。最後由澳洲聯邦科學及產業研究組織（CSIRO）Mark Hemer首席研究員介紹「離岸再生能源產業的前景」，澳洲擁有豐富且易取得之離岸再生能源，但在澳洲能源領域尚未成為主流，不過澳洲近期成立藍色經濟合作研究中心（Blue Economy Co-operative Research Centre, CRC）推動「離岸再生能源系統計畫」，Hemer認為離岸再生能源可對澳洲的減碳目標提供貢獻，並在報告中簡述產業發展性與相關部門的挑戰。

結語

本次論壇之閉幕式，由海洋委員會蔡清標副主任委員致詞，感謝在座嘉賓與各國專家的支持，對科學研究與海洋環境永續做出貢獻，由於海洋廢棄物已成為國際的關鍵問題與挑戰，需要更多正確即時的作法，讓海洋更加安全與乾淨；而潮汐能、波浪能等發電方式是未來再生能源可行的潛在替代方案，但目前仍有許多待克服的挑戰。蔡副主委承諾，將彙集本次論壇提供的專業知識與建議，作為制定政策的參考方向，以環境永續的海洋國家做為未來發展的願景，會議的結束將是行動的開始。正如《國家海洋政策白皮書》所述，讓我們不再被海所限，臺灣更將因海而偉大！

圖說／「2020臺灣海洋國際論壇」全場大合照
圖片提供／海洋委員會

東南亞國家海域意識（MDA）體制之簡介

撰文／蔡季廷（國立臺灣大學政治學系國際法副教授）
關鍵字／海域意識、資訊分享、資訊融合

東南亞地區的「海域意識」（Maritime Domain Awareness, MDA）制度，為一項相當成功的區域合作範例。本篇短文介紹東南亞區域的MDA體制，說明其如何實現國家間的海域資訊分享，並提出其對臺灣未來建立MDA體制時可能的政策啓示。

前言

現代國際間所關注的海洋安全問題，有許多是非傳統的海洋安全議題，例如：恐怖主義、非法捕魚、海上販毒、武器擴散等，都是非傳統海洋安全議題的一環。美國在911恐怖攻擊後，為了避免海洋成為反恐的漏洞，開始在全球倡議並建立「海域意識」（MDA）制度。美國政府對MDA的定義為：對全球海域可能會影響美國保安、安全、經濟或環境相關的任何事物之有效理解[1]。由於美國所強調的是對「全球」海域相關事物的有效理解（依據國際海事組織對MDA的定義，並沒有強調「全球」面向），因此，美國除了在國內於2004年開始著手規劃MDA的建立外，也推動其他區域建立MDA的合作體制。事實上，MDA的概念在1990年，即由美國海岸防衛隊提出。以往，為確保船舶航行之安全（safety）與保安（security），本即有明確掌握船舶航行環境等客觀海洋情況之觀念存在。當今的MDA，則不僅限於確保航行安全之目的的資訊掌控，更著重於辨識與預防潛在威脅。

在美國影響下所建立的區域MDA體制中，東南亞地區的MDA體制，可說是相當成功的一項區域合作範例。以單一國家的MDA體制的建立來說，一項核心要素也是最具有挑戰者，莫過於機關間的資訊分享機制。如果機關間沒有足夠的信任與分享的文化，那麼，MDA體制的硬體設備再好，也無法達到海域資訊整合，並有效發揮非傳統安全的預防功能。由此可見，在一個國家之內要建立MDA體制，尚須克服資訊「不」分享的困難，更何況要在國家之間建立這樣的體制。因此，東南亞國家MDA體制實踐的成功，最值得吾人借鏡之處，即是其國家間的信心建立與資訊合作的體制。

據此，在本篇短文中，將以介紹東南亞區域的MDA體制中，如何實現國家間的海域資訊分享為重心，並說明其對臺灣未來建立MDA體制時可能的政策啓示。

東南亞區域MDA體制設立的背景與考量因素

如前言所述，美國為了反恐的政策需求，而在其他區域推動MDA體制的建立。在此背景下，東南亞區域特殊的地緣政治與經社因素，自然也就成為美國推動該區域MDA體制建立的一項驅動力。就全球航運量來說，約有30%的海運量或50%的海運噸位量會經過東南亞的麻六甲海峽[2]。再者，在這條重要的海運航道上，從1980年代起海盜的數量開始攀升，也迫使東南亞國家必須合作採取海盜打擊機制。另外，此區域本來就充滿著島礁主權與海域劃界的爭端，使國家間必須務實合作防止海域上的事件，影響此區脆弱的航運環境與經濟發展。

在上述的背景因素下，東南亞國家也就有相當程度的誘因，合作創立MDA體制。不過，MDA並不是一個簡單的硬體設備架構起來後就可以開始運作，而必須仰賴對於各種潛在威脅或異常與可疑的船舶及人員資訊的搜集。除了資訊的搜集外，尚須進一步辨認哪些海域內的相關利益或基礎設施，可能會被異常情況所影響，並讓國家快速地決定應該採取哪些具體的回應。因此，該等資料之蒐集與資料庫之建置，往往涉及跨機關、跨國家，以及跨公、私部門（海洋或海洋相關產業）間之合作與協調，並非單獨的一個政府機關可以因應。如果該MDA又是目標涵蓋範圍更大的海域時，更不是一個國家本身能力所可及。

由此可知，東南亞國家在建立MDA合作體制時，必須在有經濟利益相連、國家能力有限、且又有部分海域爭端的情況下，克服國家間的信任問題，才能順利讓一個高度仰賴資訊流通、分享、分析與回應的機制，順利地在此區域運作。

東南亞區域MDA建制

如前所述，一個MDA體制需要克服跨國間的信任與合作問題，才能有效地讓MDA發揮其預防性效果。在東南亞區域的MDA體制發展歷程上，也是經過觀念的轉變與國家間信心建立的過程，才發展到今日跨國MDA合作的範例。就MDA整體架構來說，東南亞區域一共有3個海域資訊分享的中心。但應注意者，在MDA體制下的資訊概念，依據人為「加工」的多寡也有程度上的區別。質言之，在MDA體制脈絡下，「資訊」可以分為：海上異常事件的原始資料、對海上異常事件透過一定的知識（如：大數據運算模式）進行篩選後的資訊、和將篩選過後的資訊與其他情報進行融合分析的資訊。東南亞區域的MDA體制下的3個資訊分享中心，也就反映著上述3種類別資訊的分工。

從前段所提到的資訊類型來說，屬性上屬於原始資料為主的中心，是國際商會（International Chamber of Commerce, ICC）下的國際海事局（International Maritime Bureau, IMB）在1991年於吉隆坡所創立的海盜通報中心（Piracy Reporting Centre, PRC）[3]。又，在屬性上屬於經過一定知識所篩選後的資訊中心，為亞洲反海盜及武裝搶劫船隻區域合作協定（Regional Cooperation Agreement on Combating Piracy and Armed Robbery Against Ships in Asia, ReCAAP）下，於2006年在新加坡所創立的資訊分享中心（Information Sharing Centre, ISC）[4]。至於屬性上是情報與資訊融合分析的中心，是於2009年由新加坡海軍所負責營運的資訊融合中心（Information Fusion Centre, IFC）[5]。從這3個中心的名稱來看（通報、分享、融合），就可以知道其主要的功能差異，並共同構成了東南亞區域的MDA體制；以下即　別介紹這3個中心的主要運作模式。

一、海盜通報中心（PRC）

PRC是國際海事局所創設的資訊中心，以回應1980年代在南海與麻六甲海峽所出現的當代第一波海盜浪潮所創設。由於國際商會是一個非政府組織，因此，PRC本身在法律地位上也是非政府組織，並且在國際海事組織中具有觀察員地位。PRC主要創設的宗旨，是在航運業中提升對特定高海盜風險的海域、港口或錨泊地之意識，並傳達相關　訊給在地的執法機關，以確保船長在必要時獲得援助。在此宗旨下，PRC的資訊分享對象，同時包含了國際海事組織、政府或政府間的執法單位與航運產業。

就PRC所涵蓋的海盜資訊範圍來說，並不區分是否屬於《聯合國海洋法公約》第101條的海盜定義與否（亦即，不區分海盜與海上武裝搶劫），也不區分該等行為是否發生在公海。更重要者，PRC所通報的海盜事件所涵蓋的地理資訊範圍，是全球海域的海盜事件。在2007年以前，PRC每年會公布一份海盜事件報告，並輔以每季一次的報告。而2007年以後，在PRC的網站上，已經有即時的海盜事件實況報告與地圖（圖1），並且設置了一個24小時的海事保安熱線（maritime security hotline）。

由上述簡單說明可知，PRC的首要目的是各種海盜事件的資訊通報與即時分享，以便讓政府或航運業可以快速地採取反應為主。因此，對於當代MDA所著重的各種非傳統安全的預防面向來說，PRC扮演的比較是次要的角色[6]。

圖1／海盜通報中心網站上之即時海盜分布地圖
圖片來源／https://www.icc-ccs.org/index.php/piracy-reporting-centre/live-piracy-map

二、資訊分享中心（ISC）

ISC本身是一個由20個締約國所組成的正式國際組織。ReCAAP協議本身除了約定設有ISC外，也設有一個治理理事會，負責指導ISC的日常運作外，並與各國家聯絡點（national focal point）聯繫。目前除了有20個締約國外，另外亦有8個夥伴組織。此一組織的經費來源，主要是由新加坡政府所提供，其他國家則提供人力資源。至於ISC的主要成立宗旨，是以促進與強化各國對亞洲的海盜與武裝搶劫之打擊與防治為主。因此，ISC有區分一個特定事件是否屬於海洋法公約上的海盜。

大致上來說，為了達成上述的組織宗旨，ISC的主要工作可分為3個部分：1.資料的搜集、核實與傳布；2.資料的分析與研究；3.人員的訓練、教育與意識提升。為了達成這3個工作內容，ReCAAP協議中就已經約定，在各國必須設立聯絡點、建立事件資料庫、並且以網路為基礎的資訊分享軟體。ISC資訊搜集的來源，主要是由各國的聯絡點，或者其他單位（如前述的PRC）、國際海事組織等所提供（圖2）。ISC蒐集到的資訊，會進一步由各國的聯絡點進行資料的核實，再透過相關組織網絡進行分享，並且匯集成月報與年報。由於ISC網絡具有資料核實與分析的能力，他們會進一步地將個別事件，依據經濟損失與暴力程度，分為4個等級類別（第1類別最嚴重事件；第4類別為最輕微事件）。

相較於前述的PRC，ISC的資訊分享並沒有那麼的具有即時性，且其資訊的分享，並不是以讓政府採取快速反應為目的，因此ISC的功能也就有其侷限。曾經有一位學者提到，因為ISC是由各國的聯絡點搜集資訊，所以其運作的性質還是高度仰賴著各國政府的意願。不過，由於ISC的運作成功，積累了各國之間的互信，也才創造了接下來在2009年進一步成立資訊融合中心（IFC）的條件[6]。

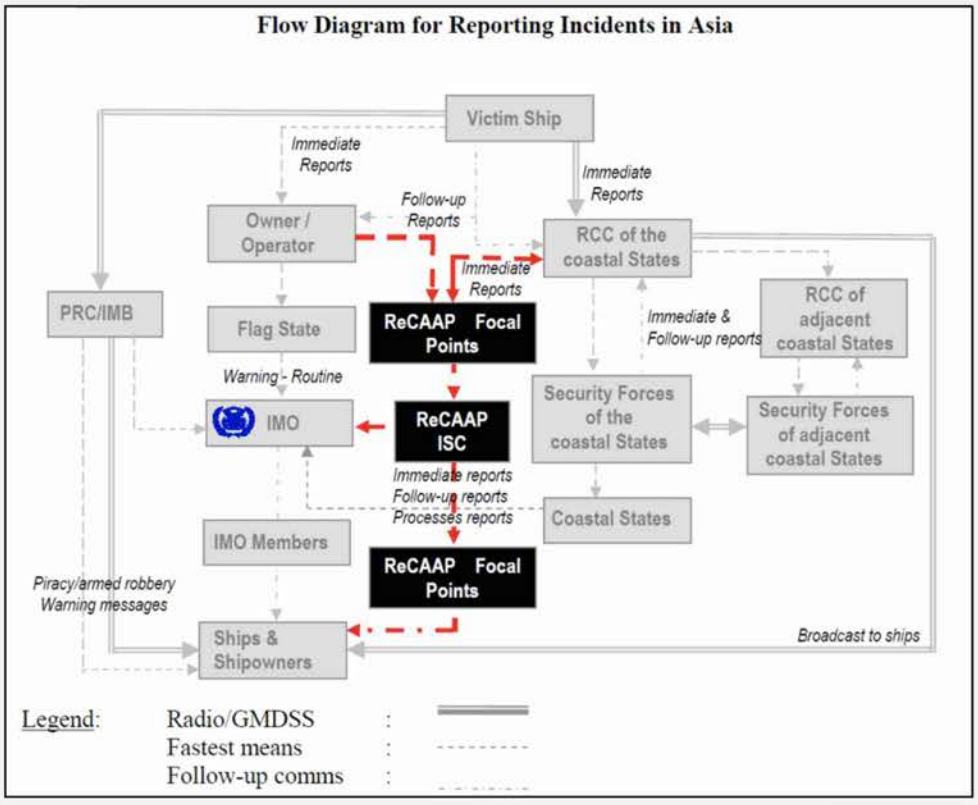

圖2／ReCAAP資訊分享中心之聯絡點通報程序圖
圖片來源／https://www.recaap.org/piracy_definitions_and_actions

三、資訊融合中心（IFC）

IFC成立的宗旨，是為了促進與共同協作，加強東南亞區域的海洋保安資訊的分享。此中心所涵蓋的海洋保安資訊，不僅只是東南亞海盜熱點（南海、麻六甲）資訊，也包括其他如武器擴散、海洋恐怖主義、武器與毒品走私、或漁業犯罪等問題。另外，雖然說IFC是東南亞的區域MDA，但其實該中心所涵蓋的範圍，包含遠及非洲南部、印度洋、部分西太平洋的水域（IFC涵蓋水域：https://www.

ifc.org.sg/ifc2web/app_pages/User/common/aboutvcr.cshtml#tab4）。IFC運作的法律基礎，是一系列新加坡政府與不同國家所簽訂的雙邊協議或備忘錄所組成，並且也包括和其他中心簽訂的協議。

目前，IFC一共有24個參與國外，IFC本身也和97個資訊中心簽訂協議。參與國會派聯絡官駐在新加坡的中心，以便與24小時運作的指揮室隨時保持聯繫。就如同IFC本身所強調者，IFC資訊融合能夠成功的主要因素，是因為有國際聯絡官系統與資訊科技。聯絡官系統可以讓多邊的海軍總部之間，不僅達到協調的作用，亦可確保在事件發生時，透過每日面對面的方式分享即時的資訊。至於IFC的資訊科技，主要是以船舶自動識別系統（Automatic Identification System）和船舶遠程識別與跟蹤系統（Long Range Identification and Tracking of ships）的資訊為基礎，配合新加坡政府所研發的船舶資訊開放與分析軟體系統（Open and Analyzed Shipping Information System, OASIS），來辨認不同的海洋保安事件。除了OASIS系統外，IFC還有一套稱為意義建構、分析與研究工具（Sense-Making, Analysis and Research, SMART）系統，亦可以讓使用者自訂規則，將不同的「點」連結起來發展成「面」，以建構出對海洋保安的潛在威脅趨勢。

由於IFC具有讓各國聚集在新加坡的聯絡官系統，即便部分國家彼此間可能政治上不信任，卻因為有了新加坡作為中介國家，而得以達到實質上的合作[6]。另外，由於新加坡本身所具有的人才與能力，得以發展出相當高程度等級的資訊系統，並讓一個潛在威脅或海洋保安事件發生時，可以依據該資訊系統的判斷，聯絡相關國家的海洋保安部門採取特定的行動。因此，IFC的成功，各國間的信任是一項關鍵因素。

結語

由前述說明可知，東南亞的MDA體制的成功，也給了其他國家或區域一定程度的啓示。尤其，如果臺灣也想要加入相關體制的話，國內本身在建立MDA制度時，也必須要有相對應的組織與能力。首先，因為與海洋安全相關的資訊，一定是存在於國家內不同的地方，所以，MDA體制不論在一國或者跨國，都必須是一個網絡的概念。換言之，各國本身內部就必須要有可以連結所有此類資訊的基礎設施與法律規章。再者，各類不同的資訊連結成為一個網絡後，也必須建立各類資訊的樞紐（hub），以便讓特定資訊可以歸存到特定的單位。最後，東南亞區域的MDA體制的成功經驗也告訴了我們，「適度地」讓不同MDA中心涵蓋重疊區域的資訊，從成本上來說或許也是必要的作法。

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海水淡化與水資源供給：新加坡之經驗

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隨著全球人口快速成長，傳統水資源供給常面臨優良壩址難尋、氣候變遷及水文不確定性等問題導致開發困難。海水淡化具有興建時程短，不受極端氣候影響，已成為各國開發新興水資源的重要方法之一。今年2020年底，颱風季已進入尾聲，但臺灣卻遭逢颱風過門不入，各大重要水庫如翡翠水庫、石門水庫及曾文水庫等儲水不過半，水情吃緊的窘境。新加坡如何利用海水淡化技術，充實國內水資源，確保民生及產業等用水無虞，實為我國水資源發展政策之重要借鏡。

圖1／2020年開始營運的新加坡濱海東海水淡化廠（廠房在屋頂公園下方）
圖片提供／Keppel Infrastructure

傳統水資源供給，常面臨水文不確定性、人口成長快速、生活及工業用水增加快速、蓄水設施抗旱能力不足、水質污染降低水資源供應量等種種問題。隨著全世界用水需求快速增加，各國紛紛開始尋找新興水源。海水淡化具有興建時程短、供水擴充彈性大及能提供穩定與潔淨水源等優勢，已成為各國開發新興水源的重要方法。新加坡處海島四面環海，由於土地面積狹小，當地集水區水源亦有限，長期以來極度仰賴從馬來西亞進口水資源。由於海水淡化供水穩定，不受乾旱、天候、降雨分布等水文條件影響，以海水淡化增加水源供應，具有海水取之不盡用之不竭之優勢。

新加坡早期水資源供給發展歷史

新加坡在英國殖民時期時，於1866年由英國人建造麥里芝水庫（Mac Ritchie Reservoir），以提供水資源。在1927年，新加坡與鄰國馬來屬邦柔佛州（Johor）簽署了一項供水協議，允許新加坡在柔佛州租用土地並使用水源，後續並進口原水且在過濾後使用。在1942年日本入侵馬來亞後，爆發了新加坡戰役，英軍撤退時炸毀了新柔長堤（Johor-Singapore Causeway），同時也破壞了向新加坡輸水的管道，使新加坡的儲備水源只能維持兩週[1]。二次世界大戰後，新加坡人口快速增長，需要更多水資源供城市發展，由馬來西亞提供的水資源越顯重要。在1965年新加坡獨立建國後，水資源卻長期仰賴由鄰國進口，且新加坡的外交政策若損及馬來西亞的利益時，馬國可以切斷柔佛州的水源來做威脅，這促使新加坡進一步開發自己水資源的強烈動機。因此新加坡成立了公用事業局（PUB, Singapore's National Water Agency），在向馬來西亞進口水的同時，也在自己境內積極進行更多的水資源開發計畫[2]。由於新加坡有充足的降雨，每年約2,200毫米，PUB早期在河口築水壩來攔阻河水，並建造了17個蓄水池來儲存雨水。

四大水喉（Four National Taps）

為滿足國內水資源需求，新加坡陸續建立了多樣化及永續供給的水資源，這些水資源來源被稱為「四大水喉」，包括[3][4]：

- 當地集水區水源
- 馬來西亞進口水
- 高級處理過的回收新生水（NEWater）
- 海水淡化水資源

早期新加坡僅有前兩項水喉，由於土地面積狹小，當地集水區水源亦有限。而在1962年與馬來西亞簽訂100年期的水供協定，每日從馬來西亞購水約100萬噸，協定將在2061年期滿，進口水需仰人鼻息亦非長遠之計。由於新加坡政府希望保障水供安全，於是在1998年開始了一項新生水研究（NEWater Study），以確定處理過後的再生水可達到飲用水標準。2002年，新加坡啓用了其第一家新生水廠，其水質還超過了世界衛生組織（World Health Organization, WHO）的飲用水標準，從而開啓了第三水喉。經過為期2年的監測以確保水質安全，還開展了開設參訪中心的營銷活動。2005年，新加坡第一座海水淡化廠開始商轉，更標誌著第四個水喉正式開啓。

新加坡的用水需求目前為每日4億3,000萬加侖。根據新加坡PUB預測，每日用水需求將增近1倍。增加的主要原因是非住宅用水。通過綜合的水管理方法，整合後的四大水喉克服了新加坡長期缺乏自然水資源的窘境，並滿足了成長中國家水資源的需求的問題。此外，在政府的積極支持下，新加坡已成為全球水研究和技術中心。

圖2／新加坡NEWater參訪中心
圖片來源／Filckr @Shaun Wong (CC BY-NC-ND 2.0)
https://www.flickr.com/photos/shaunwong/2439666209/

圖3／新加坡的回收新生水（NEWater）
圖片來源／Filckr @Tristan Schmurr
(CC BY 2.0)
https://www.flickr.com/photos/kewl/
6903183981/

海水淡化發展

PUB早在1970年代就開始進行使用海水淡化技術，提供替代性淡水資源的可行性研究。但是，由於當時海水淡化技術成本非常高，該研究並未有商業化的可能。直到1990年代末期海水淡化技術的持續精進，尤其是全球逆滲透膜（RO）技術的逐漸普及大幅降低了生產成本，這使得2000年代新加坡建設海水淡化廠奠定了成功的基礎。目前新加坡的大型海水淡化廠如表1所示。

表1／新加坡海水淡化廠現況[4][5]

海淡廠名	啓用年分	操作單位
新泉海水淡化廠	2005	凱發／吉寶
大士南海水淡化廠	2013	公用事業局
大士海水淡化廠	2018	公用事業局
濱海東海水淡化廠	2020	吉寶
裕廊島海水淡化廠	興建中	大士電力／新加坡海洋科技

資料來源／https://www.water-technology.net/

新加坡的第一座海淡廠為新泉海水淡化廠，位於大士（Tuas）工業區，是PUB首次以公私伙伴關係之方式，採用設計、建造、擁有及經營方式（DBOO），授予私營業者開發基礎建設。在2004年PUB發包給凱發公司（Hyflux）興建，於2005年完成啓用，總投資金額約新臺幣38億元。第二座大泉（Tuaspring）海水淡化廠於2011年興建，於2013年啓用，是目前亞洲最大海水淡化廠。廠房本身設有複循環發電廠（Combine-cycle power plant, CCPP），裝置容量為411MW，可向淡化製程提供可靠的電力來源，過剩的電量會售予新加坡全國電網。根據與PUB之購水協議，大泉海水淡化廠須在2013年至2038年的25年間，向PUB供應淡化水。2019年，PUB接管水廠，並更名為大士南（Tuas South）海水淡化廠[4][5][6]。

由於大士附近海域水質穩定，適合發展海水淡化，因此第三座大士海水淡化廠（圖4）也在大士工業區，與前兩座緊鄰。大士海水淡化廠首次使用先進之前處理技術，結合溶解空氣浮除法及超微過濾技術。與前兩座淡化廠不同的是，大士海水淡化廠建廠後即由PUB自行營運[4]。第四座濱海東海水淡化廠，是全球首座雙模式海水淡化廠，在雨季時可處理來自濱海堤壩內河口水庫的淡水，旱季則可淡化海水，運作上更不易受氣候因素支配。濱海東海水淡化廠人性化的設計，還包括淡化設施上設有屋頂公園，開放給大眾進行各種活動[7]。

圖4／新加坡大士海水淡化廠
圖片提供／新加坡公用事業局

結論

新加坡原本是個極度缺水的國家，且自然條件比我國更為困難，但是新加坡政府相當看重缺水的問題，加上政府的遠見及魄力，四大水喉政策使新加坡從一個缺水的小國，變成可以輸出新生水、海水淡化技術等水科技的強國，遇到乾旱民間產業用水也不虞匱乏。我國工業用水量逐年遞增，但傳統水資源卻開發不易，新加坡利用海水淡化充實國內水資源之經驗，可作為我國水資源多元規劃之重要借鏡。

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圖片提供／Pride Advertising Agency Ltd.

新加坡海洋政策簡介

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關鍵字／新加坡、海洋政策、漁業、海上安全、海洋法

新加坡擁有得天獨厚的地理位置，屬世界上重要的海洋戰略樞紐和港口，是世界第3大煉油中心、國際航運中心、國際貿易中心和區域旅遊中心；亦是中、日、韓等貿易大國與中東、歐盟貿易的必經之地。本文介紹新加坡的海洋政策，主要包括漁業行政、海域安全、海洋執法等政策。

新加坡是個城市國家，簡稱星國，是一個島國，大小島嶼共有63個，地勢起伏和緩，主島是新加坡島，其面積占全國面積約90%以上。新加坡全國面積約724.4平方公里，海岸線長193公里、領海寬度及專屬捕魚區訂為3浬，其經濟的發展離不開海洋。該國部分國土是填海產生，面積於1960年代時為581.5平方公里，預估至2030年，將會再增加100平方公里。依據新加坡總理公署國家人口及人才署公布的2020年人口簡報，總人口數達569萬人。雖然面積不大，人口不多，但該國因擁有得天獨厚的地理位置（處於麻六甲海峽與新加坡海峽的交會處，如圖1），屬世界上重要的海洋戰略樞紐和港口，而麻六甲海峽控制歐、亞、澳3洲海陸交通之要衝，是世界上最重要的航路之一，亦是世界上最繁忙的海港之一，星國同時也是世界第3大煉油中心、國際航運中心、國際貿易中心和區域旅遊中心；亦是中、日、韓等貿易大國與中東、歐洲貿易的必經之地，全球有超過600個港口與新加坡通航，2012年至2019年統計資料顯示，新加坡貨櫃港排名全球第2，僅次於上海，居世界第2位。

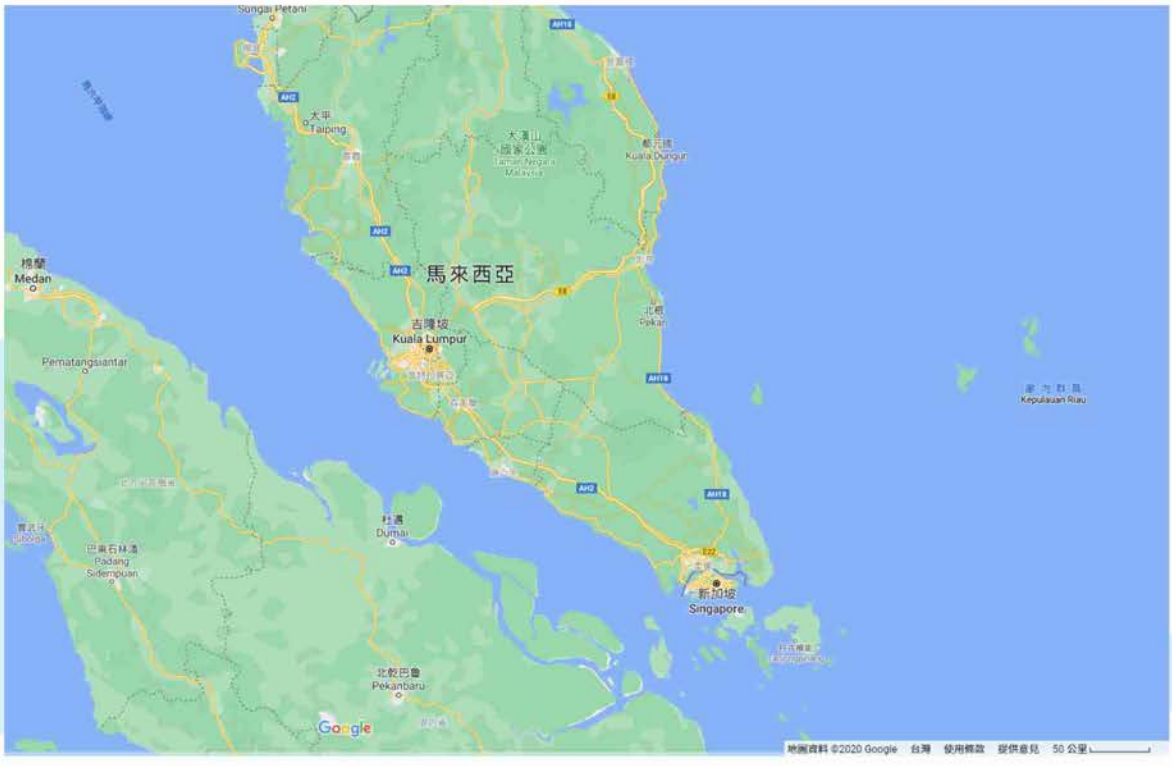

圖1／麻六甲海峽與新加坡海峽位置圖
圖片來源／https://www.google.com.tw/maps/@1.2877667,103.8512191,15z

漁業政策的實踐

新加坡沿岸海洋生態系統十分有限，深受都市開發和港口產業的影響。港口產業是該國最大的收入來源之一，港口範圍擴展到幾乎整個領海水域，開墾已遍及整個主島的南部和東北部沿海（圖2）。由於國土面積狹小，沿海附近漁業資源不甚豐富，再加上國民經濟發達，發展普通漁業較無優勢，故該國漁民數量明顯低於東南亞其他國家。新加坡的領海基本上被商港、漁港占用，海洋漁業只有2大漁港，即最大的魚市場裕廊漁港（Jurong Fishery Port）、榜鵝漁港（Punggol Fishing Port）。但漁業和其產品是當地民眾動物蛋白的重要來源，占動物蛋白消費量的30%。漁業以海洋捕撈為主，淡水漁業所占比例有限。海洋漁獲量的三分之二來自近海水域、三分之一來自沿岸水域。

因陸地面積小、經濟發達，開發利用海岸地區的要求十分迫切。那些經濟價值較低的農業土地已被具有較高經濟效益的項目所占用，透過開發將魚塘轉變為住宅和商業用地，導致沿海捕撈及其相關漁業活動的空間越來越小，也是新加坡沿海漁業發展沒落的原因。但是，新加坡氣候條件優良，養殖漁業風險較低，在種苗和水產養殖上具有優勢，再加上有良好的基礎設施和發達的物流運輸條件，在東協各國中扮演著漁業轉口貿易商的角色，這也造就新加坡成為世界最大的觀賞魚出口國和東南亞漁業轉運中心。

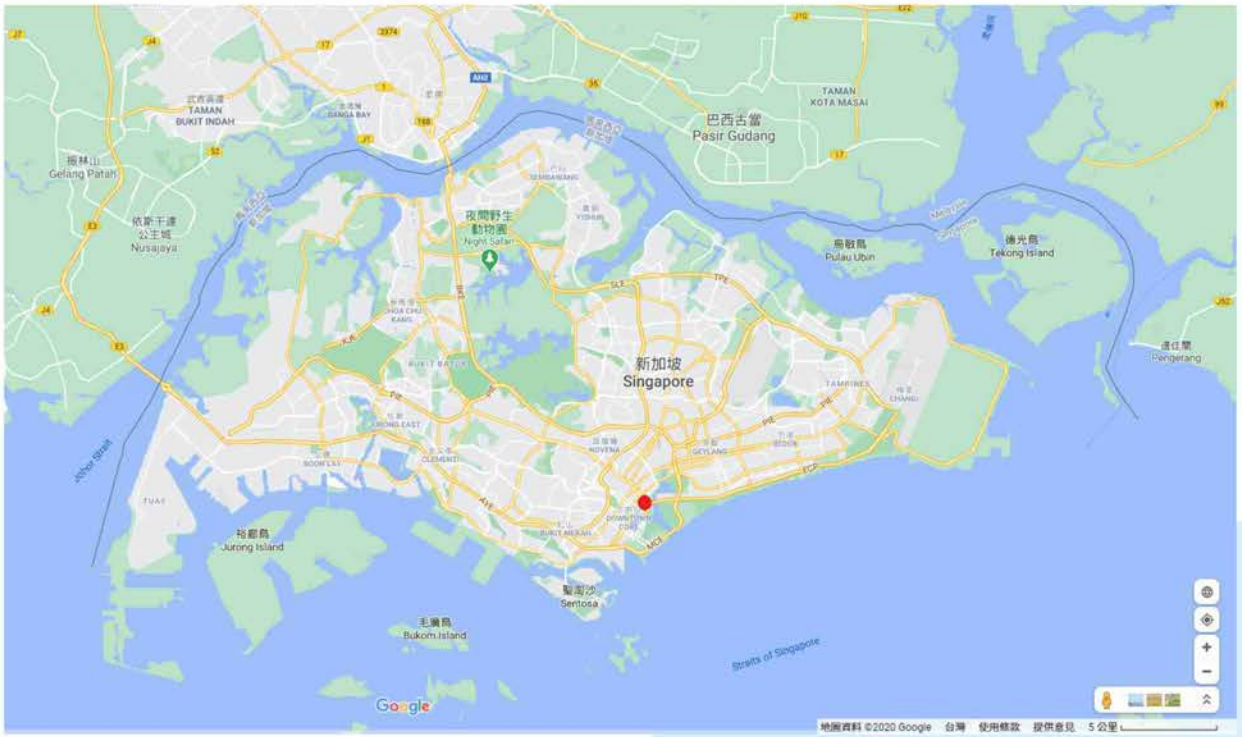

圖2／新加坡濱海灣（Marina bay）紅色點位置
圖片來源／https://www.google.com.tw/maps/@1.2877667,103.8512191,15z

海洋外交安全政策

雖然新加坡不會受到任何其他國家的直接威脅，但鄰近海域與該國的國防政策有密切影響，主要是與鄰近國家有領土與海洋權益的衝突。首先，該國需要向鄰國馬來西亞與印尼強調國家的獨立意識。新加坡自1965年從馬來西亞獨立之後，兩國曾多次出現緊張局勢。新加坡與馬來西亞和印尼存在領土與海洋劃界爭議。其次，新加坡為應付東南亞周邊國家的潛在威脅，其外交和國防機構建立廣泛的雙邊和多邊聯繫、合作網絡等，在1990年也同意美國在該國部署軍隊，確保美國第七艦隊的船隻能順利通過麻六甲海峽，2000年之後，該國也努力加強與美國的關係，美國的空軍和海軍分隊多次到新加坡進行訪問，逐步在南中國海地區奠定基礎。

新加坡高度關注南中國海地區的航行自由和地區領土爭端，該國在南海政策的基本立場是依據國際法，以和平的方式解決，並支持東協與中國所簽署的《南海各方行為宣言》，認為該宣言是南海各方合作和保持穩定的重要信任措施。新加坡亦曾在東協區域論壇發表南海問題立場聲明，主要包括：1.新加坡在南中國海沒有主權領土訴求，也不參與其中的糾紛，但是身為一個主要貿易國，任何影響國際水域航行自由的問題都事關新加坡的關鍵利益；2.中國應更明確聲明在南中國海的主權與海洋權利訴求，因為訴求模糊常引起嚴重國際關切；3.新加坡希望爭端各國能夠保持克制，創造有利於和平解決南中國海糾紛的條件；4.新加坡希望爭端各方能儘速簽署實施《南海行為準則》。

在海上安全的實踐

東南亞國家普遍面臨嚴重的海盜威脅，在亞洲金融風暴後，東南亞海域已成為世界上海盜活動最為猖狂的海域，原因之一是大多數東協國家的海上安全力量薄弱，除新加坡、馬來西亞、越南外，多數東協國家的海上軍事力量非常有限、且武器裝備陳舊落後。再加上，東南亞各國海岸線曲折，沿海各國對許多海域的歸屬仍存有爭議，難以有效監管。新加坡政府頒布《保衛新加坡—迎接21世紀的挑戰白皮書》（Defending Singapore in the 21st Century）和「21世紀的安全環境」（The Security Environment In The 21st Century）策略，明確提出擴大軍隊防禦範圍，在地區事務中發揮更大作用，其主要任務是抵禦來自海上的威脅，保障海上交通線，進行海上巡邏警戒，打擊海盜。無可置疑，新加坡的海軍儼然成為東南亞國家中海軍人員素質最好，並具備最先進的海上科技武裝力量。

國際海洋法的實踐

新加坡是東南亞國家中最晚獨立的國家，所以該國海洋法的發展史和海洋法的實踐都沒其他東南亞國家那麼複雜。但是，新加坡是國際商埠、貿易和金融中心之一，故有關國際海洋法的實踐與政策立場主張與此有關。新加坡希望在現有公海維持最大程度的航行自由，主要原因有二：1.麻六甲海峽對新加坡的自由航行至關重要；2.新加坡係屬地理不利國的海洋法立場，該國周圍海域為馬來西亞和印尼所包圍，小小的島國僅有狹窄的海洋範圍，要擴展海洋管轄權的空間顯得十分有限。基此，新加坡最關注的是各國保持狹窄領海水域，不贊成任何形式的將國家海洋管轄權擴大到公海的主張。

1968年該國所表明的官方立場是，它們沒有進行任何海底、海平面和底土的自然資源研究與開發，或與石油鑽井探勘、海底採礦有關的國家計畫和立法安排，將其地理不利國的遺憾轉而追求其他目標，也讓新加坡躍升成為世界經貿商業中心。新加坡贊成國際航道擁有完全的航行自由，這一立場對於衆多海峽使用國而言是難能可貴的，因為新加坡是身為國際海上生命線（麻六甲海峽）的沿岸國，其立場獲得多數東協國家代表的肯定，這些代表們也樂於在可能的情況下支持新加坡基於地理不利國的主張。由於《聯合國海洋法公約》承認12浬領海範圍、200浬專屬經濟海域成為慣例國際法的一部分，故新加坡外交部長於1980年9月15日發表聲明，宣布新加坡將其領海擴大到12浬，並依照國際的實踐得到一個專屬經濟區。新加坡在東南亞地區是地理不利國，理論上並沒有條件建立自己的200浬專屬經濟區，但是也依國際法劃界原則，與各國談判達成共識，建立200浬專屬經濟區，對該國來說是不可實現的夢，因此該國沒有提出專屬經濟區的最大邊界線，但該國提出建議，要求分享因開發這個地區的資源而得到的一些利益。

海洋執法機關

新加坡的海上執法力量主要是其警察海岸防衛隊（Police Coast Guard, PCG）或稱水警隊，隸屬內政部警政署，為4級機關，與該國警察組織沿革發展息息相關。PCG是新加坡警察部隊（Singapore Police Force, SPF）執行水上任務的執法單位，承擔典型的海岸防衛任務。PCG承擔的任務包括：新加坡的主權水域進行執法、與該國海事及港務管理局（Maritime and Port Authority of Singapore, MPA）和移民檢查局（Immigration and Checkpoints Authority, ICA）協同進行海上搜救。新加坡從1819年成為一個貿易港後，其海域長期受到海盜的侵害，直到1840年公開支持英國打擊海盜行為情況才有所好轉。1866年警方開始進行水上值勤，同時成立流動的警察所，有巡邏船進行水域巡邏，1924年才成為一個獨立的職能機構，更名為海警。在1993年2月13日海事部進行重組，改成警察海岸防衛隊（PCG），賦予海上執法更大的權力，包括阻止海上非法移民的入境、阻止外國非法船舶的入境、保護新加坡主權爭端的白礁（Pedra Branca）上的霍士堡燈塔（Horsburgh Lighthouse）。PCG亦執行海域國境控制（Maritime border control）及反恐怖主義（Anti-terrorism）任務。911事件後該國政府開始重視海上恐怖主義，由樟宜海軍基地主導反海上恐怖主義勤務，政府開始加強檢查往來船隻，尤其由國外返國的客輪，從2004年以來PCG人員加強反恐訓練及精進各項執勤技能與裝備。該國的執法團隊負責海洋管理任務不斷增加，而所屬的警察海岸防衛隊也因為其高效率的執法能力被委以全面執法的重任。

另外，新加坡政府為規範海事與港口業務，頒布了《新加坡海事及港務管理局法》（Maritime and Port Authority of Singapore Act），負責的機關是海事及港務管理局。目前新加坡是國際海洋法法庭在漢堡以外唯一能審理海事糾紛的國家。星國為保護、保育漁業資源，頒訂了《漁業法》（Fisheries Act 1996）；為防止海洋污染頒訂了《防止海洋污染法》（Prevention of Pollution of the Sea Act）和其他海洋相關法規，《防止海洋污染法》目的在防止海洋污染，無論是陸地污染還是船舶污染，該法案還賦予海事及港務管理局採取預防措施以防止污染的權力，包括拒絕入境或扣留船舶。

儘管新加坡透過各種政治和外交方式解決糾紛，但該國依然建立一支強大的海軍並透過國防工業現代化以保衛海域安全，21世紀初期新加坡在東南亞地區亦扮演戰略性重要的角色，並努力在維持軍事力量建設與國際合作之間微妙的平衡關係。2019年新加坡與中國正式簽署國防交流與安全合作協定，新加坡與我國間也有長期合作的星光計畫，雖說星光計畫如期舉行，但因為遇到疫情，星國人員暫停來臺受訓，後續會發生如何的變化，也需持續關注。

圖3／新加坡警察海岸防衛隊巡邏艇
圖片提供／海委會海巡署偵防分屬特勤隊

圖4／新加坡警察海岸防衛隊訓練中心
圖片提供／海委會海巡署偵防分屬特勤隊

人工藻場：海洋農場發展新契機

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關鍵字／海洋環境、繁殖培育、人工藻場、海洋農場、馬尾藻

近年來，海洋環境因為受到人類活動、棲地破壞、污染、外來種入侵及氣候變遷等問題，而面臨甚大的壓力，且在未經妥善的管理及適當的保護機制下，可能會造成物種瀕臨滅絕，甚至已經滅絕或生態系失衡等問題，進而直接或間接影響人類的存活及發展及生存。所以為了讓生物多樣性得以永續，需要透過一些方式來保護，像是「保育」、「復育」、「永續利用」、「教育」與「研究」等，其中復育包含物種的繁殖培育及棲地回復或改善，而「人工藻場」亦是棲地復育方式中的一項。

圖說／綠蠵龜吃食馬尾藻之狀況
圖片提供／國家海洋研究院海洋生態及保育研究中心

海藻的重要性

海藻一般而言，指的是生長於海洋中的「大型藻類」，它們因內部構造無維管束組織的分化，所以不具有真正的根、莖、葉等器官，主要是藉由類似根的附著器攀附在潮間帶及亞潮帶之礁石上。臺灣目前已記錄生長在海岸的大型藻類種類約有600種，在分類上可分為4類群，分別為藍綠藻門（Cyanophyta）、綠藻門（Chlorophyta）、淡色藻門（Ochrophyta）及紅藻門（Rhodophyta）的種類。「海藻」在生態系內扮演著重要的基礎生產者角色，除能產生氧氣、提供食物、淨化水質、沉積碳酸鈣（$CaCO_3$）協助珊瑚造礁外，其形成的海藻林可提供給海洋生物，成為棲息、覓食、繁殖，以及庇護的場所。此外，海洋生物所排泄出的含氮廢物、殘餌等沉積物，可讓藻場充分吸收養分，同時能進行光合作用及固定二氧化碳，具達到優化海底環境及增殖漁業資源的功能。

利用人工藻場發展海洋農場之價值

目前國內外學術與產業界關於海洋農場只是概念，並無統一的定義，但就廣義來說，海洋農場是指在一定海域範圍內，採用放任式自由化管理制度，並且有計劃性地對當地的海洋生態資源進行復育及放流；狹義來說，海洋農場是指在特定的海域或受天然屏障的環境，有規劃的培育當地原生種，以及在人為管理下與人工種苗培育的海洋生物進行放流（養），藉以營造休閒觀光型及複合型的生態海洋農場。目前國內已有成功的案例，像是澎湖縣政府農漁局營造人工藻床，將人工培育的馬尾藻磚，移植在當地烏崁保護區，作為人工流放的海膽苗的食物來源，增加海膽的活存率；農委會水產試驗所澎湖海洋生物研究中心則是利用人工馬尾藻藻繩，在澎湖紅羅海域營造240平方公尺的人工藻床，並放流5萬尾沙蟹蟹苗，且藉由藻床上豐富的餌料生物供作蟹苗的食物來源，進而提高放流效益。所以利用馬尾藻來發展海洋農場除能增進沿近海生物資源外，並具有下列的價值：

一、水產養殖及生態價值

可進一步建立經濟性藻類養殖技術，研發室內培育並生產種苗，且可作為海洋生物的食物來源，或增殖漁業資源的原料。此外，在野外栽植的人工藻場可供給其它海洋生物成長、覓食、繁殖、避難的場所，也能夠產生氧氣與淨化海洋環境等效果。

二、環保價值

可改善海洋生物棲地、淨化海洋環境、吸收海洋中的氨氮及重金屬離子等。且利用海洋生物所排泄出的含氮廢物、殘餌等沉積物，亦可讓海藻充分吸收養分、行光合作用及固定二氧化碳，藉以達到優化海底環境。另外，也可作為一種天然生物濾材，應用於廢水處理及水質改良，頗具潛在的開發價值。

三、海洋觀光產業價值

可規劃低度利用漁港成為示範的培育中心，並設置浮動式箱網平臺，栽植原生種人工藻場營造天然海洋農場觀光園區，且可規劃水下巡禮觀光體驗路線，讓遊客在水下能親自體驗穿梭藻林間的感覺，同時觀察生活於藻林中之海洋生物種類，如魚類、蟹類、海膽等。

四、原料價值

藻類可製作成食品或工業原料來源，如馬尾藻可製成生鮮馬尾藻或乾燥馬尾藻粉。此外，沿海居民也常用來當作飼養陸生動物（雞、豬、牛、羊）、經濟水產生物（魚類等）或種植蔬菜的肥（飼）料來源。

五、保健及生技美容產品價值

藻類具有高蛋白、低脂肪、高碳水化合物並富含礦物質、碘、鉀、甘露醇和褐藻膠等元素，因此在醫藥保健和化工食品工業中，皆具多項開發潛力。未來可開發保健產品如飲品（褐藻糖膠）、膠囊（褐抑定）、益生菌；生技美容產品如化妝品（洗髮精、沐浴乳、肥皂）、保養品（面膜）等。

六、食用價值

目前臺灣食用的海藻大多是以紫菜與龍鬚菜居多，以及近年發展的海葡萄。另外，還可研發食品加工如馬尾藻海鹽、生菜沙拉（泡菜）、酒精、茶包、飲料、優格、蛋捲、霜淇淋、饅頭等。

圖說／附著於空心磚上之人工培育馬尾藻
圖片提供／國家海洋研究院海洋生態及保育研究中心

人工藻場的建置

野外藻場的營造主要是透過全人工或半人工的方式進行修復或重建，並利用栽植技術來建立藻床，使其在野外逐步形成人工藻場，並利用藻場的多面向功能逐漸恢復海洋資源。

臺灣適合發展人工藻場的地區及藻種

臺灣四面環海，又屬於海洋國家，位處在全球海洋生物多樣性最高、且擁有「海中熱帶雨林」美名的「珊瑚大三角」區域，因此造就豐富的海洋生物資源。加上臺灣東岸有黑潮主流流經，西岸則有黑潮支流、南海季風流及中國沿岸流在臺灣海峽相互交會，因而形成良好的漁場。近年來，我國配合國際全球溫室氣體減量的趨勢與達成非核家園的願景，所以政府積極推動離岸風電場的綠色能源政策，並大規模進行臺灣西岸離岸風電場的開發。然而離岸風電場海域的開發有可能會影響原有的漁場功能與生物組成，並連帶影響當地漁業活動及收益，所以可以利用人工藻場的方式設法改善或回復棲地的狀態，藉以減少開發活動對生物的衝擊。除了離岸風電場之外，海洋牧場亦可推動漁業、觀光之產業發展，根據屏東縣政府2016年「屏東縣沿海空間利用規劃委託服務工作（含後續擴充）總結報告書」指出，為了結合地方漁村的永續發展，並且推動漁業資源復育及改造漁場，所以優先推動琉球鄉、枋山鄉及車城鄉3處海洋牧場之規劃，因此也可利用栽植的藻場來增裕沿近海資源，以達到漁業資源永續經營的願景。

在藻類的選擇上，主要考慮是否適應當地的環境，例如光照強度、水溫、鹽度及海水中營養鹽類等物理化學因素，也需考慮藻類本身的易培養程度及是否能有效提供空間給生物棲息。當然，選擇當地原生的藻種是最適合不過了！然而透過實地勘察結果，發現馬尾藻具有上述所有特點，而且也

是當地原生藻種，因此國家海洋研究院目前已著手進行原生種馬尾藻人工藻床育苗技術開發，未來將利用此培育技術拓展臺灣西南海域的馬尾藻復育，並營造馬尾藻海洋農場，藉以增進沿近海生物資源，並達到生物資源永續的目的。下列為馬尾藻的基本介紹：

「馬尾藻」在分類上是屬於淡色藻門（Ochrophyta）、褐藻綱 （Phaeophyceae）、墨角藻目（Fucales）、馬尾藻科（Sargassaceae）內的種類，全世界已記錄的馬尾藻約539種，主要生長在世界上各暖水和溫水海域，且部分品種的馬尾藻可生長至2至3公尺高，而目前臺灣海域（含離島）共發現有13種，也是臺灣海域常見的藻種類群。馬尾藻常被人們誤稱為「海草」，但其實是一群多細胞組成的「大型藻類」，缺乏根部，取而代之的是附著器，也不具維管束、不會開花與結果，亦不會產生種子。但在外部形態上，除了附著器外，並具有柄、葉狀體、氣囊及生殖托等5部位，與植物器官構造有所差異，所以不能與植物混為一談。

馬尾藻種苗生產與育苗技術

馬尾藻的生殖方式有「營養繁殖」與「有性生殖」，前者是藻體的固著器具有再生能力，並且可以在合適的條件下，由藻體直接長出新的幼苗；「有性生殖」是在生殖季節時進行卵配生殖，也是大量產生種苗的主要方式，馬尾藻為雌雄異體，雌、雄株會各別排放精子和卵子，並在體外受精結合成接合子，發育成為新的孢子體幼苗。全世界馬尾藻種苗生產及育苗技術研究，主要以臺灣、中國、日本及韓國居多，因馬尾藻生活史之世代交替較為複雜，有別於其它藻類。經過研究人員花費多年的時間進行研發、改良及測試，人工栽培技術已有所突破，將人工附苗方式黏附在繩索或礁石上，穩定蓄養藻苗至不易脫落的情況，再進一步進行移置和布放。培養馬尾藻的場地，除了需具有大的蓄養空間和方便天然海水外，還必須有適宜的溫度（25～30℃）及充足的光照（10,000 Lux以上）。待場地設置好後，即可開始進行育苗作業，流程如下：

一、野外採集成熟的馬尾藻

在臺灣，馬尾藻的生長季節約在10月至隔年5月，而在6月到9月大多消失不見。因此在採集前除需配合成熟的季節外，還需搭配潮間帶退潮的時間進行藻體的採收，並帶回蓄養。

二、人工刺激授精

當馬尾藻繁殖季節來臨時，野外採收已成熟的藻體，利用人工陰乾法刺激2小時，使雌、雄生殖托同時受到緊迫，再以人工方式放入水中，就會同時排出卵及精子，進行體外授精。

三、人工採苗及附苗技術

將已授精的雌性生殖托放入塑膠容器內，採以人工強烈震盪方式釋放受精卵，收集受精卵做為種苗來源，用篩網過濾藻體碎片後取得種苗，並以毛刷沾附種苗，即刻刷附至空心磚或繩索表面作為附苗基質。

四、藻苗成長情形

受精後24小時內受精卵會發育成胚胎，48小時內會長出附著器，之後發育成發芽體，又稱為藻苗。馬尾藻養成階段主要可分成4期，依序為幼苗期、成長期、繁殖期及衰退期。

未來的挑戰及經營管理

雖然利用人工藻場來發展海洋農場確實有多方面的優勢和價值，但是也會面臨不同程度的挑戰，例如在野外設置的藻場，有可能會遭受到褐籃子魚（臭肚）、瓜子鱲（黑毛）或是刺尾鯛科等藻食性魚類的啃蝕，進而影響人工藻床的效能。因此為了應付藻食性魚類的取食，可選擇堅韌度較強的當地原生藻種（如冬青葉馬尾藻），或是人工藻體必須培育成長至一定程度的大小及密度才能進行野外布放，以降低被攝食的機率。

在水產養殖方面，單一物種的大量養殖可能會因為遺傳基因庫的限縮，使得物種無法適應劇烈的環境變化而產生疾病或造成大量死亡；或者是選擇外來種來當作培育的對象，這有可能會與當地原生種產生競爭或雜交，導致原生種被外來種取代，甚至造成嚴重的外來入侵種問題。因此，若可以在當地建立育種中心，除了在養殖條件上可以有效降低原生種對環境上的不適應外，也可就近採集新鮮野外的藻體進行配種，減少基因窄化的問題，以提升種苗育成率。

馬尾藻科的「銅藻」為太平洋西岸特有的暖溫帶性藻類，喜低溫環境，在春天時會隨著冷水團大批漂浮來到臺灣的中、北部及澎湖海岸，這些「銅藻」多夾雜著垃圾及刺河豚的屍體，堆積在海岸線潮間帶，被視為海洋廢棄物，造成困擾及危害。這些銅藻除部分被清運處理外，部分經過分解後，會把養分釋回海洋，重新回到海洋食物鏈的營養循環中。因此，在人工藻場操作上，必須準確掌握藻場繁生及瞭解馬尾藻成熟的時機點，提早進行收割，減少海藻脫落的機率，或是設置繩索攔截點，阻擋馬尾藻漂至岸上，也成為海洋廢棄物的來源。另外也可透過漁民協助採收，並儲放藻體作為冷凍蔬菜或加工成飼料或肥料，發展馬尾藻創新的用途。

利用馬尾藻人工藻場是未來國家海洋研究院復育海洋棲地的方式之一，可以針對不同類型的棲地環境進行不同方式的藻床營造（如藻磚或藻繩），且同時結合經濟性水產生物放流，藉以打造生態資源永續及產業發展雙贏的海洋農場。

圖說／棲息於馬尾藻林的雀鯛
圖片提供／國家海洋研究院海洋生態及保育研究中心

新加坡海事法規與海域劃界之實踐

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新加坡在海域劃界及海洋法方面的實踐深受到英國殖民時期法律及國際海洋法發展影響，然而，除承繼英國針對領海管轄之法令及依照1982年《聯合國海洋法公約》提出海域主張外，如何爭取國家權益並解決與鄰國之間的海域主張爭端，考驗著新加坡獨立後各時期的相關政府部門，新加坡的經驗亦可作為其他國家之參考。

前言－新加坡海事法規概況

1982年《聯合國海洋法公約》（以下簡稱《公約》）通過前，新加坡即積極參加第3屆聯合國海洋法會議，尤其特別關注用於國際航行之海峽及內陸國與地理不利國之權利等議題，《公約》甫開放簽署時，新加坡即成為簽署國，並於1994年11月17日完成《公約》及《關於執行1982年12月10日〈聯合國海洋法公約〉第十一部分的協定》之批准。在新加坡國內法體系中，行政機關有權與他國締結條約，且其憲法並未要求批准條約前，須經國會同意，然而未經國會立法，新加坡參加之條約於其國內並無法律效力，故《公約》中針對管轄區之規範，仍須透過國會立法轉化。就新加坡目前已制定之相關海事法規而言，尚無海域空間規劃或劃定管轄區之法律。

新加坡國會至今通過之海事法規主要規範對象為港口及懸掛新加坡旗幟的船舶，此等法規包括：《新加坡海事及港務管理局法》（Maritime and Port Authority of Singapore Act）、《防止海洋污染法》（Prevention of Pollution of the Sea Act）、商船航運（油污染損害民事責任與賠償）法（Merchant Shipping〔Civil Liability and Compensation for Oil Pollution〕Act）、商船航運（燃油污染損害民事責任與賠償）法（Merchant Shipping〔Civil Liability and Compensation for Bunker Oil Pollution〕Act）等，並由新加坡海事及港務管理局於授權範圍中訂定補充規則（subsidiary legislation）[1]。就海事法規之執法而言，領海範圍內由隸屬於內政部警政署的警察海岸防衛隊（Police Coast Guard, PCG）負責，並適時協助海關，領海範圍外則由新加坡海軍負責。

新加坡領海制度及《領海管轄法》

如前述，新加坡至今尚未制定海域空間規劃或劃定管轄區之法律，然而，就領海寬度之主張而言，可從新加坡之外交實踐觀之。於第3屆聯合國海洋法會議期間，新加坡注意到幾項重要發展，包括：承認12浬之領海寬度、200浬之專屬經濟區及海峽過境通行權等，新加坡外交部並於1980年9月15日發出聲明，表示新加坡自1878年起即以3浬作為領海寬度，而「有鑑於前述國際發展趨勢，新加坡將行使其權利，延伸領海寬度至12浬。同樣的，新加坡也將建立專屬經濟區」[2]，同時提及若新加坡主張之專屬經濟區與他國主張重疊，新加坡將與該等國家協商，以依據國際法達成劃界之共識。

長期以來，新加坡與馬來西亞就白礁島、中岩島及南礁即有主權爭議，兩國於2003年決定將該3座島礁的主權歸屬案提交給國際法院後，新加坡於訴訟程序期間亦不斷重申以上的領海主張。經過2010年港界修正後（經2018年再度修正後之港界圖如圖1），新加坡本島外水域大多屬於港界內，或屬分道通航制適用範圍，純屬領海性質的範圍相對較小[3]。

除上述海事法規外，英國殖民時期於新加坡施行之1878年《領海管轄法》至今仍然有效，其中並未提及領海寬度，僅以「離海岸若干距離」（a certain distance of the Coast）的文字指出範圍，而該法即是規範發生於該範圍內之犯罪行為的管轄相關問題，條文內容包括：管轄權範圍（於領海內發生之犯行，不論行為人是否屬本國國籍）、管轄權之限制、程序規定、海盜罪例外等。

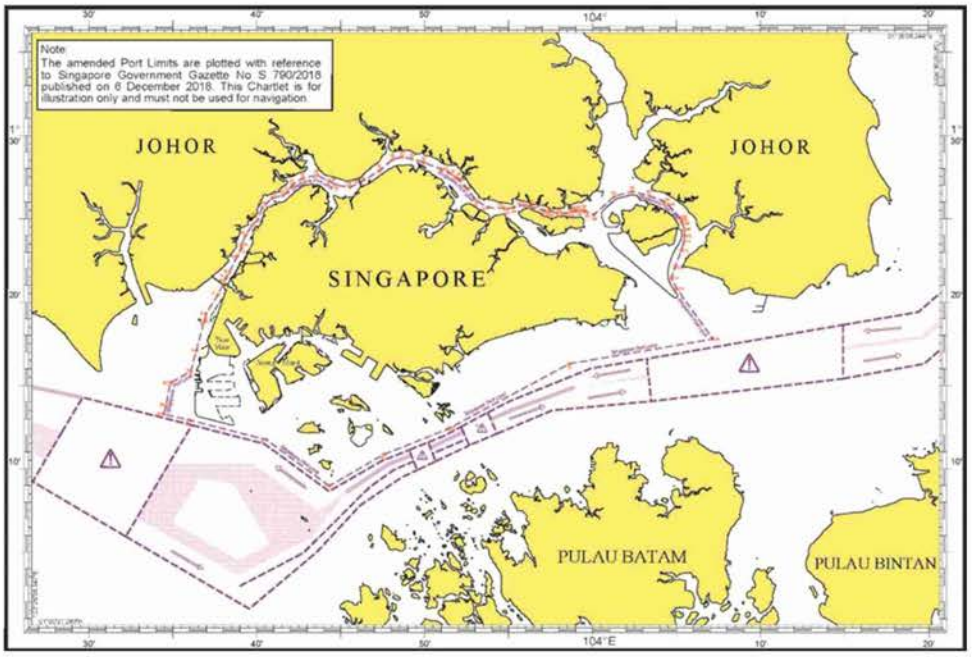

圖1／新加坡港界圖（2018年修正版）
資料來源／新加坡海事及港務管理局[4]

新加坡海域劃界實踐

承上，新加坡國內法規並無海域外部界線或劃界的明文規定，在前述1980年外交部聲明中曾強調，若與他國主張重疊，將以談判方式，試圖取得共識。新加坡在這部分的實踐主要展現於分別與印尼及馬來西亞之雙邊談判及成果。

新加坡及印尼針對新加坡海峽內兩國領海的界線經過多次談判，於1973年首度簽訂條約，該條約中指定6個點座標，並以連接該6點的直線作為兩國領海界線，其中3點距離兩國大致上等距，但另外3點較靠近印尼，故有論者稱兩國的劃界方法為「經修正之等距線」[5]，1973年條約僅解決了部分的劃界爭議，如何將該條約中所劃的界線延伸，尚須兩國的進一步協商，也需另與鄰近的馬來西亞締結劃界協定[5]，1973年條約締結後，新加坡進行之填海工程曾引發印尼的關注，擔心新加坡海岸線的改變影響其水域主張，但後來兩國均同意填海工程不影響兩國已劃定之界線。除1973年條約外，兩國另外分別於2009年及2014年締結條約，3部條約對兩國領海劃界情況如圖2，在此基礎下，確認了兩國之間水域的法律適用狀態，也釐清為促進航行安全所需進行之管轄範圍界線[3]。

圖2／新加坡與印尼雙邊劃界協議簽訂之領海界線示意圖
資料來源／新加坡與印尼2014年劃界協議附件B

新加坡與馬來西亞兩國之間，在新加坡獨立前，就曾於1927年由新加坡海峽殖民地（Straits Settlement of Singapore）和柔佛國（State of Johor）締結領海協定，全名為：Straits Settlements and Johore Territorial Waters Agreement，依循柔佛海峽深水航道中心的假想線（an imaginary line following the center of the deep-water channel in the Johore Strait）作為兩國之間領海之界線，但是這樣的「假想線」畢竟欠缺劃界所需的明確性，故新加坡與馬來西亞兩國於1980年展開聯合水文調查，決定該「深水航道」的位置[5]，並於1995年締結雙邊劃界條約，其中指定72座標點，作為兩國於柔佛海峽劃界之基準。該條約中並未處理白礁島附近的劃界問題，針對這部分的主權爭議，兩國於2003年決定共同提交由國際法院裁決。國際法院於2008年做出判決，白礁島歸屬於新加坡，中岩礁則歸屬於馬來西亞，而屬低潮高地的南礁主權歸屬，則視其為於何者的領海範圍。在此基礎下，兩國成立「聯合技術委員會」（Joint Technical Committee），監督兩國聯合調查工作，並準備劃界談判所需之資料。調查工作於2013年完成，在「聯合技術委員會」的主導下，相關工作持續進行中，2020年1月委員會議中，雙方同意成立「海洋邊界劃界次委員會」（Sub-Committee on Maritime Boundary Delimitation）展開談判[6]。

結論

自第3次聯合國海洋法會議召開期間之參與及後續實踐，可看出新加坡對海洋法議題之重視及立場，雖然其未經由國內法律明確提出海域寬度及範圍的主張，然而仍然透過其他海事法規確保附近水域航行安全及港口的管制，針對與鄰國主張有重疊的部分，亦適時善用雙邊協商及國際司法機制處理跨國爭議，其對海洋法及國際爭端解決之態度，確有可供我國參考之處。

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Creating Key Competitiveness Through Ocean Sustainability

Translated by Linguitronics

Minister of the Ocean Affairs Council: Chung-Wei Lee

Embraced by the sea on all sides, Taiwan's surrounding oceans feature high marine biodiversity and offer access to rich fishing grounds and abundant marine energy. The key to Taiwan's marine management therefore lies in using marine resources sustainably. The Ocean Affairs Council held the "Taiwan International Ocean Forum 2020" on November 5 to discuss the development direction of marine debris processing technology, ocean energy, and marine scientific research. In this issue of "Special Report", we will in particular introduce discussion highlights from the forum to our readers. "Latest News", contributed by the staff from the Marine Ecology and Conservation Research Center of the National Academy of Marine Research, offers insight into using "artificial algae forest" to rehabilitate marine habitats and achieve the goal of sustainable fishery resources. Furthermore, this year, as we experience the least rainfall in four decades, all of us here in Taiwan are even better aware of the importance of water resources. In light of this predicament, "Industry Dynamics" introduces how Singapore, the theme country of this issue, utilizes seawater desalination to ensure an increased and stable water supply. Its diversified water resource planning "Four National Taps" is worthy of our reference.

Singapore, located at the intersection of the straits of Malacca and Singapore, is not only the world's third largest oil refining center, international shipping center, international trade center and regional tourism center, but also a necessary midway point on the trade route between major trading countries such as China, Japan, and Republic of Korea and the Middle East and European Union. Due to its unique geographical location, it is even more important for Singapore to fine-tune and monitor its cooperation and coordination with other countries in all aspects of maritime affairs. This issue introduces how Singapore formulates demarcation regulations in accordance with international law and conducts maritime negotiations with neighboring countries such as Malaysia and Indonesia. In particular, the "International Issues" column focuses on the Maritime Domain Awareness (MDA) system in Southeast Asia, and introduces the Southeast Asian MDA system consisting of three maritime information centers engaging in the reporting, sharing, and fusion of information, and explains how the system operates successfully and efficiently, creating a paradigm that may serve as a reference for Taiwan's future establishment of related mechanisms.

Singapore Marina Bay
Image by akenarinc from Pixabay
https://pixabay.com/photos/marina-bay-singapore-ao-city-1435072/

Understanding the Ocean, Becoming Great Because of the Ocean – A Report on the Taiwan International Ocean Forum 2020

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Translated by Linguitronics
Keywords: Marine Waste, Marine Energy, Marine Scientific Research

The Ocean Affairs Council (OAC) held the 2020 Taiwan International Ocean Forum on November 5, 2020, and planned two panels, "Ocean Energy Research and Innovative Development" and "Reducing Marine Debris by Marine Science." The OAC hopes to contribute to scientific research and marine environmental sustainability and allow Taiwan to accord with international trends through knowledge and experience sharing.

Group photo of honored guests at the 2020 Taiwan International Ocean Forum
Image by Ocean Affairs Council

The OAC held the 2020 Taiwan International Ocean Forum at the Ambassador Hotel Kaohsiung on November 5, 2020, and Deputy Minister Ching-Piao Tsai of the OAC gave a speech during the opening ceremony. After the United Nations (UN) announced the goal of "innovation for a sustainable ocean" in 2020, the decade starting from 2021 will be the "UN decade of ocean science for sustainable development." The two panels of the forum this year are "Ocean Energy Research and Innovative Development" and "Reducing Marine Debris by Marine Science." The OAC hopes to establish the future vision for an ocean nation through the participation of industry, government, academia, and research institutes in publication and discussion, and bring Taiwan into accord with international trends.

Due to the impact of COVID-19, the forum this year featured virtual-real integration, and invited foreign scholars to pre-record videos or show their findings via video conferencing. AIT Kaohsiung, Australian Office Taipei, British Office Taipei, Japan-Taiwan Exchange Association Kaohsiung Office,

and National Taiwan Ocean University provided assistance and support to the event. Besides sharing knowledge and experience, the event also declared to international society Taiwan's determination to participate in international ocean affairs.

Opening ceremony and keynote speech

After the opening ceremony, Jonathan D Lindsay, Operations and Technology Director of the European Marine Energy Centre (EMEC), gave the first keynote speech on "Ocean Energy Research and Innovative Development in Europe" in a pre-recorded video. Lindsay first shared developments in marine energy in the UK and indicated that global warming is not only an unprecedented topic of concern, but also a priority of European countries in policy making. According to estimates, the installed capacity of marine energy devices in Europe can reach 100 GW, accounting for 10% of Europe's total power generation. Many European countries have already established marine energy testing centers, and planned numerous national-level testing projects. So far EUR165 million has been invested in 44 R&D projects, of which 19 are ongoing. In the future, marine energy needs to be combined with government subsidies, bank financing, and insurance to lower the financial costs and increase the possibility of commercialization.

Jenna Jambeck, Professor at the University of Georgia gave a speech on "Plastic Marine Debris from Sea to Source." Jambeck and 13 women joined the cross-Atlantic eXXpedition voyage in 2014, and began a survey of the Ganges River in 2019, researching plastic waste discharge before and after the rainy season. She worked with members in five countries that the Ganges River flows through, and successfully gathered water and air samples. Jambeck believes that working together with local communities puts things in context, while UAV tracking and AI recognition technologies improve recognition of plastic. Jambeck hopes to gain greater influence in the future and continue to take action to prevent more waste from flowing into the ocean.

Panel 1: Reducing Marine Debris by Marine Science

Hsin-Chen Sung, Deputy Director-General of the Ocean Conservation Administration, was the first speaker, who introduced "The Opportunities and Challenges for Marine Debris Governance Using Oceanic Scientific Approach." Marine debris disposal is already an important topic of concern worldwide. Taiwan uses remote sensing technology and AI to expand monitoring and obtain real-time information, bringing together local governments and fishermen's associations to clean marine debris from the source, which is then used to produce fuel oil through pyrolysis. In the future, the Ocean Conservation Administration will also plan platforms and design a certification mechanism and QR code for tracing product footprints, in order to help citizens better understand products made from marine debris. Chi-Farn Chen, Professor at National Central University, was the second speaker, who introduced "Studies on Marine Debris Identification Using UAV Image with Artificial Intelligence." Having studied the application of AI technology in marine debris monitoring and identification, he is currently capable of recognizing images with a ground resolution better than 5 cm; the marine debris is divided into PET bottles, Styrofoam, and fishing float ball. Professor Chen explained that he hopes to combine the current AI model with an app, and encourage public participation to increase training data. An open data platform can be established in the future and shared with the government and NGOs to increase the model's recognition accuracy.

Atsuhiko Isobe, Professor of Kyushu University, was the third speaker, who introduced "Recent Advances in Ocean Microplastic Research in Japan." Japan dispatched 2 vessels to conduct an on-site survey of the concentration of microplastic (smaller than 5 mm) and medium plastic (larger than 5 mm) in middle and upper layers of the sea area around Japan. The total amount of microplastic found within

the research area was 1.72 million pieces/km2, 16 times the amount in the North Pacific. Another on-site survey was conducted in the Southern Ocean in 2016. Based on numerical model and cross-ocean survey results, the research team estimates that mass concentration in the upper layer of the western and central parts of the North Pacific will reach 103 mg/m3, and the microplastics will become a potential hazard to marine organisms in this region. Chelsea M. Rochman, Professor of Ecology at University of Toronto, was the fourth speaker, who shared "Think Global, Act Local: Local Knowledge is Critical to Inform Positive Change When It Comes to Microplastics." Her research team visited four river and lake basins in the US and Canada, and found that microplastics flowed into the basins through urban wastewater, agriculture runoff, and storm runoff; installing filters in washing machines, building bioretention cells or rain gardens for stormwater drainage systems, and setting up seabins or recovery wheels at branch streams can effectively filter microplastics and reduce discharge. Rochman believes that collaboration among the world, nations, and regions, as well as solutions adapted to local conditions, are all indispensable.

During the afternoon session, Ingrid Giskes, Director of Global Ghost Gear Initiative (GGGI), was the fifth speaker, who defined “ghost gear” as lost or abandoned fishing gear, which accounts for 46-70% of large debris. A small amount of the fishing gear was abandoned due to illegal fishing, but most were accidentally lost. Giskes shared the example of Indonesia promoting labels for fishing gear and tracking debris hotspots in Vanado and Canada using a low cost method. She said that GGGI launched a global ghost gear information platform and multilingual app, and published a best practices framework in 2017, in hopes of facilitating international cooperation. Chia-Ying Jessie Ko, Associate Professor of National Taiwan University, was the sixth speaker, who introduced "Global Distribution and Cleanup Opportunities for Marco Ocean Litter." Her research team conducted a global analysis and believed that "wind" was very important to the regional redistribution of marine debris, particularly at the equator and north pole. As a result of cross-ocean debris transport due to the effect of wind resistance, marine debris may gather in polar regions. Hence, projects for information exchange and cooperation between countries helps the public to understand and take action. Achieving multi-faceted response in science, policy, and practice is the only way to ensure that the marine environment is protected.

Ellen Ramirez, Deputy Chief at the National Oceanic and Atmospheric Administration (NOAA), USA, was the seventh speaker, who introduced "Strengthening the Marine Debris Monitoring Capacity." Ramirez explained that the Satellite Analysis Branch makes climate predictions and collects and analyzes information on ocean microplastics, using light wave analysis to generate different wavelengths, using multi-spectral, monochromatic, and panchromatic analysis to find gathering points of marine debris, and importing data into the spectral database. However, remote sensing and satellite technologies have a limited scanning range. The combination of visual inspection and spectral inspection can be considered to distinguish between plastic and other components. Kuo-Tung Chang, Associate Professor of National Kaohsiung University of Science and Technology, was the eighth speaker, who introduced "Development of Marine Debris Drifting Simulation Technology and Its Dynamic

Discussion among scholars from various nations over video conferencing during the Taiwan International Ocean Forum 2020
Image by Ocean Affairs Council

Map Based on Wind and Ocean Currents Information." Associate Professor Chang explained that wind and ocean currents cause marine debris to drift, and his team used the Lagrangian formulation and ocean simulation technology to calculate the drifting of marine debris at different times. Simulation results can be used when considering response measures, and will draw public attention.

Panel 2: Ocean Energy Research and Innovative Development

Cameron Johnstone, Executive Director at the University of Strathclyde, was the first speaker during the morning session, who introduced "How Much Can Tidal Energy Learn from the Wind Energy Sector in Reducing Costs through Physical Scaling Up on Size." Electricity generation of wind turbines can be increased from 100 kW to 7,000 kW by increasing the diameter of the rotor, but there are no spatial limitations on the diameter of wind turbines, while tidal turbines need to withstand the density of seawater, which is 860 times higher than that of air. At present, the maximum diameter is 27 m, so installed capacity can only be increased to 2,000 kW (33%-50% higher than current demonstration turbines). Johnstone discussed how to develop less complex turbines with the optimal size. Jiahn-Horng Chen, Vice President of National Academy of Marine Research, Taiwan, was the second speaker, who introduced "The Opportunities and Challenges to the Development of Ocean Energy in Taiwan." Taiwan has an abundance of ocean energy potential, but aside from current technology bottlenecks, the impact of typhoons and earthquakes in Taiwan on ocean energy should not be overlooked. Vice President Chen explained that the OAC has subsidized the independent development of two ocean current energy generators and is currently preparing for tests in the ocean. With regard to thermal energy, eastern Taiwan is one of the best places in the world for developing thermal energy. The Industrial Technology Research Institute has developed a 5 kW thermal energy electricity generation system. As for wave energy, the high density of wave energy in some parts of Taiwan has attracted the interest of a number of companies.

Yi-Hsiang Yu, Senior Research Scientist of National Renewable Energy Laboratory, USA was the third speaker, who shared "Ocean Energy - Recent Development and Future Perspective of Wave Energy Technologies." Research institutes and developers in ocean nations such as Ireland, Denmark, Portugal, Sweden, the UK, and the US have already proposed many wave energy designs and tests. However, the design of a successful wave energy converter must take into consideration the device's power output, installation and maintenance costs, and environmental impact in order to be cost effective. Ken Takagi, Professor at the University of Tokyo, was the fourth speaker, who shared the "Recent Development and Future Perspective of Ocean Current Turbines." The Kuroshio Current flows past both Taiwan and Japan and has potential ocean current energy. Professor Takagi introduced the full scale floating dual turbine system developed by the Ocean Energy Technology Development Project of Japan's New Energy and Industrial Technology Development Organization (NEDO), which further developed the 100 kW “Kairyu” (Sea Dragon) ocean current turbine system. The system successfully generated 100 kW of electricity in the towing test. At present, NEDO has entered the "Ocean Energy Electricity Generation Long-term Demonstration Project" phase, and actual application is expected to begin after 2030, allowing ocean current electricity generation to be applied in remote islands of Japan.

During the afternoon session, Markus Mueller, Professor at the University of Edinburgh, was the fifth speaker, who shared "A Study on Ocean Energy Power Transmission and Conversion." He introduced power conversion options and direct drive system, as well as developments in C-GEN technology. Chih-Wei Yen, Division Director of the ITRI, was the sixth speaker, who shared "Anti-typhoon Procedure and Technology of Marine Energy Systems." Ocean current energy equipment mainly withstands waves, ocean current, and wind at sea. July to September of each year is the typhoon season in Taiwan, and theextreme waves brought by typhoons are a threat to ocean current energy equipment. Division Director Yen analyzed the wave energy electricity generation system and found that its structure may be

damaged when the typhoon season arrives, facing issues of passing the dead points when moving up and down and the floating structure leaking and sinking. Hence, proposing a feasible strategy for resisting typhoons is the only way for Taiwan to develop a commercialized ocean current energy system.

Andrea Copping, Senior Program Manager of Pacific Northwest National Laboratory, USA, was the seventh speaker, who introduced "Environmental Impact Assessment and Economic Evaluation of Ocean Energy Development." Copping ascertained the potential environmental impact of ocean energy, including sea animals colliding with tidal turbines, noise from ocean current energy equipment disturbing sea animals, and impact from electromagnetic fields surrounding power cables, through the Ocean Energy Systems Collaboration Project. Information on most impacts could be obtained from the oil drilling and offshore wind power industries, while a small portion required on-site surveys. However, the cost of related industries is still relatively high, and it is currently more likely to generate electricity in rural areas, offshore farming, or ocean exploration. Lastly, Mark Hemer, Principal Research Scientist of Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, introduced "Potential Pathways for a Promising Offshore Renewable Energy Sector." Australia has an abundance of easily accessible offshore renewable energy, which has not yet become the mainstream in Australia. However, Australia recently established the Blue Economy Co-operative Research Centre (CRC) to implement the "Offshore Renewable Energy System Project." Hemer believes that offshore renewable energy can contribute to Australia's carbon reduction goal, and briefly described the industry's development potential and challenges of related departments in the report.

Conclusion

Deputy Minister Ching-Piao Tsai of the OAC gave a speech during the closing ceremony of the forum this year, and thanked the honorable guests and experts from various countries for their support, as well as their contribution to scientific research and marine environmental sustainability. Marine debris has become an international issue and challenge, and even more of the correct measures must be immediately taken to make the ocean safer and cleaner. Tidal energy and wave energy are feasible alternatives for renewable energy in the future, but there are still many challenges that need to be overcome. Deputy Minister Tsai promised to use the professional knowledge and recommendations provided during the forum for direction when formulating policies to establish a development vision for an ocean nation with environmental sustainability. With the ending of the forum, action can begin. As described in the National Ocean Policy White Paper, let us no longer be limited by the ocean, and instead make Taiwan great because of the ocean!

Group photo at the 2020 Taiwan International Ocean Forum
Image by Ocean Affairs Council

Introduction to the Maritime Domain Awareness (MDA) System in Southeast Asian Countries

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Translated by Linguitronics
Keywords: Maritime domain awareness, information sharing, information fusion

The Maritime Domain Awareness (MDA) system in the Southeast Asian region is a very successful example of regional cooperation. This short article will introduce the approaches to realizing maritime information sharing among countries in the MDA system in Southeast Asia, and explain the possible policy implications for Taiwan's future establishment of the MDA system.

Introduction

Many of the maritime security issues that the global community of today is concerned about are non-traditional maritime security issues including terrorism, illegal fishing, maritime drug trafficking, and weapons proliferation, etc. After the 9/11 terrorist attacks, the United States began to advocate and establish a Maritime Domain Awareness (MDA) system globally in order to prevent the ocean from becoming a loophole for counter-terrorism. The U.S. government defines MDA as: An effective understanding of anything associated with the global maritime domain that could impact the security, safety, economy, or environment of the United States [1]. As what the United States emphasizes is an effective understanding of the "global" maritime domain (according to the definition of MDA by the International Maritime Organization, emphasis is not placed on the "global" aspect), therefore, in addition to planning the establishment of MDA in the United States in 2004, the U.S. has also promoted the establishment of MDA cooperation systems in other regions. In fact, the concept of MDA was proposed by the US Coast Guard in as early as 1990. In the past, in order to ensure the safety and security of ship navigation, objective ocean conditions such as the ship's navigation environment were regarded as vital information that must be fully grasped. Today, however, MDA entails more than just information control for the purpose of ensuring navigation safety, but is to a larger extent necessary for identifying and preventing potential threats.

Among the regional MDA systems established under the influence of the United States, the MDA system in Southeast Asia can be said to be a very successful example of regional cooperation. For a single country to establish the MDA system, the most vital and most challenging aspect is the information sharing mechanism between agencies. If there is not a sufficient culture of trust and sharing between agencies, however good the hardware equipment of the MDA system may be, it will not be able to achieve the integration of maritime information and effectively carry out the preventive functions of non-traditional security. This shows that in order to establish an MDA system within a country, it is still necessary to overcome the difficulty of "not" sharing information, not to mention the establishment of such a system between different countries. Therefore, the successful practice of the MDA system in Southeast Asian countries is worthy of our reference, specifically the system of confidence-building and information cooperation among such countries.

Accordingly, this short article will focus on introducing the approaches to realizing the sharing of maritime information among countries in the MDA system in Southeast Asia, and explain the possible policy implications for Taiwan's future establishment of the MDA system.

Background and considerations of establishing the MDA system in Southeast Asia

As mentioned in the preface, the United States has promoted the establishment of MDA systems in other regions for counter-terrorism policy needs. In this context, the special geopolitical, economic and social factors in Southeast Asia have naturally driven the United States to promote the establishment of the MDA system in the region. In terms of global shipping volume, about 30% of shipping volume or 50% of shipping tonnage will pass through the Strait of Malacca in Southeast Asia [2]. Furthermore, on this important shipping route, the number of pirates has increased since the 1980s, which has forced Southeast Asian countries to cooperate in adopting a counter-piracy mechanism. In addition, this region is inherently rife with disputes over island sovereignty and maritime delimitation, hence countries must cooperate pragmatically to prevent maritime incidents that may affect the fragile shipping environment and economic development of this region.

Due to the aforementioned background factors, Southeast Asian countries are also to a considerable degree keen to cooperate in the establishment of the MDA system. However, MDA is not just a simple hardware device that becomes operational as soon as it is set up. It is instead a system that must rely on the collection of information on various potential threats or abnormal and suspicious ships and personnel. In addition to the collection of information, it is necessary to further identify the relevant interests or infrastructure in the sea areas that may be affected by abnormal conditions, and allow the corresponding countries to quickly determine which specific responses should be adopted. Therefore, the collection of such data and the establishment of a database often involve cooperation and coordination across agencies, countries, and public and private sectors (ocean or ocean-related industries), which is beyond what any single government agency can undertake. If the MDA is to target a larger maritime domain, the tasks entailed will be beyond what any single country can take on.

As evidenced above, when establishing an MDA cooperation system, Southeast Asian countries must overcome the issue of trust between countries in the presence of interconnected economic interests, limited national capabilities, and maritime disputes in certain areas in order to successfully enable a mechanism highly reliant on information flow, sharing, analysis and response to smoothly operate in this region.

MDA establishment in Southeast Asia

As aforementioned, to establish an MDA system, it is necessary to overcome the problems of trust and cooperation between countries so that MDA can effectively exert its preventive effects. In the development process of the MDA system in Southeast Asia, today's example of transnational MDA cooperation was also achieved through a process of conceptual changes and confidence building between countries. With regard to the overall MDA framework, there are three maritime information sharing centers in Southeast Asia. However, it should be noted that the concept of information under the MDA system also differs in degree based on the amount of artificial processing involved. In short, in the context of the MDA system, "information" can be divided into three types: the raw data of maritime anomalous events, information that is filtered through certain knowledge (such as big data computing models) of maritime anomalies, and information that is filtered and then fused and analyzed with other information. The three information sharing centers under the MDA system in Southeast Asia also reflect the division of labor for the above three types of information.

In terms of the types of information mentioned in the previous paragraph, the center that primarily processes information characterized as raw data is the Piracy Reporting Centre (PRC) established by the International Maritime Bureau (IMB) of the International Chamber of Commerce (ICC) in Kuala

Lumpur in 1991 [3], while the information center that primarily processes data filtered through certain knowledge is the Information Sharing Centre (ISC) established in Singapore in 2006 under the framework of the Regional Cooperation Agreement on Combating Piracy and Armed Robbery Against Ships in Asia (ReCAAP) [4]. As for information that is filtered then fused and analyzed with other data, the responsible site is the Information Fusion Centre (IFC) operated by the Singapore Navy established in 2009 [5]. Judging from the names of these three centers (reporting, sharing, fusion), we are able to identify their main functional differences and their respective roles in constituting the MDA system in Southeast Asia. The following is an introduction to the main operating modes of these three centers.

I. IMB Piracy Reporting Centre (PRC)

PRC is an information center established by the International Maritime Bureau under the International Chamber of Commerce in response to the first contemporary wave of pirates in the South China Sea and the Strait of Malacca in the 1980s. Since the International Chamber of Commerce is a non-governmental organization, PRC itself is also a non-governmental organization in terms of legal status, and has observer status in the International Maritime Organization. The main purpose of establishing PRC is to raise awareness of specific high piracy risk maritime domains, ports or anchorages in the shipping industry, and to convey relevant information to local law enforcement agencies to ensure that the captain can obtain assistance when necessary. Under this premise, subjects with whom PRC shares information include the International Maritime Organization, government or intergovernmental law enforcement agencies and the shipping industry.

Regarding the scope of piracy information covered by the PRC, it does not distinguish whether the information falls within the definition of piracy in Article 101 of the United Nations Convention on the Law of the Sea (that is, it does not distinguish between piracy and armed robbery at sea), nor does it distinguish whether such acts occurred in high seas. More importantly, the scope of geographic information covered by the piracy incidents reported by the PRC include piracy incidents in the global waters. Before 2007, PRC would publish a report on piracy incidents each year, supplemented by a quarterly report. Since 2007, real-time live reports and maps of piracy incidents (Figure 1) and a 24-hour maritime security hotline have been set up on the PRC website.

From the above brief description, we can see that the primary purpose of PRC is to inform and share information about various piracy incidents in real time, so that governments or the shipping industry can quickly respond. Therefore, in terms of the various non-traditional security prevention aspects that contemporary MDA focuses on, PRC plays a relatively minor role [6].

Figure 1/ The real-time pirate distribution map on the Piracy Reporting Centre website
Source/ https://www.icc-ccs.org/index.php/piracy-reporting-centre/live-piracy-map

II. ReCAAP Information Sharing Centre (ISC)

ISC itself is a formal international organization composed of 20 contracting states. Aside from the ISC established under the ReCAAP Agreement, ReCAAP is also fitted with a governing council responsible for directing the daily operations of the ISC and contacting national focal points. At present, in addition to the 20 contracting states, there are also 8 partner organizations. The funding source of this organization is mainly provided by the Singapore government, while other countries provide human resources. As for the main purpose of the establishment of ISC, the primary goal is to promote and strengthen the combat and prevention of piracy and armed robbery in Asia by various countries. Therefore, ISC distinguishes whether a specific event belongs to piracy under the Convention on the Law of the Sea or not.

Generally speaking, in order to achieve the above-mentioned organizational purpose, ISC's primary tasks can be divided into three parts: 1. Collection, verification and dissemination of information; 2. Data analysis and research; 3. Staff training, education and awareness raising. To achieve these three tasks, the ReCAAP Agreement has stipulated that each country must set up focal points, establish event databases, and utilize network-based information sharing software. ISC's information collection sources are mainly provided by the focal points in various countries, or provided by other units (such as the aforementioned PRC), and the International Maritime Organization, etc. (Diagram of the ReCAAP ISC's focal point notification procedure. Retrieved from https://www.recaap.org/piracy_definitions_and_actions). Once the information is collected by ISC, it will be further verified by the focal points in various countries, and then shared through the network of relevant organizations, and consolidated into monthly and annual reports. Because the ISC network has the ability to verify and analyze data, it will further divide individual incidents into four levels based on the degree of economic loss and violence (the first category encompasses incidents of the greatest severity; the fourth category encompasses incidents of the least severity).

Compared with the aforementioned PRC, ISC's information sharing is not completely conducted in real-time, and the goal of its information sharing is not to allow governments to quickly respond, therefore the function of ISC is limited. A scholar once mentioned that because ISC collects information from focal points in various countries, the nature of its operation is highly dependent on the intentions of various governments. However, the successful operation of ISC and the accumulation of mutual trust between countries culminated in favorable conditions for the further establishment of IFC in 2009 [6].

III. Information Fusion Centre (IFC)

The purpose of the IFC is to promote and collaborate in strengthening the sharing of maritime security information in Southeast Asia. The marine security information covered by this center includes not just information on pirate hotspots in Southeast Asia (South China Sea, Malacca), but also other issues such as weapon proliferation, marine terrorism, arms and drug smuggling, or fishing crimes. In addition, although it is a regional MDA in Southeast Asia, the scope of the center includes waters as far as southern Africa, the Indian Ocean, and part of the Western Pacific (IFC VCR Area: https://www.ifc.org.sg/ifc2web/app_pages/User/common/aboutvcr.cshtml#tab4). The legal basis for the operation of IFC is composed of a series of bilateral agreements or memorandums signed between the Singapore government and different countries as well as agreements signed with other centers.

At present, IFC has a total of 24 participating foreign countries, and IFC itself has signed agreements with 97 information centers. Participating countries send liaison officers to be stationed the center in Singapore to keep in constant touch with the 24-hour command office. As emphasized by IFC itself, the main factors for the success of IFC's information integration are the international liaison officer system and information technology. The liaison officer system not only serves to facilitate coordination between multilateral naval headquarters, but also ensures that real-time information is shared face-to-face on a daily basis when incidents occur. The information technology utilized by IFC is mainly based on the information of the Automatic Identification System and system for Long Range Identification and Tracking of Ships, while the Open and Analyzed Shipping Information System (OASIS), a software developed in collaboration with the Singapore government, identifies different marine security incidents. In addition to OASIS, IFC also has a system referred to as Sense-Making, Analysis and Research (SMART) that enables users to customize rules for connecting different "points" into a "surface" to construct a trend of potential threats to marine security.

As IFC has a liaison officer system that allows countries to gather in Singapore, even though some countries are distrustful of each other politically, substantial cooperation can be achieved with Singapore as the intermediary country [6]. In addition, due to Singapore's own talents and abilities, it has been able to develop a fairly advanced information system, and when a potential threat or marine security incident occurs, the marine security departments of the relevant countries can be contacted to take specific action based on the judgment of the information system. Therefore, trust between countries is a key factor for the success of IFC.

Conclusion

From the foregoing description, we can see that the success of the MDA system in Southeast Asia is to a certain degree enlightening for other countries or regions. In particular, if Taiwan intends to take part in relevant systems, the country itself must have the corresponding organizations and capabilities when establishing the MDA system. First of all, as information related to maritime security is scattered across different locations within a country, the MDA system must be formulated based on the concept of a network, whether domestically or transnationally. In other words, each country itself must have infrastructure and laws and regulations that can link all such information. Furthermore, after various information is linked to become a network, information hubs must also be established so that specific information can be stored in specific units. Lastly, the experience of establishing an MDA system in Southeast Asia also tells us that it may be necessary, from a cost perspective, to "with moderation" allow different MDA centers to cover information in overlapping areas.

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The Importance of Desalination in Singapore's Water Supply Strategy

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Keywords: desalination, national taps, emerging water sources, climate change, water resources, Singapore

With the rapid growth of the global population, traditional water resources development often encountered with problems such as good sites for dam hard-to-find and hydrological uncertainties due to climate change, resulting in development difficulties. Due to its short construction time and being non-weather dependent, desalination has become an important emerging water resource in all countries. At the end of the typhoon season in 2020, Taiwan has suffered a tough problem of low precipitation since no typhoon have entered. Major reservoirs such as Feitsui Reservoir, Shimen Reservoir, and Zengwen Reservoir have not even reached half of their designed storage capacity. The way Singapore uses seawater desalination technology to enrich water supply and meet the domestic and industrial water demand is indeed an important reference for Taiwan's water resources development policy.

Figure 1/ Singapore opened Marine East Desalination Plant in 2020 (the plant is under its rooftop park)
Image by Keppel Infrastructure

Traditional water resources often encountered with various problems such as hydrological uncertainty, rapid population growth, rapid increase in domestic and industrial water demand, insufficient drought resistance of water storage facilities, and reduced water supply due to water quality degradation. With the rapid increase in water demand, countries around the world have searched for emerging water resources. Seawater desalination has the advantages of short construction time, flexibility of expansion in capacity, and providing stable and clean water that it has become an important emerging water resource in various countries. Singapore is an island state surrounded by the sea. Due to its small land area and limited water resources in the local catchment, it has long been extremely dependent on the imported water from Malaysia. Since the water supply from utilizing desalination technology is stable, it is also not affected by uncertain hydrological conditions such as drought, and uneven precipitation distribution. Hence, using desalination to increase water supply has the advantage of inexhaustible seawater.

Early History of Water Resources Development in Singapore

During the British colonial period in Singapore, the British built the MacRitchie Reservoir in 1866 to provide water resources. In 1927, Singapore signed a water purchase agreement with the neighboring Johor of the Unfederated Malay States. It allowed Singapore to rent land and use water in Johor, and then import raw water and use it after filtration treatment. After the Japanese invasion of Malaya in 1942, the Battle of Singapore broke out. When the British troops retreated, they blew up the Johor-Singapore Causeway and destroyed the water pipeline to Singapore, making Singapore's reserved water only last for two weeks [1]. After the World War II, Singapore's population grew rapidly and demanded more water for urban development. The water resources imported from Malaysia became more important. After Singapore became an independent state in 1965, its water resources have long relied on imported water from Malaysia. If Singapore's foreign policy conflicts with Malaysia's interests, Malaysia can threat to cut off Johor's water supply, which has prompted strong motivation for Singapore to further develop its own water resources. Singapore established PUB, Singapore's National Water Agency, as a result. While importing water from Malaysia, it is also actively carrying out more water resources development plans in its own territory [2]. Due to the abundant precipitation in Singapore, about 2,200 mm per year, PUB built dams at the estuary to contain the freshwater in the early days, and built 17 reservoirs to store rainwater.

Four National Taps

In order to meet the water demand, Singapore has successively developed diversified and sustainable water resources. These water resources are called "Four National Taps", including [3][4]:

- Water resource from local catchment
- Malaysia imported water
- High-grade reclaimed water (NEWater)
- Desalination water

In the early days, Singapore had only the first two taps. Due to the small land area, water sources developed from the local catchment were limited as well. In 1962, a 100-year water purchase agreement was signed with Malaysia, stating that one million tons of water can be purchased from Malaysia every day. Since the contract will expire in 2061, the imported water is not a long-term solution for Singapore's water demand. Since the Singapore government hopes that water resources can be self-sufficient, it started a NEWater Study in 1998 to investigate if the treated reclaimed water can meet drinking water standards. In 2002, Singapore opened its first NEWater plant, and its water quality exceeded the World Health Organization (WHO) drinking water standards, thus signifying the

commencement of the third tap. After two years of monitoring to ensure the safety of water quality, a marketing campaign to open a NEWater Visitor Centre was also carried out. In 2005, Singapore's first desalination plant started to operate, marking the official opening of the fourth tap.

Singapore currently uses about 430 million gallons of water per day. According to PUB's prediction, total water demand is expected to almost double by 2060 [4], primarily due to demand from non-residential use. Through integrated water resource management, the Four National Taps overcome Singapore's long-term problem of lacking natural water resources and meet the water demand. In addition, with the active support of the government, Singapore has become a global hub of water research and technology.

Figure 2/ NEWater Vistor Centre
Image by Shaun Wong from Filckr (CC BY-NC-ND 2.0)
https://www.flickr.com/photos/shaunwong/2439666209/

Figure 3/ NEWater
Image by Tristan Schmurr from Filckr
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https://www.flickr.com/photos/kewl/6903183981/

Development of Seawater Desalination

As early as the 1970s, PUB began to conduct feasibility studies using seawater desalination technology to provide alternative water resources. However, due to the high cost of seawater desalination technology at that time, the research was not commercialized. Until the end of the 1990s, the continuous improvement of seawater desalination technology, especially the gradual popularization of reverse osmosis (RO) technology, greatly reduced production costs. It laid the foundation for the successful development of desalination plants in Singapore in the 2000s. The current commercial desalination plants in Singapore are shown in Table 1.

Table 1/ Current status of Singapore's desalination plant [4][5]

Name of Plant	Date of Commissioning	Operator
Singspring Desalination Plant	2005	Hyflux/Keppel
Tuas South Desalination Plant	2013	PUB
Tuas Desalination Plant	2018	PUB
Marina East Desalination Plant	2020	Keppel
Jurong Island Desalination Plant	Under construction	Tuas Power/Singapore Technologies Marine

Source/ https://www.water-technology.net/

Singapore's first desalination plant is the Singspring Desalination Plant, located in the Tuas Industrial Zone. It is the first time PUB has adopted a public-private partnership, employing a "design, build, own and operate" approach (DBOO) to grant private sector on developing infrastructure. In 2004, PUB awarded a contract to Hyflux for plant construction, which was completed in 2005 with a total capital investment of approximately NT$3.8 billion. The second Tuaspring Desalination Plant was built in 2011 and opened in 2013. It is currently the largest desalination plant in Asia. The plant itself is equipped with a combined-cycle power plant (CCPP) with a capacity of 411MW, which can provide reliable power source for the desalination process, and the excess power was sold to the Singapore National Grid. According to the water purchase agreement with PUB, the Tuaspring Desalination Plant should supply PUB with desalinated water for 25 years from 2013 to 2038. In 2019, PUB took over and renamed the plant as Tuas South Desalination Plant [4][5][6].

As the sea water quality near Tuas is stable and suitable for the development of desalination, the third Tuas Desalination Plant (Figure 4) is also located in the Tuas Industrial Zone, next to the first two plants. For the first time, the Tuas Desalination Plant uses advanced pre-treatment technology, including dissolved air floatation and ultrafiltration technology. Different from the first two desalination plants, the Tuas Desalination Plant was operated by PUB after its commission [4]. The fourth Marine East Desalination Plant, is the world's first dual-mode seawater desalination plant. It can treat fresh water from the estuary reservoir of the marine barrage during the wet season and desalinate seawater during the dry season. It is even less susceptible to the climate factors. The humanized design of Marine East Desalination Plant also includes a rooftop park on the desalination facility, which is open to the public for various activities [7].

Figure 4/ Tuas Desalination Plant
Image by Singapore's National Water Agency

Conclusion

Singapore was originally an extremely water-scarce country, and its natural conditions are more difficult than Taiwan. However, the Singapore government attaches great importance to the problem of water shortage. With the government's foresight and ambition, the Four National Tap policy has made Singapore from a water scarce country to a water technology powerhouse that can export recycled water and seawater desalination technology. In addition, there is no more water shortage problem for private industries in drought. Taiwan's industrial water demand is increasing year by year, but the development of traditional water resources is getting more difficult. Singapore's experience in using seawater desalination to enrich domestic water resources can be an important reference for Taiwan to diversify the planning of water resources.

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Overview of Singapore's Ocean Policy

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Translated by Linguitronics
Keywords: Singapore, ocean policy, fisheries, maritime safety, Law of the Sea

Singapore, with its unique geographical location, is an important maritime strategic hub and port in the world. It is the world's third largest oil refining center, international shipping center, international trade center and regional tourism center, also a necessary midway point on the trade route between major trading countries such as China, Japan, and Republic of Korea and the Middle East and European Union. This article introduces Singapore's maritime policies, including primarily the nation's fisheries administration, maritime security, and maritime law enforcement.

The Republic of Singapore is a city-state and island country, also referred to as Singapore, with a total of 63 islands large and small, and a largely gentle terrain. The main island, Singapore Island, accounts for more than 90% of the nation's total area Singapore's total area is approximately 724.4 square kilometers, its coastline is 193 kilometers, and 3 nautical miles of territorial waters and exclusive fishing zones. As such, it is a country whose economic development is highly dependent on the ocean. A portion of the country's territory is obtained via reclamation. The area of reclaimed land was 581.5 square kilometers in the 1960s, and it is estimated that by 2030, surface area will increase by another 100 square kilometers. According to the Population in Brief 2020 published by the National Population and Talent Division of the Prime Minister's Office of Singapore, the nation's total population has reached 5.69 million. Although small in area and population, the country is an important maritime strategic hub and port in the world due to its unique geographical location (at the intersection of the Straits of Malacca and Singapore, as shown in Figure 1). As the Strait of Malacca is the key to controlling sea and land traffic from and to Europe, Asia, and Australia, it is one of the most important shipping routes in the world, enabling Singapore to become one of the busiest seaports across the globe. The country is also the world's third largest oil refining center, international shipping center, international trade center and regional tourism center, also a necessary midway point on the trade route between major trading countries such as China, Japan, and Republic of Korea and the Middle East and Europe. With links to more than 600 ports in the world, statistics from 2012 to 2019 show that Singapore's container port ranks second in the world only after one other port, Shanghai.

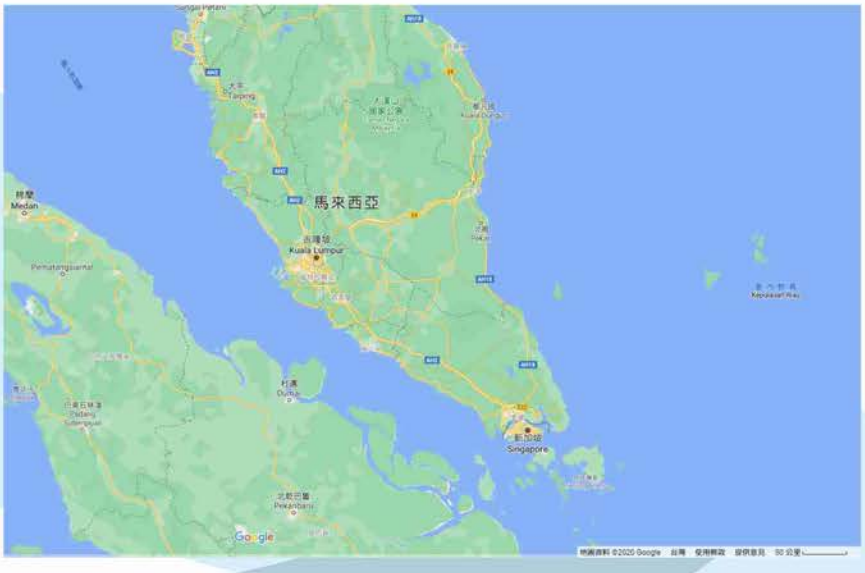

Figure 1/ Map showing location of the Straits of Malacca and Singapore
Source/ https://www.google.com.tw/maps/@1.2877667,103.8512191,15z

Fishery policy practices

Singapore's coastal marine ecosystem is very limited due to the profound impact of urban development and the port industry. As the port industry is one of the country's largest in terms of source of revenue, the port range has expanded to almost the entire territorial waters, and reclamation has spread throughout the southern and northeastern coasts of the main island (Figure 2). Due to the small size of the country, the lack of rich fishery resources near the coast, and the advanced development of the national economy, there is no advantage in developing ordinary fisheries, hence the number of fishermen in Singapore is significantly lower than other countries in Southeast Asia. Since Singapore's territorial waters are basically occupied by commercial ports and fishing ports, there are only two major fishing ports for marine fisheries, namely Jurong Fishery Port, the largest fish market, and Punggol Fishing Port. Fishery and its products are however an important source of animal protein for the local population, accounting for 30% of animal protein consumption. Singapore's fishery is mainly based on marine fishing, while the proportion of freshwater fisheries is limited with two thirds of marine catches coming from nearshore waters and one third from coastal waters.

Due to small land area and a highly developed economy, the development and utilization of coastal areas is also imperative as agricultural land with lower economic value has been repurposed for projects with higher economic benefits. Following the development of fish ponds into residential and commercial land, the space for coastal fishing and related fishery activities is becoming increasingly small, contributing to the decline of coastal fishery development in Singapore. However, Singapore has favorable climatic conditions, low risk of fish farming, and advantages in seedling and aquaculture. Coupled with a good infrastructure and well-developed logistics and transportation conditions, Singapore is able to play the role of a fishery re-export trader in ASEAN countries, making the country the world's largest ornamental fish exporter and a fishery transshipment center for the Southeast Asia region.

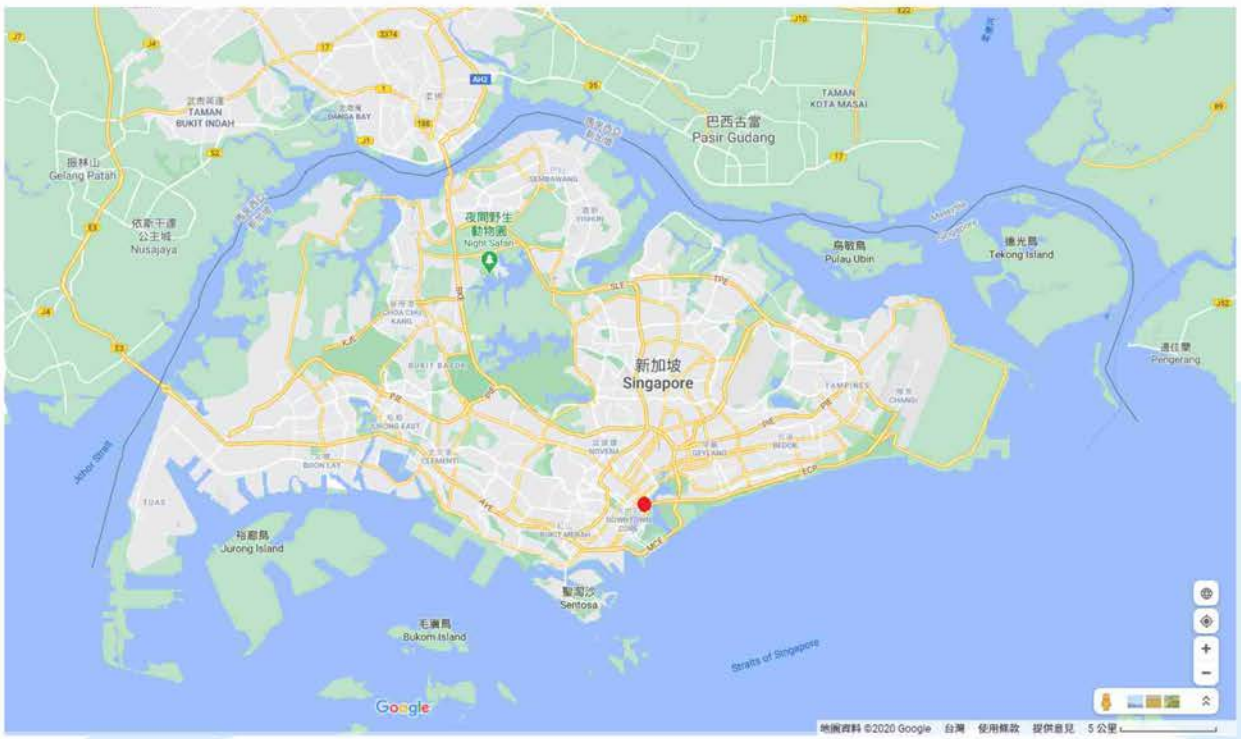

Figure 2/ Location of Marina Bay, Singapore (red dot)
Source/ https://www.google.com.tw/maps/@1.2877667,103.8512191,15z

Marine foreign and security policy

Although Singapore is not directly threatened by any other country, neighboring territorial waters have considerable influence on the country's national defense policy, primarily territory and maritime rights conflicts with neighboring countries. First, the country needs to emphasize its sense of independence to neighboring Malaysia and Indonesia. Since Singapore became independent from Malaysia in 1965, there have been tensions between the two countries on multiple occasions as territory and ocean delimitation disputes exist between Singapore, Malaysia, and Indonesia. Second, in order to cope with potential threats from neighboring countries in Southeast Asia, Singapore's diplomatic and defense agencies have established extensive bilateral and multilateral ties and cooperation networks. In 1990, it was also agreed that the United States would deploy troops in the country to ensure that ships of the US Seventh Fleet could smoothly pass through the Malacca Strait. After 2000, the country also dedicated considerable effort to strengthening its relations with the United States. With US Air Force and Navy units respectively visiting Singapore many times over the years, the country has gradually defined its stance and position in the South China Sea.

Singapore closely monitors the freedom of navigation and regional territorial disputes in the South China Sea. The country's fundamental stance in terms of its South China Sea policy is that conflicts must be resolved peacefully based on international law while supporting the Declaration on the Conduct of Parties in the South China Sea entered into by and between ASEAN member states and China. Singapore believes that the declaration is an important confidence measure for cooperation and stability among all parties in the South China Sea, and has also issued a position statement on the South China Sea issue at the ASEAN Regional Forum (ARF), the main points of which include: 1. Singapore has no claims for sovereign territories in the South China Sea, nor does it participate in disputes arising therefrom. However, as a major trading nation, any issues affecting the freedom of navigation in international waters are related to Singapore's key interests; 2. China should more clearly state its claims for sovereignty and maritime rights in the South China Sea, because vague claims often cause serious international concerns; 3. Singapore hopes that the countries in dispute can exercise restraint and create conditions conducive to the peaceful settlement of disputes in the South China Sea; 4. Singapore hopes that the disputing parties can sign and implement the South China Sea Code of Conduct as soon as possible.

Maritime safety practices

Southeast Asian countries generally face serious threats of piracy. After the Asian financial turmoil, the waters of Southeast Asia have become the most rampant waters for piracy in the world, one of the reasons being that most ASEAN countries have weak maritime security forces. Except for Singapore, Malaysia, and Vietnam, the majority of ASEAN countries have very limited maritime military power and outdated weapons and equipment. In addition, Southeast Asian countries have tortuous coastlines, and as disputes over the ownership of many sea areas still exist for countries along the coastline, it is difficult to effectively supervise all activity in these areas. In response to this issue, the Singapore government issued Defending Singapore in the 21st century and a strategy titled The Security Environment In The 21st Century, clearly proposing to expand its scope of military defense and play a greater role in regional affairs. As such, its main task is to resist threats from the sea, protect maritime communication lines, conduct maritime patrols, and combat piracy. There is no doubt that Singapore's navy now consists of the most outstanding naval personnel among Southeast Asian countries and possesses the most advanced maritime science and technology armed forces.

International Law of the Sea practices

Singapore is the latest country to become independent among Southeast Asian nations, therefore the history of development and practice of its Law of the Sea are not as complicated as that of other Southeast Asian countries. As Singapore is one of the world's international commercial port, trade and

financial centers, its practices of international Law of the Sea and policy stances are informed thereby. It advocates maintaining maximum freedom of navigation on the existing high seas for two major reasons: 1. The Strait of Malacca is vital to Singapore's free navigation, and 2. With territorial waters surrounded by Malaysia and Indonesia, Singapore's stance in terms of the Law of the Sea is that of a geographically disadvantaged country; the small island country has very restricted maritime space, and the expansion of maritime jurisdiction appears to have limited possibility. For these reasons, what is of utmost importance for Singapore is that all countries maintain narrow territorial waters and that any form of extending national maritime jurisdiction to the high seas is not approved.

The official position stated by the country in 1968 was that it did not have any national plans and legislative arrangements related to the research and development of natural resources on the seabed, sea level and subsoil, or oil drilling and exploration and seabed mining. By openly acknowledging its geographical disadvantages and pursuing other goals instead, Singapore has evolved into a world economic and trade center. The position that Singapore has taken in favor of complete freedom of navigation on international waterways is commendable for many countries that use the strait. Because Singapore is a coastal state on an international maritime lifeline (the Strait of Malacca), its position has been affirmed by most representatives of ASEAN nations. These representatives are also happy under certain circumstances to support Singapore's position as a geographically disadvantaged country. Since the United Nations Convention on the Law of the Sea recognizes that 12 nautical miles of territorial waters and 200 nautical miles of exclusive economic waters have become part of customary international law, the Minister of Foreign Affairs of Singapore issued a statement on September 15, 1980 announcing that Singapore will expand its territorial waters to 12 nautical miles and obtain an exclusive economic zone in accordance with international practices. As Singapore is a geographically disadvantaged country in the Southeast Asia region, in theory, it is unequipped to establish its own 200-nautical-mile exclusive economic zone. According to the delimitation principle of international law, negotiating with countries to reach a consensus on a 200 nautical mile exclusive economic zone will likely prove to be futile for this country. Therefore, Singapore did not propose to delineate the maximum boundary of its exclusive economic zone, but merely requested the sharing of certain benefits from the development of resources in this area.

Maritime law enforcement agency

Singapore's maritime law enforcement is performed primarily by agency, mainly the Police Coast Guard (PCG) or Marine Police Force, which is subordinate to the Singapore Police Force (SPF) of the Ministry of Home Affairs and is a level 4 agency that has undergone changes and restructuring along with the history and development of the country's police organization. PCG is a law enforcement unit of the SPF that performs maritime missions, undertaking typical coastal defense missions. Its tasks include law enforcement in Singapore's sovereign waters, and maritime search and rescue in collaboration with the Maritime and Port Authority of Singapore (MPA) and the Immigration and Checkpoints Authority (ICA). After Singapore became a trading port in 1819, its waters were infringed by pirates over the course of many years. It was not until 1840 when Singapore publicly supported Britain's anti-piracy activities that circumstances improved. In 1866, the police began to perform water duties, establishing a mobile police station in the meantime with patrol boats patrolling the waters. It was not until 1924, however, that the unit became an independent functional agency and was renamed the Coast Guard. On February 13, 1993, the Marine Division was restructured and reorganized into the Police Coast Guard (PCG), giving maritime law enforcement greater powers, including preventing the entry of illegal immigrants at sea, preventing the entry of illegal foreign ships, and guarding of the Horsburgh Lighthouse on the disputed island of Pedra Branca. PCG also performs maritime border control and anti-terrorism tasks. After 9/11, the Singapore government began to attach importance to the prevention of maritime terrorism, designating Changi Naval Base as the headquarters for leading anti-terrorism missions at sea and reinforcing inspections of ships, especially passenger liners returning from abroad. Since 2004, PCG personnel have strengthened anti-terrorism training and refined various

professional skills and equipment necessary for exercising their duties. The country's law enforcement team is responsible for an increasing number of maritime management tasks, and the subordinate PCG has also been entrusted with the responsibility of comprehensive law enforcement due to its efficient law enforcement capabilities.

In addition, to regulate maritime and port operations, Singapore has promulgated the Maritime and Port Authority of Singapore Act, designating the Maritime and Port Authority of Singapore (MPA) as the responsible agency. Singapore is currently the only country outside of Hamburg that serves as a venue for the International Tribunal for the Law of the Sea for resolving maritime disputes. The country furthermore enacted the Fisheries Act (Fisheries Act 1996) to protect and conserve fishery resources, the Prevention of Pollution of the Sea Act (The Prevention of Pollution of the Sea Act) to prevent marine pollution as well as other marine-related laws. The purpose of the latter is to prevent marine pollution, whether the source is land pollution or ship pollution, while also giving the MPA the power to take preventive measures to prevent pollution, including denying entry or detaining ships.

Even though Singapore seeks to resolve disputes through various political and foreign policy approaches, the country has nevertheless established a strong navy and protects maritime security through a modernized defense industry. In the early 21st century, Singapore also played a strategically important role in Southeast Asia, remaining committed to maintaining a delicate balance between military power building and international cooperation. In 2019, Singapore and China furthermore formally signed an agreement on defense exchanges and security cooperation. In light of this new relationship, although the Starlight Project, a long-term collaboration between Taiwan and Singapore, continues to operate as usual, as training of Singaporean troops in Taiwan has been suspended due to the epidemic, subsequent developments and changes will require continuous monitoring and attention.

Figure 3/ Singapore Police Coast Guard Patrol Boat Images by Investigation Branch Special Service Company, CGA, OAC

Figure 4/ Singapore Police Coast Guard Training Center
Images by Investigation Branch Special Service Company, CGA, OAC

Artificial Algal Forest: A New Opportunity for the Development of Ocean Farming

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Translated by Linguitronics
Keywords: Marine environment, cultivation, artificial algal forest, Ocean farm, Genus Sargassum

In recent years, the marine ecosystem has been under great pressure due to issues such as human activities, habitat destruction, pollution, invasive alien species and climate change. Without adequate management and proper protection mechanisms, many species will be on the verge of extinction; some species have already become extinct, and ecosystems are becoming imbalanced. These issues will, directly or indirectly, have an impact on human development and survival. Therefore, if we want to achieve sustainable biodiversity, we need to protect it by implementing a variety of strategies, including conservation, rehabilitation, sustainable use of resource, education and research, etc. Among these, rehabilitation works include the cultivation of species and habitat improvement or restoration. One of the ways to rehabilitate habitats is by introducing artificial algal forest.

Feeding green sea turtles with Sargassum
Image by Marine Ecology and Conservation Research Center, National Academy of Marine Research

Importance of Seaweed

In general, seaweed refers to the macroalgae that grow in the ocean. They did not have roots, stems or leaves because their inner structure lacks vascular tissue; therefore, they mainly rely on root-like attachments at the base to help them cling to reef rocks in the intertidal and subtidal zones. Currently, Taiwan have been recorded about 600 macroalgae species on the coast, which can be classified into four groups: Cyanophyta, Chlorophyta, Ochrophyta and Rhodophyta. Seaweeds play a crucial and fundamental role in the ecosystem. They not only produce oxygen, provide food, purify water, and help

calcium carbonate ($CaCO_3$) be deposited into coral reefs, but also the seaweed forest they create can provide marine life with a place to live, forage, reproduce and shelter. In addition, the nitrogenous waste excreted by marine life and residual bait, among other sediments, provide ample nutrients for algal forest. Furthermore, seaweeds can carry out photosynthesis and carbon dioxide fixation, which optimizes the seabed environment and increases fishery resources. The purpose of the construction of artificial algal forest through artificial or semi-artificial methods is mainly to repair or rebuild an ecosystem. Additionally, planting techniques are used to create algal beds, so they can gradually form natural algal forest in the wild, and to take advantage of the multifaceted functions that algal forest provide to gradually replenish the ocean resources.

The Benefits of Developing Ocean Farms Through Artificial Algal Forest

There is currently no consensus on the definition of ocean farms in academic or industrial circles in Taiwan or overseas. A broad definition would be that a ocean farm is a defined sea area with a laissez-faire management system and a systematic and adequate approach to the rehabilitation and release of local marine resources. More specifically, a marine farm can be defined as a designated sea area or an environment protected by a natural barrier where local native species are cultivated in a planned manner; in these areas, marine organisms cultivated using artificial seedling technology are released (kept) to create a leisure and sightseeing ecological ocean farm compound. Currently, there are already several successful cases in Taiwan. For example, the Agriculture and Fisheries Bureau of Penghu County Government used artificially cultivated Sargassum spp. on bricks to create artificial algal beds in the local Wukan protected area, which provided sufficient food sources for the sea urchin larvae, increasing their survival rate. The Penghu Marine Biology Research Center from the Fisheries Research Institute, Council of Agriculture used artificially grown Sargassum spp. in ropes to make an artificial algal bed of 240 square meters at the local sea area in Hongluo village. In this area, 50 thousand swimming crab larvae were released. The abundant food resources found on the algal bed provided them with enough sustenance to improve the effectiveness of their release. Therefore, the use of Sargassum in the development of ocean farms not only increases marine resources along the coast, but also provides the following benefits:

I. Aquacultural and Ecological Value

Ocean farms can be to establish a basis of economical seaweeds culture technology and to conduct research or develop indoor mass production methods, as well as to provide food sources for marine organisms or raw materials for enhancing fishery resources. In addition, artificial algal forest planted in the wild can supply places for other marine life to grow, forage, reproduce, and shelter; they can also produce oxygen and purify the marine environment.

II. Environmental Protection Value

Ocean farms can improve the ocean's ecosystem, purify the marine environment, and absorb ammonia and heavy metal ions in the ocean. Furthermore, the nitrogenous waste excreted by marine life and residual bait, among other sediments, can allow algae to fully absorb nutrients, carry out photosynthesis, and carbon dioxide fixation. As a result, it can optimize the seabed environment. In addition, marine farms can serve as a natural biological filter for the treatment of wastewater and water quality improvement, which has a high potential for development.

III. Value for the Marine Tourism Industry

Underutilized fishing ports can be redesigned into cultivation demonstration centers, and floating box net platforms can be installed for planting native species of artificial algal forest, thereby creating a natural sightseeing park. Additionally, an underwater sightseeing route can be created to allow visitors to experience the feeling of traveling through an algal forest while observing different types of marine life living in these environments e.g., fish, crabs, and sea urchins.

IV. Value in Terms of Raw Materials

Seaweed can be made into food or industrial raw material sources (e.g., Sargassum can made fresh Sargassum, dry Sargassum powder). Moreover, coastal residents frequently use it to feed terrestrial livestock (chickens, pigs, cows, sheep), aquatic livestock (fish, etc.), or as a source of fertilizer or plant food for vegetables.

V. Value in Terms of Health and Biotechnology Beauty Products

Algae is high in protein and carbohydrates, low in fat, rich in minerals and other elements such as iodine, potassium, mannitol, and algin. Therefore, it has great potential to be applied in the health care and food chemistry industries. In the future, health products such as drinks (fucoidan), capsules (oligofucoidan), and probiotics can be developed, as well as biotechnology beauty products like cosmetics (shampoo, shower gel, soap), skin care products (facial masks), etc.

VI. Nutrition Value

Nowadays, genus Pyropia, Gracilaria, and the recently developed Caulerpa lentillifera are the most commonly consumed types of seaweed in Taiwan. Additionally, other edible products can be researched and developed such as Sargassum salt, raw salads (pickled vegetables), alcohol, tea bags, drinks, yogurt, egg rolls, ice cream and steamed buns.

Establishment of Artificial Algal Forest

Restoration or reconstruction of field algal forest by using artificial or semi-artificial planting techniques. Moreover, artificial algal forest formed in the wild can gradually restore marine resources.

Taiwanese Regions and Seaweed Species Suitable for the Development of Artificial Algal forest

Taiwan is surrounded by the ocean; it is an island country that sits at the Coral Triangle—the world's richest marine life hot-spot—with coral reefs also known as the "tropical rainforest of the sea". Thus, Taiwan enjoys abundant marine resources. On the east coast, the Kuroshio Current flows past Taiwan. On the west coast, the Kuroshio Branch Current, the waters of the South China Sea and the Chinese Coastal Current meet each other in the Taiwan Strait, thus forming excellent fishing grounds. In line with the international trend of reducing global greenhouse gas emissions, and to achieve the vision of a Nuclear-Free Homeland. Therefore, the government has actively promoted the green energy policy of offshore wind farms and has carried out large-scale development of offshore wind farms on the west coast of Taiwan. However, the development of offshore wind farms may affect the functions and biological composition of the original fishing grounds, as well as the local fishery activities and revenue. Therefore, artificial algae farms can be built to try to improve or restore habitats, and to reduce the negative impacts of development on the marine ecosystem. According to the Pingtung County Government Summary Report of 2016 (Final Report of Commissioned Service Works [Including the Following Expansion] of Coastal Ocean Space Utilization Planning in Pingtung County), in order to integrate the sustainable development of local fishing villages, and promote the restoration of fishery resources and the rehabilitation of fishing grounds, not only should we focus on building offshore wind farms, but should also prioritize the planning of the three ocean farms in Liuqiu Township, Fangshan Township and Checheng Township. Therefore, the algae farms can also be used to increase coastal resources to achieve the sustainable management of fishery resources.

When choosing a species of algae, the main consideration should be whether it can adapt to the local environment; for example, whether or not it is compatible with the ecosystem's physical and chemical

factors such as light intensity, water temperature, salinity, and nutrients in the seawater. It is also necessary to contemplate how difficult the easy to cultivate and whether or not it can effectively provide a living environment for organisms. Of course, the best choice is to use native local species of algae! Interestingly, the results of on-site investigation showed that Sargassum has all the above-mentioned characteristics, and it is also a native local species; therefore, the National Academy of Marine Research has begun the development of artificial algae bed cultivation technology using local Sargassum. In the future, this technology will be used to expand the restoration of Sargassum in the southwestern waters of Taiwan, and to build a Sargassum marine farm to increase the marine resources along the coast, thereby achieving the goal of sustainable bioresources. The following is a basic overview of Sargassum:

Sargassum is a genus belonging to the family Sargassaceae, order Fucales, Class Phaeophyceae, phylum Ochrophyta, about 539 species recorded in the world. They mainly grow in warm ocean waters around the world. Some species can grow to up to 2-3 meters. Currently, a total of 13 Sargassum species are found in Taiwan waters (including outlying islands), which are common in the region. Sargassum is often mistakenly referred to as "seaweed", but it is actually a group of multi-celled macroalgae that lack roots and instead have holdfast. It is a type of non-vascular algae that does not bloom, bear fruits, or produce seeds. In terms of external morphology, in addition to holdfast, they consist of 5 different parts: stipe, frond, air bladders, and receptacles. They should not be confused with plants, which are organisms with a very different structure.

Production of Sargassum Seedlings and Cultivation Technologies

Sargassum is dioecious, meaning the female gamete and male gamete are released separately; the ovum is fertilized externally by the sperm to produce a zygote, which then forms a new sporophyte seedling. Sargassum can reproduce vegetatively and sexually. In the former, the algae's holdfast has the ability to regenerate and to reproduce vegetatively under suitable conditions and grow new seedlings; in the latter, oogamy occurs during the reproductive season producing fertilized eggs. This is the primary method of producing a large number of seedlings. At present, most of the research on the production and cultivation technology of Sargassum seedlings has been conducted in Taiwan (including Penghu), China, Japan and Republic of Korea. The life cycle of Sargassum is more complicated than other algae, therefore researchers need years to carry out the proper research, improvements and testing. Currently, artificial seedlings can be attached to ropes or reef rocks and be stably stored and grown until the point where they cannot easily detach, then they can be transferred to the sample area for deployment. This shows that significant breakthroughs have been made in artificial cultivation technology. The site for cultivating Sargassum not only requires a large storage space, but also a source of natural, easily accessible seawater, with an appropriate temperature (25-30°C), and sufficient sunlight (over 10,000 Lux). Cultivation works can start once the site has been established. The process is as follows:

I. Harvesting of Wild Sargassum

The growing season of Sargassum is from about October to May of the following year, and it mostly disappears from the wild from June to September. Therefore, in addition to harvesting the algae during the right season, it must be harvested and brought back for storage during the low tide at the intertidal zone.

II. Artificial Fertilization

When the Sargassum breeding season comes, mature algae are harvested in the wild. The artificial shading method is used to stimulate for 2 hours, so that the female and male reproductive receptacles are pressed simultaneously. After putting it in the water artificially, the eggs and sperm will be discharged at the same time for in vitro fertilization.

III. Artificial Techniques for Picking and Attaching Seedlings

Put the fertilized eggs discharged from the female reproductive nursery into a plastic container. The fertilized eggs are collected by artificial strong shaking at the source of seedlings. Then filter the algae fragments with a sieve to obtain seedlings, and attach the seedlings with a brush. Immediately brush attached to the surface of the hollow brick or rope as a substrate for seedling attachment.

IV. Sargassum Seedlings Growth

After the mature female and male Sargassum receptacles are stimulated, they release the ovum and sperm, which fertilize externally to form a zygote. Embryos develop within 24 hours after fertilization; within 48 hours they grow holdfast, to later develop into sprouts, also known as algae seedlings. In conclusion, the life cycle of Sargassum can be divided into 4 stages: seedling, growing, reproduction, and decline, in that order.

Future Challenges and Management

As the previously mentioned examples show, developing marine farms through the implementation of artificial algae farms can bring a lot of benefits, but they can also come with a variety of challenges. For example, algae farms built in the wild may be eaten by algae-eating fish e.g., rabbit fish, small scale black fish, or scorpionfish. These can negatively impact the effectiveness of the artificial algal bed. Therefore, in order to cope with algae-eating fish, local native species of algae with a higher degree of toughness (e.g., Sargassum ilicifolium) can be planted. Another way to combat this issue is to ensure that the artificially cultivated algae have grown to a certain size and density before being transferred into the wild to reduce its chances of being eaten.

In terms of aquaculture, large-scale breeding of a single species may cause diseases or a large amount of deaths due to a limited genetic gene pool, making the species unable to adapt to drastic environmental changes; or a foreign species might be chosen to be cultivated, which may compete or hybridize with the local native species, leading to the replacement of the latter, or even cause an invasive alien species problem. Therefore, if a cultivation center is established locally, it will effectively reduce the problem of native species not adapting to the local environment. In addition, it will make it easier to collect fresh wild algae nearby for breeding, thereby enriching the gene pool and increase seedling's breeding rate.

Additionally, Sargassum is seen as "marine debris." This mostly refers to "devil weed" (Sargassum horneri), which is also part of the family Sargassaceae. This species of warm-temperate algae is unique to the west coasts of the Pacific Ocean; it prefers low temperature environments, and during spring, following the cold water mass, it floats to central and northern Taiwan as well as the coast of Penghu. Unfortunately, a large amount of garbage and dead pufferfish become intertwined in the "devil weed" that washes up on Taiwan's shores, piling up on the coastline and causing trouble and harm. Therefore, when a large mass of "devil weed" washes up on the intertidal zone, it not only needs to be cleared out and disposed of, but also some of it should be released back into the ocean after decomposition, thereby reincorporating it into the ocean food chain's nutrient cycle. Besides, these natural resources can have practical uses in aquaculture, health products, and biomass energy. Consequently, it is essential in artificial algae farms to have an accurate understanding of algae reproduction and Sargassum's growth cycle, to carry out early harvesting in order to reduce the chances of it detaching, or to set up rope interception points to prevent it from floating into the shore. Fishermen can also assist in harvesting, and store algae as frozen vegetables or process it into animal feed or fertilizer to reduce the problem of marine debris.

The National Academy of Marine Research plans to use Sargassum as one of the ways to rehabilitate marine habitats; in the future, they will build algal beds using a variety of methods (e.g., algae attached to bricks or ropes) for different types of habitats, and will simultaneously release economical aquatic animals to create a marine farm with sustainable ecological resources, thus enabling industrial development that benefits all parties.

Maritime Legislation and Delimitation - Practice of Singapore

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Keywords: Maritime Delimitation, Singapore, Territorial Sea, United Nations Convention on the Law of the Sea, Maritime Legislation, Case Concerning Sovereignty over Pedra Branca/Pulau Batu Puteh, Middle Rocks and South Ledge

Singapore's practice regarding law of the sea and maritime delimitation is heavily influenced by the development of the law of the sea at the international level, as well as colonial-era laws and agreements. In addition to announcing maritime claims pursuant to the United Nations Convention on the Law of the Sea and recognizing the Territorial Waters Jurisdiction Act of 1878 enacted by the United Kingdom, Singapore has striven to pursue national interests and resolve maritime disputes with neighboring States. Its efforts in this regard can also be of reference to other States facing similar challenges.

Introduction: Overview of Singapore's Maritime Laws and Regulations

Prior to the adoption of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), Singapore actively participated in the Third United Nations Conference on the Law of the Sea. It paid special attention to issues such as straits used for international navigation and the rights of landlocked and geographic disadvantaged States. Upon the UNCLOS's open for signature, Singapore signed the Convention and ratified it, along with the Agreement relating to the implementation of Part XI of the UNCLOS, on November 17, 1994. Under Singapore's domestic law, the executive branch has the right to conclude treaties with other States, and its Constitution does not require parliamentary approval before submitting instruments of ratification to depositaries. However, treaties to which Singapore is a party would not have domestic legal status unless the parliament adopts legislation to that effect. Thus, rules concerning maritime zones in the UNCLOS do not automatically become domestic rules in Singapore. A survey of existing maritime laws and regulations in Singapore would reveal that the parliament has not adopted any legislation for the purpose of maritime spatial planning or delimitation of maritime zones.

Current maritime laws and regulations generally focus on ports and vessels flying Singaporean flags. Such laws include Maritime and Port Authority of Singapore Act, Prevention of Pollution of the Sea Act, Merchant Shipping (Civil Liability and Compensation for Oil Pollution) Act, and Merchant Shipping (Civil Liability and Compensation for Bunker Oil Pollution) Act. The Maritime and Port Authority is tasked with adopting subsidiary legislation within the scope authorized by the aforementioned laws [1]. In terms of law enforcement, the Police Coast Guard is in charge in the territorial sea, and the Singapore Armed Forces, led by the Minister of Foreign Affairs, are mandated to enforce laws outside of its territorial sea.

Singapore's Territorial Sea Regime and the Territorial Waters Jurisdiction Act

As previously stated, Singapore has not adopted laws on maritime zones. Yet, regarding the width of territorial sea, Singapore's practice via diplomatic channels can provide guidance. During the Third United Nations Conference on the Law of the Sea, Singapore noticed a few important trends of development, including the recognition of 12-n.m. territorial sea and 200-n.m. exclusive economic zone, and the transit passage in straits used for international navigation. On September 15, 1980, Singapore's Ministry of Foreign Affairs issued a press release, proclaiming that Singapore had adopted a 3-n.m. territorial sea since 1878, and "in the light of the said international developments, Singapore will exercise its rights to extend its territorial sea limit up to a maximum of 12 nautical miles [2]." The same

statement also stipulated that if Singapore and its neighboring States have overlapping maritime claims, Singapore would be "negotiate with these countries with a view to arriving at an agreed delimitation in accordance with international law".

In Singapore's submissions to the International Court of Justice after it and Malaysia brought the Case Concerning Sovereignty over Pedra Branca/Pulau Batu Puteh, Middle Rocks and South Ledge to the Court, it reaffirmed its claims concerning the territorial sea. It should also be noted that after the revision of port limits in 2010, the waters outside Singapore's mainland fall largely within the port limits or the traffic separation scheme. The remaining territorial sea is limited in scope [3].

In addition to the maritime laws concerning ports and vessels flying Singaporean flags, the 1878 Territorial Waters Jurisdiction Act remains in force. The Act does not designate the width of territorial sea, it only adopted the term "a certain distance of the Coast" to identify the scope of application of the Act, which is aimed at providing jurisdictional basis for offences which took place with that scope. The provisions include the scope of jurisdiction, restrictions of jurisdiction, procedural matters and exceptional clauses, such as in the case of piracy. Under this Act, all individuals, regardless of nationality, committing the offences are subjected to Singapore's jurisdiction, but jurisdiction over foreign nationals may be restricted under the terms of the Act.

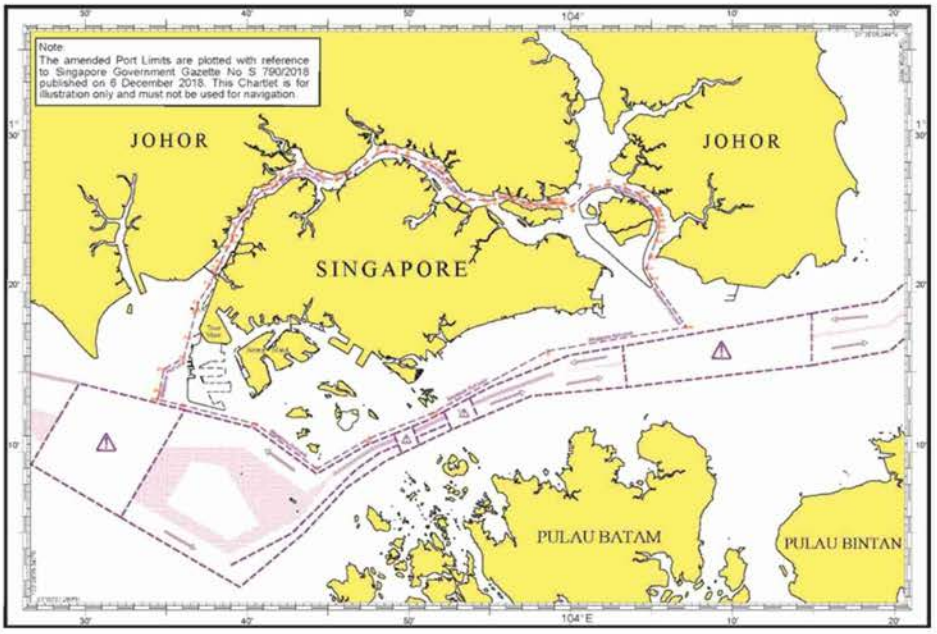

Figure 1/ Singapore's Port Limits (as revised in 2018)
Source/ Singapore's Maritime and Port Authority [4]

Singapore's Practice Regarding Maritime Delimitation

While the domestic law of Singapore does not provide rules concerning the outer limits of maritime zones, in its 1980 statement, the Ministry of Foreign Affairs emphasized its commitment to negotiations. In this regard, Singapore's practice can be observed in its negotiations with Indonesia and Malaysia and the resulting agreements.

Singapore and Indonesia has undergone multiple rounds of negotiation in order to determine the delimitation of the two States' territorial Seas. In 1973, the Treaty between the Republic of Indonesia and the Republic of Singapore relating to the Delimitation of the Territorial Seas of the Two Countries in the Strait of Singapore was concluded. Six points were designated in the 1973 Treaty, and the straight lines connecting the points formed the maritime boundary between the two States. Among the six points, three are equidistant from the baselines of Singapore and Indonesia, and the other three are closer to

Indonesia. Thus the line has been dubbed as "modified equidistance line" [5]. The 1973 Treaty provided solution to only part of the overlapping claims. Therefore, further negotiations between Singapore and Indonesia were needed, and for part of the disputes, Malaysia should also be brought in the negotiation considering the latter's proximity and maritime claims. Singapore's land reclamation activities also brought uncertainties to the agreement reached with Indonesia. Fortunately, both States took the position that such activities would not affect the boundary drawn by the 1973 Treaty. In the following years, the two States concluded delimitation agreements in 2009 and 2014 respectively, and these efforts contributed to a more stable legal order in the Strait of Singapore and clarified the jurisdictional lines for each State.

Figure 2/ Maritime Boundary as Designated by Treaties between Singapore and Indonesia
Source/ Annex B of the 2014 Treaty between the Republic of Singapore and the Republic of Indonesia relating to the Delimitation of the Territorial Seas of the Two Countries in the Eastern Part of the Strait of Singapore

Delimitation talks between Singapore and Malaysia began before the two States' declaration of independence. In 1927, the Straits Settlements and Johore Territorial Waters Agreement was concluded, and it designated "an imaginary line following the center of the deep-water channel in the Johore Strait" as the boundary between the two sides. Such an "imaginary line" lacks the specificity necessary for delimitation. Thus, Singapore and Malaysia began joint hydrographic surveys in 1980 to determine the location of the "deep-water channel" in the Johore Strait. On that basis a treaty was concluded in 1995 to identify the coordinates of 72 points used to draw the boundary. The delimitation of waters surrounding Pedra Branca/Pulau Batu Puteh was not addressed in this Treaty due to its location and sovereignty disputes. In 2008, the International Court of Justice finds that Pedra Branca/Pulau Batu Puteh belongs to Singapore; Middle Rocks belongs to Malaysia and the sovereignty of South Ledge depends on whose territorial sea it is located in. On the basis of the Court's judgment, the two States established a Joint Technical Committee, which oversees their joint survey and prepared materials for delimitation negotiations. The survey was completed in 2013, and under the auspice of the Committee, the efforts continued, and it has been decided in January 2020 that a Sub-Committee on Maritime Boundary Delimitation would commence negotiation [6].

Conclusion

Taking into consideration Singapore's participation in the Third United Nations Conference on the Law of the Sea and its subsequent practice, it can be clearly observed that Singapore pays close attention to the development of the law of the sea. Although it has not adopted legislation or other official acts to comprehensively clarified its claims regarding the width and scope of maritime zones, it nevertheless enacted other maritime laws and regulations to ensure navigation safety and port control. As for disputes with neighboring States regarding overlapping maritime claims, it utilizes diplomatic and legal tools to resolve the differences. Its methodology and attitudes toward issues concerning the law of the sea and international disputes can be of reference to other States facing similar situations and challenges.

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