我國中西太平洋與印度洋之丫髻鮫科無危害評估



農業部漁業署

2026 年 7 月

中　華　民　國　1　1　5　年　7　月

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一、前言

丫髻鮫科（Sphyrnidae）物種因其獨特頭部形態與高階掠食者之生態角色，長期在海洋食物網中扮演關鍵功能，對於調節中小型魚類與頭足類族群結構、維繫生態系穩定具有重要意義。然而，多數丫髻鮫物種具備成長速率緩慢、性成熟晚、繁殖力低及壽命長等 K 型生活史特性，使其對漁業捕撈壓力高度敏感，一旦族群量下降，恢復所需時間往往極為漫長。

近數十年來，隨著全球魚翅與鯊魚相關產品需求增加，丫髻鮫類在遠洋延繩釣與圍網漁業中頻繁成為混獲物種，其族群狀態亦受到國際社會高度關注。根據國際評估結果，丫髻鮫科多數物種已被列為 IUCN 受脅等級，且其族群量在多個洋區呈現明顯下降趨勢。為因應此一情勢，瀕危野生動植物國際貿易公約（CITES）已將丫髻鮫科多數物種納入附錄二管理，要求出口國於進行國際貿易前，必須完成「無危害評估」（Non-detriment Findings, NDF），以確認貿易行為不致對野外族群造成不利影響。

在區域性漁業管理層面，中西太平洋與印度洋多個區域性漁業管理組織（RFMOs）亦已針對丫髻鮫類採取禁止留艙、強制釋放及漁獲回報等管理措施，顯示丫髻鮫已逐漸由傳統混獲物種，轉為需專門管理與監測之高風險資源。然而，由於丫髻鮫分布範圍廣泛、跨越多個管轄海域，加上不同洋區之漁業型態、捕撈強度與管理措施存在差異，使得其族群狀態與風險程度呈現高度區域性，

亟需以各洋區進行系統性評估。

臺灣為全球重要遠洋漁業國家，遠洋鮪延繩釣漁業在中西太平洋與印度洋作業期間，仍可能混獲多種 CITES 附錄二之丫髻鮫科物種。在兼顧國際貿易責任、漁業管理合規與資源永續利用之前提下，建立具科學依據且符合國際規範之無危害評估，已成為我國漁政管理的重要基礎工作。

鑒於此，本報告以中西太平洋與印度洋丫髻鮫科物種為評估對象，整合國內外族群、生物學、漁業利用、國際貿易與管理措施等相關資料，依循 CITES 與既有 NDF 指引架構，系統性評估其貿易利用對野外族群可能造成之風險，期能提供我國執行丫髻鮫科物種無危害評估與後續管理決策之科學依據。

二、文獻回顧

(一)丫髻鮫科之資源與管理概況

臺灣周邊曾有三種丫髻鮫之捕獲紀錄，其主要分布範圍位於南北緯55度之間的沿近海域，依據過去漁業研究與統計資料顯示，臺灣於周邊海域皆可漁獲此三種，其中以紅肉丫髻鮫漁獲產量相對較高，丫髻鮫（*S. zygaena*)次之，八鰭丫髻鮫（*S. mokarran*）之漁獲紀錄則相對較少（Liu, 2002）。紅肉丫髻鮫具有高度洄游性，多棲息在溫暖的海域和熱帶沿近海，分佈範圍從水表到潮間帶至水深至少275公尺深的海域，幼魚與亞成魚以沿近海海域為棲息地，該物種具有季

節性洄游及群游行為（Compagno et al., 2005；Fowler et al., 2005）。1989年臺灣東部紅肉丫髻鮫年漁獲量約為500噸，2003年起紅肉丫髻鮫漁獲量從525噸持續下降至2013年最低的195噸，近幾年則介於200-300噸間。

IUCN 鯊魚專家群以生命地球指數（Living Planet Index, LPI）及 IUCN 紅色名錄（Red List）指數針對全球半世紀以來31種表層鯊魚及魟進行資源變動評估，蒐集目前最完整的生物學及漁業相關文獻及資料，同時也參考過去區域性漁業組織（RFMOs）進行資源評估的結果，進行分析，結果發表於權威的期刊 Nature。此研究結果顯示自1970年以來，由於漁獲壓力增加了18倍，這些表層鯊魚及魟資源減少了71%，且3/4的指標性物種有滅絕風險（Pacoureau et al., 2021）。2018年 IUCN 鯊魚專家小組針對表層鯊魚與魟鰩之保育等級再次進行評估，將全球紅肉丫髻鮫由易危（Vulnerable, VU）提升至極危（Critically Endangered, CR）等級（Rigby et al., 2019d），而丫髻鮫則由易危提升至瀕危（Endangered, EN）等級（Rigby et al., 2019a），顯示該物種過去10年資源狀況在某些海域有明顯惡化情形。

瀕危野生動植物國際貿易公約（Convention on International Trade in Endangered Species of Wild Flora and Fauna, CITES）於2013年將紅肉丫髻鮫、丫髻鮫與八鰭丫髻鮫列入附錄二（Appendix II）名錄。而經濟物種被列入附錄二之物種並非不能進行貿易，而是需要提出該物種之「無危害評估（Non-

detriment Findings, NDF）」，無危害評估係透過科學評估，該物種的出口不會危害到該物種野生族群的資源狀況，才能發出許可出口貿易之證明。如果物種漁獲海域超過200海浬經濟海域，還須提出「從海洋引進規定（Introduction from the sea, IFS）」類似產證之文件。

紅肉丫髻鮫及丫髻鮫的成熟雌魚會在臺灣周邊沿岸海域（特別是西部）產仔，這些幼魚會遭到沿近海多種魚法捕/混獲，而較大體型（>150 cm 全長）的魚則會被宜蘭南方澳及臺東成功新港的延繩釣或流刺網所漁獲。因此，為了確保丫髻鮫類資源的永續利用，其資源調查及 NDF 評估之研究刻不容緩。

國內紅肉丫髻鮫之研究，過去有 Chen et al.（1988）針對西北太平洋紅肉丫髻鮫進行生殖研究，出生體長（L_b）為48.5 cm，50%性成熟體長（L_m）為230 cm TL，產仔數（f）平均為25.8尾，生殖週期（R_c）為2年。Chen et al.（1990）針對西北太平洋紅肉丫髻鮫進行年齡成長研究，雄魚之極限體長（L_∞）為320.6 cm TL、成長係數（k）為0.222 $year^{-1}$、體長為零時之理論年齡（t_0）為-0.75 year，雌魚之極限體長為319.7 cm TL、k 為0.249 $year^{-1}$、t_0為-0.41 year，性成熟年齡（t_{mat}）為4.7年，最大年齡（T_m）為15歲。Liu （2002）針對西北太平洋丫髻鮫進行生殖研究，出生體長（L_b）為55 cm，50%性成熟體長（L_m）為259.4 cm TL，產仔數（f）平均為30尾，生殖週期（R_c）為2年。Chou （2004）針對臺灣東北海域丫髻鮫進行年齡成長研究，雄魚之極限體長（L_∞）為358.8 cm TL、成長係

數（k）為0.128 $year^{-1}$、體長為零時之理論年齡（t_0）為-0.72 year，雌魚之極限體長為375.2 cm TL、k 為0.111 year-1、t_0為-1.31 year，性成熟年齡（t_{mat}）為11 year。

劉光明等（2013）利用年級群解析法進行紅肉丫髻鮫及丫髻鮫資源量與漁獲死亡率之估算，其結果顯示紅肉丫髻鮫之資源量從1989年開始即呈現下滑之趨勢。單位加入親魚量之結果則指出紅肉丫髻鮫除1991-1995年間，2000-2002年間與2008年 SPR 之95%信賴區間有涵蓋 SPR=0.4之生物參考點外，其他10個年度之 SPR 均低於0.4，且有6個年度低於0.3。因此，建議應減少其漁獲量，並且針對已成熟之個體進行保護。丫髻鮫之結果則顯示其資源狀態應屬良好，所有年度 SPR 的95%信賴區間皆高於0.3的生物參考點，且有13個年度高於0.3的生物參考點，然其 SPR 在近年來有下降之趨勢，需要持續監控其資源狀況。Tsai et al.（2018）使用 YPR 和 SPR 來估計西北太平洋丫髻鮫的生物學參考點（BRP）和族群狀況。YPR 結果顯示，當前捕撈死亡率（Fcur），雄性低於 F0.1的 BRP，但高於雌性的 $F_{0.1}$。此外，SPR 分析的結果表明，當前的 SPR （SPRcur）大大低於目標參考點（SPR35%）和閾值參考點（SPR30%）。這一發現表明，在目前的捕撈水平下，西北太平洋雌性丫髻鮫被過度開發。建議應不斷監測丫髻鮫的族群狀況，以確保其可持續發展。

Liu et al.（2015）以族群統計法估計的結果，在無漁獲的狀況下，紅肉丫

髻鮫的族群內部成長率（λ）為1.275，族群變為兩倍的時間為2.9 year，世代間隔為7.1 year。丫髻鮫的族群內部成長率（λ）為1.166，族群變為兩倍的時間為4.5 year，世代間隔為15.6 year。

Liu et al.（2021）針對我國11種表層鯊魚進行生態風險評估，係利用族群內部增加率法估算生產力指標，以及利用釣獲率百分比、選擇性與捕獲後死亡率估算敏感性指標進行分析，最後再與魚種瀕危狀態、漁獲體型變化趨勢與族群成長曲線反趨點，將這四項進行整合式生態風險評估，紅肉丫髻鮫屬於風險最高之群組。因紅肉丫髻鮫具有生命週期長、性成熟晚、體型大之生活史特性，雖然產仔數量相對其他大型鯊魚物種較多，但生殖週期長。因此，西北太平洋紅肉丫髻鮫無法忍受長期針對低齡魚進行高度開發，一但資源量下降，將非常難以復原，實行資源評估與漁業管理刻不容緩（Liu and Chen, 1999）。

劉（2015）提出我國無危害評估之步驟流程，並完成紅肉丫髻鮫之無危害評估，但是紅肉丫髻鮫資源狀態呈現下滑及過漁之趨勢。因此，目前針對紅肉丫髻鮫並不應核發無危害證明文件，即不應准許出口。朱（2020）針對我國丫髻鮫進行無危害評估，其結果顯示為「有條件之 NDF」，即必須進行管理並要滿足某些新的條件後，才得以給予正面 NDF。

因應丫髻鮫類已被 CITES 列入附錄二名錄與 IUCN 保育等級為極危及瀕危等級，以及我國仍未對丫髻鮫類提出相關管理措施。因此，本研究將嘗試針對

我國沿近海捕獲之丫髻鮫類進行資料調查與進行無危害評估，提出我國丫髻鮫類管理措施與建議供行政單位參考。

(二)無危害評估(NDF)發展概況

無危害評估（Non-Detriment Findings, NDF）是《瀕臨絕種野生動植物國際貿易公約》（Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES）對附錄物種實施國際貿易前，締約國管理機關必須完成的核心程序，其目的在於評估該物種之貿易不會對其野外族群存續造成負面影響。換言之，僅有在科學證據支持出口不致危害族群狀況的前提下，方可核發出口許可。

為協助各國建立標準化且具一致性的評估作業，德國聯邦自然保育署（Federal Agency for Nature Conservation, BfN）於 2014 年邀集 14 國鯊魚保育學者及漁業管理專家，制定《鯊魚 NDF 指導綱領手冊》（Mundy-Taylor et al., 2014），提出六大步驟的評估流程與一套可操作之指標架構，成為多國發展鯊魚 NDF 制度的重要參考藍本（Mundy-Taylor, 2014）。其後，各締約國亦陸續發展自身之 NDF 評估指引。例如，日本於 2016 年發布無危害風險評估指引；斯里蘭卡則依 Mundy-Taylor et al.,（2014）指引，於 2017 年完成平滑白眼鮫及三種丫髻鮫之 NDF 評估，結果為「有條件 NDF」，並設定兩年有效期限（Abernethy, 2017；Pierce, 2017）。澳洲則針對紅肉丫髻鮫、八鰭丫髻鮫、丫髻鮫、鼠鯊及污

斑白眼鮫等五種大型鯊魚執行 NDF 分析，提出具體漁業管理建議（Australian Government, 2014）。紐西蘭亦針對專屬經濟區（EEZ）內之灰鯖鮫完成 NDF 評估，以確認其出口之合法性與可持續性；印度則針對 CITES 附錄二所列之丫髻鮫、污斑白眼鮫、平滑白眼鮫與兩種蝠魟建立 NDF 程序（Zacharia et al., 2017；Kizhakudan et al., 2019），顯示 NDF 已逐漸成為鯊魚國際貿易管理的重要工具。

臺灣方面，早期即參考德國與澳洲之評估架構，針對西北太平洋紅肉丫髻鮫、丫髻鮫、深海狐鮫及灰鯖鮫等物種進行 NDF 評估，結果顯示除灰鯖鮫外，其餘物種族群狀態均不理想（劉，2015, 2016, 2017, 2019）。2018 年，國際野生動植物貿易調查會（TRAFFIC）與德國 BfN 共同建立電子化無危害評估（electronic NDF, e-NDF）系統，將原有步驟與指標轉化為系統化流程與預設計算公式，使用者僅需輸入必要數據，即可得出相對應之風險評估與 NDF 判定（正面、負面或附帶條件），大幅提升 NDF 實務操作的透明度與一致性。

臺灣近年亦已運用 e-NDF 架構進行多項評估。張（2016）針對太平洋紅肉丫髻鮫、朱（2020）針對太平洋丫髻鮫進行 e-NDF 評估，並指出我國在資料蒐集、監測制度及管理配套上仍有待強化。劉（2022a, 2022b）則綜整前述成果，修訂臺灣鯊魚 NDF 步驟，迄今已完成西北太平洋紅肉丫髻鮫、丫髻鮫、深海狐鮫、平滑白眼鮫及灰鯖鮫等物種之評估作業。印度洋部分，蔡（2019）、張（2022）與黃（2024）亦完成 NDF 研究，結果顯示平滑白眼鮫及灰鯖鮫通常為

「有條件 NDF」，鋸峰齒鮫則可給予正面 NDF。整體而言，各項 NDF 研究已成為臺灣漁政單位審核物種貿易出口的重要科學依據，亦具體指出未來管理需加強之面向。

在此脈絡下，本計畫將蒐集與分析國內外相關資料，以建構我國於不同洋區漁業中之重要貿易管制鯊種之無危害評估（NDF）流程與方法。資料來源包括國內外學術論文與期刊、政府官方資訊、出版品、研討會資料及相關產業網站，內容涵蓋各評估物種之生活史參數、族群資源量、國際貿易現況及管理措施概況等。此外，亦將參考德國、澳洲、日本、斯里蘭卡、印度及紐西蘭等國科學機關與管理單位對 CITES 附錄二鯊魚物種實施 NDF 之程序與評估結果，分析其評估指標與管理作法，並彙整我國過去於不同海域執行鯊魚物種 NDF 之研究成果，作為本研究制定漁業重要貿易管制鯊種 NDF 架構與提出後續管理建議之基礎。

三、研究目的

無危害評估（Non-detriment Findings, NDF）於國際間仍屬相對新興之管理工具，其制度化與實務執行尚在持續發展階段，目前僅有少數國家陸續建立實際執行案例。丫髻鮫科物種為中西太平洋與印度洋遠洋鮪延繩釣漁業中常見之混獲鯊魚類群，且多數物種已因族群風險與國際貿易壓力，被列入《瀕臨絕種

野生動植物國際貿易公約》（CITES）附錄二，需於出口前完成無危害評估，以確保其貿易行為不致危害野外族群資源。

鑒於丫髻鮫科物種分布廣泛、跨洋區作業頻繁，且不同洋區之漁業型態與管理措施存在差異，有必要針對主要作業洋區進行分區評估。因此，本計畫將依據臺灣既有鯊魚無危害評估之步驟與架構，針對我國鮪延繩釣漁船於中西太平洋與印度洋作業期間混獲之丫髻鮫科物種，進行系統性無危害風險評估，並綜整評估結果提出具體管理與政策建議，作為我國後續執行丫髻鮫科物種 NDF 審查與管理措施調整之參考依據。

四、電子化無危害評估(e-NDF)判定法

第一步驟：初步資訊蒐集

此步驟為評估前的事前準備，需蒐集物種基本初步資料並加以彙整，以確認物種是否需要進行 NDF 評估以辦理出口。評估對象須為 CITES 附錄二名單物種，且來源需為合法取得。接續蒐集區域漁業管理組織（RFMOs）之資料，確認該物種是否屬於規範內之禁捕鯊種；若在禁捕名單內，即無需繼續進行 NDF 判定，評估隨即停止；若符合上述條件，則該物種將進入後續步驟進行評估。

第二步驟：既有的生物易危性及保育關注程度

此步驟包含兩部分：

2.1. 既有的生物易危性

評估物種於開發利用後，是否因其生物特性而造成資源難以恢復，指標共11項：成熟年齡（t_{mat}）、成熟體長（L_m）、最大年齡（T_m）、極限體長（TL_∞）、自然死亡率（M）、產仔數（f）、族群內在增加率（r）、地理分布範圍、資源評估、行為因素、營養位階。各指標之判定標準及分數依原表格規範，最終將各項分數加總，總分11–17分為低風險，18–26分為中風險，27–33分為高風險，風險程度越高，表示物種資源因開發利用而難以恢復之風險越大。

「既有的生物易危性」之各項判定標準如下:

(1)成熟年齡(t_{mat})

如成熟年齡小於5歲代表風險程度低，獲得分數1分；介於5歲至15歲代表風險程度中，獲得分數2分；大於15歲代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(2)成熟體長(L_m)

如成熟體長小於40公分代表風險程度低，獲得分數1分；介於40公分至200公分代表風險程度中，獲得分數2分；大於200公分，代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(3)最大年齡(T_m)

如最大年齡小於10歲代表風險程度低，獲得分數1分；介於10歲至25歲代表風險程度中，獲得分數2分；大於25歲代表風險程度高，獲得分數3分；若缺乏

此項數據代表風險程度未知，獲得分數3分。

(4)極限體長(TL_∞)

如極限體長小於100公分代表風險程度低，獲得分數1分；介於100公分至300公分代表風險程度中，獲得分數2分；大於300公分代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(5)自然死亡率(M)

如自然死亡率 M 值大於0.4代表風險程度低，獲得分數1分；介於0.17至0.4代表風險程度中，獲得分數2分；小於0.17代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(6)產仔數(f)

如產仔數f值大於15代表風險程度低，獲得分數1分；介於2至15代表風險程度中，獲得分數2分；小於2代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(7)族群內在增加率(r)

如族群內在增加率r值大於0.35代表風險程度低，獲得分數1分；介於0.15至0.35代表風險程度中，獲得分數2分；小於0.15代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(8)地理分布範圍

如物種資源分布於全球性的範圍代表風險程度低，獲得分數1分；分布於區

域性的範圍代表風險程度中，獲得分數2分；分布於國家性的範圍代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(9)資源評估

如物種資源評估 F<=F_{MSY} 且 B>=B_{MSY} 代表風險程度低，獲得分數1分；F=F_{MSY} 且 B=B_{MSY} 代表風險程度中，獲得分數2分；F>=F_{MSY} 且 B<=B_{MSY} 代表風險程度高，獲得分數3分。

(10)行為因素

此項目所指之「行為因素」係指與物種生態與行為特性相關，且可能影響其被漁業捕捉機率、存活率或族群恢復能力之行為層面特徵（例如群聚行為、垂直或水平洄游習性、對漁具的接觸傾向等），並非泛指所有生物學特性。如物種少數行為因素會增加系群風險代表風險程度低，獲得分數1分；部分行為因素會增加系群風險代表風險程度中，獲得分數2分；多數行為因素會增加系群風險代表風險程度高，獲得分數3分；若缺乏足夠行為相關資料者：其風險程度視為未知，基於審慎原則，給予 3 分。此分級方式可反映不同物種因行為特性所導致之相對風險差異，並符合 CITES NDF 在資料有限情況下採取保守評估的基本原則。

(11) 營養位階

如物種位於營養位階底層代表風險程度低，獲得分數1分；位於營養位階中

間代表風險程度中，獲得分數2分；位於營養位階頂層代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

2.2. 保育關注程度

進一步針對保護關鍵因子進行評估，包括：保護與資源評估情況、族群趨勢、受保育關注之區域範圍。各指標依原表格判定，總分3–4分為低風險，5–7分為中風險，8–9分為高風險。理論上，物種若生物易危性高，亦會有較高之保育關注，尤其多數鯊魚具K選擇生活史，族群對捕撈影響極為敏感。

「保育關注程度」之各項判定標準如下:

(1)保育與資源評估的情況

若該物種資源沒有過漁且目前被 IUCN 列為無危（LC）等級，代表風險程度低，獲得分數1分；若物種資源正處於過漁狀態或已經過漁，且目前被 IUCN 列為近危（NT）等級、易危（VU）等級，代表風險程度中，獲得分數2分；若物種資源正處於過漁狀態且已經過漁，且目前被 IUCN 列為瀕危（EN）等級、極危（CR）等級，代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(2)族群趨勢

若物種族群呈現上升趨勢代表風險程度低，可得分數1分；若物種族群呈現穩定趨勢代表風險程度中，可得分數2分；若物種族群呈現下降趨勢代表風險程

度高，可得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(3)受保育關注的區域範圍

評估的重點在於判斷該洋區所承受的主要威脅，是否可能影響該物種整體族群狀態或其重要的繁殖、補充與遷移過程。若物種面臨的主要威脅僅會影響少數系群代表風險程度低，獲得分數1分；若物種面臨的主要威脅會影響部分系群代表風險程度中，獲得分數2分；若物種面臨的主要威脅會影響全球系群代表風險程度高，獲得分數3分；若系群結構尚未明確釐清之前，則依循 CITES NDF 所採取之審慎原則，將此類威脅視為具有潛在的跨區域影響代表風險程度未知，獲得分數3分。

第三步驟：物種承受之壓力(以漁業壓力評估為主)

IUCN 全球鯊魚紅皮書評估（Global Shark Red List Assessment）指出，漁業死亡（包含目標性捕撈與混獲）是導致鯊魚族群衰退的最大單一原因，而且國際貿易推動了此死亡量中的相當大部分。因此，步驟三著重於漁業開發對鯊魚族群的影響，因為在進行 CITES 非危害性判定（NDF）時，漁業造成的死亡是必須納入的核心因素。

然而，本步驟的前半部分（3.1）也會考量貿易動態，因為貿易會推動漁撈行為，並為理解後續（3.2）所評估之漁撈壓力提供重要背景。在缺乏漁業依賴或漁業獨立資料時，貿易資料也可作為評估漁撈壓力嚴重度的替代指標。

相較於漁業開發，其他對鯊魚的威脅，如棲地喪失及破壞、污染、食物來源減少與氣候變遷等通常僅對其狀態造成次要影響。因此，第三步驟不會特別討論這些威脅。然而，若某一族群確實受到這些威脅影響，則在判斷是否應給予正面或負面 NDF 時，應考量是否需要採取較高程度的預警。

3.1評估評估貿易壓力（Evaluate trade pressures）

貿易活動可能對物種的存續造成重大不利影響，主要因其會提高漁撈壓力與不具永續性的捕撈率，進而增加族群總死亡量，此亦為 CITES 所關注的核心威脅之一。科學管理機關可透過掌握合法與非法貿易（包含國內與國際）之規模與變動趨勢，據以辨識並評估其對族群造成的影響。

貿易動態分析有助於理解漁撈壓力的形成與開發模式；在缺乏漁業資料時，相關貿易資訊亦可作為替代依據。然而，本步驟的最終目的仍在於評估整體漁業死亡量，相關內容將於步驟 3.2 詳述。

儘管步驟 3.2將檢視所有捕撈活動（不論產品最終流向國內或國際市場）對族群的影響，但比較國際與國內貿易（包含合法與非法）對族群所造成的相對壓力仍具必要性。若某些鯊魚產品於國際市場具有高經濟價值，該需求可能促使捕撈量上升，尤其是在管理不足的族群中（Lack et al., 2014）。此外，較高的國際價格亦可能增加產品被「洗白」後流入合法貿易體系的風險。

本節依 CITES 指引將貿易壓力區分為兩大因子：

(a) 合法貿易規模（Magnitude of legal trade）：

包含交易量相較物種豐度極小、貿易量或市場需求下降、市場無產品短缺情形，代表風險程度低，獲得1分。交易量相較物種豐度為中等、貿易量或需求穩定或緩步增加等，代表風險程度中級，獲得2分。物種具多重商業用途，涉及多類產品與市場、貿易量相較物種豐度或利用部位偏高、貿易量快速上升，或因資源有限而下降、產品價格高或快速上升，市場出現短缺，以及缺乏足夠資訊以評估等，代表風險程度高，獲得3分。

(b) 非法貿易規模（Magnitude of illegal trade）：

此評估項目顯示，我國現行貨品號列（CCC Code）之設置具高度重要性。透過細分至物種層級之貨品列號，可有效提升特定物種於合法貿易申報與統計資料中的辨識度與精確性，對於貿易管理具有實質助益。然而，非法貿易行為之追蹤多仰賴查緝、司法或執法案件等資訊來源，受限於資料可得性與案件揭露特性，較難全面反映實際流通情形（'t Sas-Rolfes et al., 2019；UNODC, 2024）。未來若能逐步結合風險導向查核機制、跨國貿易資料比對、物種鑑別技術，以及執法資訊之整合運用，將有助於降低評估過程中的不確定性，並強化相關分析基礎。儘管非法貿易仍可能透過未申報、錯報、轉運或其他規避手段而未被納入官方貿易統計，並可能因跨國轉口行為或各國申報制度差異，導致貿易流向與實際來源之落差，進而增加非法貿易規模判讀上的不確定性，惟出口貨品

號列之建立，對於強化貿易管理機制與遏止非法貿易行為，仍具有正面且重要之制度性意義。

國內與國際貿易紀錄完整、貿易鏈透明、相似物種替代疑慮低、捕撈量與合法國內交易量及申報出口量相符，均表示風險程度低，獲得1分。貿易紀錄部分完整、貿易鏈追蹤困難、存在相似物種替代疑慮、捕撈量與合法申報量之間存在不一致疑慮，代表風險程度中整，獲得2分。有非法貿易紀錄、貿易紀錄不足或品質不佳、貿易鏈不透明、相似物種替代風險甚高、合法出口量顯著低於進口國回報量等資訊，則代表風險程度高，獲得3分。而受到評估所可取得資料之性質與限制，缺乏足夠資訊以評估，則代表風險程度未知，即採保守評估，獲得3分。

3.2評估物種所承受之漁業壓力

包括漁獲死亡率、丟棄活存率、漁具選擇性、IUU 漁業規模等四項指標。由於臺灣近年才設立丫髻鮫、狐鮫等鯊魚專屬貨品分類號列（CCC Code），目前難以獲得詳細貿易輸出量與交易價格資料以評估貿易壓力，故本研究將貿易壓力列為日後管理建議之參考，第三步驟先以「漁業壓力」評估為主。各指標依原表格判定，總分4–6分為低度壓力，7–9分為中度壓力，10–12分為高度壓力。

「物種承受之壓力」之各項判定標準如下:

(1)漁獲死亡率

若漁業行為減少低比例的族群資源，代表風險程度低，獲得分數1分；若漁業行為減少部分比例的族群資源，代表風險程度中，獲得分數2分；若漁業行為減少高比例的族群資源，代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(2)丟棄活存率

若對於物種少數漁獲被丟棄，且其釋放後存活率偏高，代表風險程度低，獲得分數1分；若對於物種部分漁獲被丟棄，且其釋放後存活率中等，代表風險程度中，獲得分數2分；若對於物種多數漁獲被丟棄，且其釋放後存活率偏低，代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

(3)漁具的選擇性

若漁具具高度選擇性，能有效針對特定年齡、體型或性別之個體進行捕撈，表示其對族群結構的干擾相對較小，風險程度較低，評分為1分。若漁具有中度選擇性，雖對部分族群結構具有限制性捕撈能力，仍可能對族群造成中等程度影響，風險程度屬中等，評分為2分。若漁具選擇性低，無法有效區分或排除特定年齡、體型或性別之個體，可能對族群結構造成較大衝擊，風險程度較高，評分為3分。若缺乏相關資料以評估漁具選擇性，則風險程度視為未知，亦評分為3分以反映潛在不確定性。

(4)IUU 漁業規模

若對於物種有詳細的貿易紀錄，交易鏈透明公開，貿易量與漁獲量大致相符，代表風險程度低，獲得分數1分；若對於物種有適當的貿易紀錄，交易鏈難以追蹤，貿易量與漁獲量部分相符，代表風險程度中，獲得分數2分；若對於物種的貿易紀錄不齊全，交易鏈不透明公開，貿易量與漁獲量差異甚大，代表風險程度高，獲得分數3分；若缺乏此項數據代表風險程度未知，獲得分數3分。

第四步驟：評估現有管理措施

此步驟旨在確認 CITES 附錄二物種是否具備適當管理措施以降低利用風險並達到永續目標。本步驟旨在確認目前已對該物種族群實施的各項管理措施，內容可能來自國家、區域或國際層級，並分為兩大類：

(1)一般性漁業管理措施(Generic fisheries management measures)：

此類措施並非專門針對特定物種，但可能對其族群帶來一定益處。例如：漁業准入限制（limited entry）、其他魚種的捕撈量或漁撈努力量管控、對特定物種群的規範（如割鰭禁令、鯊魚全連體上岸規範）、漁具使用限制（如禁止特定網具）等，雖然不是專門為該物種設計，但仍可能間接降低捕撈壓力。

(2) 物種專屬管理措施 (Species-specific management measures) ：

此類措施是直接針對所評估的物種設計，例如：該物種的專屬捕撈額度（catch quota）；該物種目標漁業的努力量管控；為保護其特定生命史階段而設

置的區域性禁漁區；某些區域性漁業管理組織（RFBs）也會禁止保留特定非目標鯊魚物種，並要求若發生混獲，須立即、安全地放回海中，以提高其存活率（Lack et al., 2014）。

本步驟評估現行管理措施在「設計」與「執行」兩方面是否足以減緩影響目標物種族群的漁撈與貿易壓力。至於這些措施是否實際有效，則於問題 4.1(b) 進一步評估。

(a) 管理設計：

為判斷管理措施是否「設計得當」，需將於第 4 步前置階段整理的「一般性管理措施」及「物種專屬管理措施」，與第 3 步辨識出的漁撈與貿易壓力相互比對，對既有管理措施評估是那些可減輕哪些漁撈或貿易壓力？例如：某措施是否能降低混獲壓力，進而保護本物種？此處主要評估「措施類型」是否適當；至於是否符合理科學建議，則在問題 4.1(b) 評估其有效性時再行討論。

(b) 管理執行：

這部分需評估監測、控制與監測（Material Control System，MCS）制度是否足以確保管理措施的落實與遵循。MCS 是確保漁業管理政策、計畫與策略得以執行的重要機制，也是管理制度不可或缺的基礎。對於前述所有管理措施（管理設計部分），需判斷：有哪些 MCS 措施能確保其執行與遵循？

若物種之生物易危性、保育關注程度與漁業壓力風險越高，則需更嚴格之

管理措施以減緩衝擊。為了系統性評估既有管理措施對族群所面臨之壓力的實際緩解效果，本研究建構一套以風險為導向的評分架構，將各項管理工具依其可減輕壓力的直接性與強度，區分為「低風險（1 分）」、「中風險（2 分）」與「高風險（3 分）」三個等級。整體原則為：管理措施越能直接與有效地限制捕撈或減少死亡率，其風險越低；措施愈間接或執行依賴度高，則風險相對中等；若完全缺乏相關管理措施，則視為高風險。

在捕撈壓力方面，能直接限制族群總捕撈量的 TAC／ITQ 等配額制度被視為最低風險（1 分），因其可明確設定可接受的捕撈上限。努力量管制、有限准入制度與漁獲資料蒐集等措施雖能調控漁撈能力或支持後續管理，但其效果較為間接，因此列為中風險（2 分）。若在該壓力來源下欠缺管理措施，則評為高風險（3 分）。

丟棄死亡率的管理中，採用混獲減緩措施及安全放流規範、放流後存活率研究等，可直接降低被釋回個體的死亡風險，因此屬低風險（1 分）。觀察員或電子監測制度、卸港查核與生物抽樣雖能提升資料品質並提供死亡率估計，但無法直接減少死亡率，因此屬中風險（2 分）。若無相關措施，則評為高風險（3 分）。

在體長、年齡與性別選擇性的管理上，最小可捕體長限制、網目尺寸規範，以及針對幼魚或產卵場的空間／時間封閉，可直接保護特定生命史階段，故屬

低風險（1 分）。作業深度或區域限制等間接影響族群結構之措施列為中風險（2 分），缺乏措施則視為高風險（3 分）。

非法、未報、未受管制（IUU)漁業相關風險的評分則反映透明度與執法強度。船位追蹤（VMS／AIS）、白名單管理、港口國措施與禁止海上轉載，皆能直接提升可追蹤性並抑制未授權作業，故屬低風險（1 分）。具嚇阻效果的裁罰制度、觀察員與電子監測、追溯制度以及具 IUU 措施的國家行動計畫，雖能強化治理，但實際效果高度依賴執法落實，因此為中風險（2 分）。若在該壓力來源下未有任何措施，則被評為高風險（3 分）。

第五步驟：進行 NDF 判定

綜合第二步驟至第四步驟之風險分數，加總後判定 NDF 結果：

(1) 25–40分為正面 NDF，可核發證明辦理出口。

(2) 41–60分為有條件 NDF，需於滿足附帶條件後，方可核發。

(3) 61–75分為負面 NDF，則需進行管理改善。

第六步驟：管理建議

第六步驟旨在依據前述評估結果，提出適合我國執行之監控計畫與管理建議，作為後續管理精進與資源改善之依據。該步驟不僅適用於負面 NDF 之物種，亦可視物種風險程度與管理需求，針對「有條件 NDF」或其他具管理調整空間之物種，提出相應之管理建議與監測措施。

透過第六步驟所建立之管理與監控機制，執行單位得以在實務上逐步改善

資料品質、降低管理不確定性，並於後續重新評估時，依本流程系統性檢視相關管理措施之執行成效，據以修訂與更新 NDF 之最新判定結果，以形成具回饋性與調適能力之管理循環。

參照德國 BfN 指導綱領，NDF 有效期限為一年，需於到期後依據最新資源情況重新審理與更新，以達到有效控管物種資源（Mundy et al., 2014）。

五、計畫成果

(一)太平洋與印度洋紅肉丫髻鮫(Scalloped hammerhead) 無危害風險評估報告

第一步驟：初步資訊蒐集

物種	CITES 附錄二	RFMOs 管制措施		符合 NDF 流程
紅肉丫髻鮫	2013列入	中西太平洋	未禁捕	是
		印度洋	未禁捕	是

符合以上條件，代表該物種將進入本流程後續步驟之評估。

第二步驟：既有的生物易危性及保育關注程度

此步驟包含了既有的生物易危性及保育關注程度。

1. 既有的生物易危性

各既有生物易危性指標的判定結果如下：

項目		風險等級			紅肉丫髻鮫	
2.1生物易危性指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	成熟年齡(t_{mat})	<5	5-15	>15	4.7	13.2
2	成熟體長(L_m)	<40	40-200	>200	230	220.5
3	最大年齡(T_m)	<10	10-25	>25	15	35
4	極限體長(TL_∞)	<100	100-300	>300	319	399
5	自然死亡率(M)	>0.4	0.17-0.4	<0.17	0.4185	0.18
6	產仔數(f)	>15	2-15	<2	25.8	26.5
7	族群內在增加率(r)	>0.35	0.15-0.35	<0.15	0.243	0.175
8	地理分布範圍	全球性	區域性	國家性	全球性	全球性
9	資源狀態	$F<=F_{MSY}$ $B>=B_{MSY}$	$F=F_{MSY}$ $B=B_{MSY}$	$F>=F_{MSY}$ $B<=B_{MSY}$	未知	未知
10	行為因素	少數行為	部分行為	多數行為	多數行為	多數行為
11	營養位階	低	中	高	高	高
總分/等級		**11-17**	**18-26**	**27-33**	**23**	**26**

Remark (data source): Chen et al. (1988), Chen et al. (1990), Chodrijah and Faizah (2021), Geng et al. (2021), Hearn et al. (2010), Huynh and Tsai (2023), IOTC Secretariat. (2015), Geng (2022), Jacoby et al. (2012), Jacoby et al. (2022), Klimley (1985), Liu and Chen (1999), Liu et al. (2021), Thomas et al. (2022), Galván-Magaña et al. (2019), Li et al. (2024), Zhang et al. (2025).

生物易危性指標之評估項目計有成熟年齡（t_{mat}）、成熟體長（L_m）、最大年齡（T_m）、極限體長（TL_∞）、自然死亡率（M）、產仔數（f）、族群內在增加率（r）、地理分布、資源狀態、行為因素、營養位階等計11項。本研究參考前人研究所提供之生物學、族群統計及生態與環境適應性相關文獻，分別對紅肉丫髻鮫在中西太平洋及印度洋進行生物易危性評估與風險分級。

在本步驟中，紅肉丫髻鮫在中西太平洋之生物學參數採用 Chen et al.(1988)、Chen et al.(1990)、Liu and Chen (1999)、Liu et al. (2021)等研究資料，於印度洋之生物學參數採用 Chodrijah and Faizah (2021)、Geng et al. (2021)、IOTC Secretariat. (2015)、Jacoby et al. (2022)、Thomas et al. (2022) 等研究資料；生態與環境適應性參數參考：中西太平洋根據 Huynh and Tsai (2023)、Rigby et al. (2019d)、Klimley (1985)、Hearn et al.(2010)、Jacoby et al. (2012)，印度洋則參考 Geng et al. (2021)、IOTC Secretariat. (2015)、Geng (2022)、Jacoby et al. (2022)，並結合(IOTC－2015－SC18－ES19[E]) 報告後得出印度洋之紅肉丫髻鮫聚集習性和幼體佔據沿岸育幼場是造成高脆弱性的關鍵行為因素。

資源狀態係依據西中太平洋漁業委員會（WCPFC）科學委員會第二十一屆會議（SC21）及秘書處於 2025 年 10 月所發布之最新回顧結果，目前該物種之資源狀態被評定為「未知」。由於漁獲資料中常與其他雙髻鯊物種混淆（如 *Sphyrna zygaena* 與 *Sphyrna mokarran*），且歷史漁獲與生物資料不完整，現階段尚無法進行傳統年齡結構模型之資源評估。此外，因缺乏足夠資訊以建立紅肉丫髻鮫之明確目標參考點，亦無法對其資源狀態進行量化判定。

在印度洋方面，根據印度洋鮪類委員會（IOTC）生態系統與混獲工作小組（WPEB）於 2022 年提出之報告（IOTC－2022－WPEB18－R[E]），以及 2025 年科學委員會報告附錄 IX（IOTC-2025-SC28-ES19_SPLE），官方對該物種的定性評估結果仍維持為「資訊匱乏，資源狀態高度不確定」。透過多項穩定同位素研究證實，遠洋鯊魚在海洋食物網中處於高營養位階（High-trophic niche），扮演不可或缺的頂級掠食者（Apex predator）角色（Galván-Magaña et al., 2019）。研究指出，熱帶遠洋鯊魚群透過營養生態位區隔維持生態系功能（Li et al., 2024）；最新研究更透過南中國海物種之多組織分析顯示，部分鯊魚之營養位置可高達 $TP_{mustle} \approx 4.6$，再次實證其位於海洋食物鏈頂端的關鍵地位（Zhang et al., 2025）。

綜合評估後，中西太平洋之生物易危性總分為 23 分，印度洋之生物易危性總分為 26 分，整體皆判定為中度風險。

2. 保育關注程度 Degree of conservation attention

各保育關注程度指標的判定結果如下：

項目		風險等級			紅肉丫髻鮫	
2.2生物易危性指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	保育與資源評估的情況	LC	NT/VU	EN/CR	CR	CR
2	族群趨勢	上升	穩定	下降	未知	下降
3	受保育關注的區域範圍	影響少數	影響部分	影響全球	影響全球	影響全球
總分/等級		**3-4**	**5-7**	**8-9**	**9**	**9**

Remark (data source): Camhi et al. (2008), Clarke et al. (2006a), Clarke et al. (2006b), Dent and Clarke (2015), Dudley and Simpfendorfer (2006), Fields et al. (2018), Martínez-Ortiz et al. (2015), Rigby et al. (2019d), Simpfendorfer et al. (2010), Temple et al. (2019)

在本步驟中，紅肉丫髻鮫評估資料主要採用 IUCN 提供的 Rigby et al. (2019d) 評估結果，除西北大西洋及墨西哥灣因採取管理措施而呈現穩定或回復跡象外，其他區域族群均持續呈下降趨勢。根據對各海域族群變化進行加權後的全球評估結果，其全球族群在三個世代長度（約 72.3 年）內的中位數下降幅度介於 76.9% 至 97.3%，且下降幅度超過 80% 的可能性最高。相關區域研究亦顯示類似趨勢，包括南太平洋（Simpfendorfer et al.，2010）及印度洋（Dudley & Simpfendorfer，2006）。中西太平洋缺乏相關文獻參考，因此在族群趨勢呈現未知。由於該物種在全球範圍被捕撈（目標捕撈及混獲）(Camhi et al. 2008)；大多在沿岸環境, 即受到威脅遍布不同地區(Camhi et al. 2008、 Martinez-Ortiz et al. 2015、 Temple et al. 2019)；商業價值(Clarke et al. 2006a、 Clarke et al. 2006b、Dent and Clarke 2015、Fields et al. 2018)。

第三步驟：物種承受的壓力(原貿易壓力評估列為參考)

1. 物種所受的漁業壓力

各漁業壓力指標的判定結果如下：

項目		風險等級			紅肉丫髻鮫	
3.1 貿易壓力指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	合法貿易的規模	規模小	規模中	規模大	規模小	規模小
2	非法貿易的規模	規模小	規模中	規模大	未知	未知
總分/等級		**1-2**	**3-4**	**5-6**	**3**	**3**
3.2 漁業壓力指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	漁獲死亡率	死亡率低	死亡率中等	死亡率高	未知	未知
2	丟棄活存率	活存率高	活存率中等	活存率低	活存率低	活存率低
3	漁具的選擇性	漁具選擇性高	漁具選擇性中	漁具選擇性低	漁具選擇性高	漁具選擇性高
4	IUU 漁業規模	紀錄詳細	部分記錄	紀錄不齊	紀錄詳細	紀錄詳細
總分/等級		**4-6**	**7-8**	**9-12**	**8**	**8**

Remark (data source): Cortés et al. (2010), de Bruyn et al. (2005), Casper et al. (2005), Murua et al. (2018), Bhanja and Mandal (2024).

漁具選擇性低表示易捕獲大量非目標物種與幼魚，對生態系影響顯著，因此為高風險；漁具選擇性高則表示漁具能有效選擇目標魚種，副捕獲少，對非目標物種及幼魚影響很小，故為低風險。

就合法貿易而言，自2023年4月紅肉丫髻鮫相關產品已可透過較細緻之 CCC Code 進行申報與統計，使得官方貿易資料在產品類型與數量上具備一定程度的可辨識性。根據 CITES 與 FAO 對貿易資料應用於 NDF 的指引，當出口數量可由正式報關系統掌握，且未顯示異常快速成長或顯著偏離漁獲來源量時，通常可將「合法貿易規模」視為偏低風險（CITES, n.d.）。既有研究指出，對於已納入國家海關分類體系並持續監測之水產品項，其合法貿易本身並不必然構成對族群的主要壓力來源，除非出現貿易量與資源狀況明顯不相符的情形（Mundy-Taylor, 2014）。因此，本研究將中西太平洋與印度洋紅肉丫髻鮫之合法貿易規模均評為低（1 分）。

儘管我國已建立相對完善之 CCC Code 分類制度，並配合相關漁業與貿易管理措施，對於提升合法貿易之可追溯性與整體透明度已有相當助益；然而，依據國際文獻與 CITES 非致危判定（NDF）之相關指引，非法與 IUU 貿易行為本質上較不易完整反映於正式報關與貿易統計之中。特別是在鯊魚產品多屬加工後型態、即時物種鑑識具一定技術限制的情況下，仍存在非法來源產品混入合法供應鏈之潛在不確定性(Cardeñosa et al. , 2017, 2018；Sas-Rolfes et al., 2019)。基於目前可取得之資訊，尚缺乏足以進一步量化非法貿易規模之查獲案件趨勢、司法裁罰統計或系統性生物鑑識資料，然而根據 CITES. (2023)指出，雙髻鯊魚翅因價格遠高於一般鯊魚，被非法捕撈者鎖定，即使在禁捕或 CITES 管制下，仍有非法貿易的紀錄；爰此，本研究依循國際 NDF 實務所建議之審慎原則，將我國紅肉丫髻鮫之非法貿易規模暫評為「未知」，並以中度風險（2 分）進行處理，以確保評估結果之穩健性與國際可比性。依據 CITES 非致危判定（NDF）之實務原則，非法貿易規模在缺乏可量化證據時，應列為「未知」，並非直接等同於特定規模大小。其風險程度之判定，則需綜合考量物種之國際市場需求、產品加工型態、物種鑑識難度與既有文獻對非法貿易熱點之指認結果。在市場誘因與供應鏈不透明性較高之情境下，採取較為審慎之中至高風險處理；反之，若非法誘因有限，則可合理評估為低風險。

第四步驟：評估現有的管理措施

項目		風險等級			紅肉丫髻鮫	
4 是否具備適當管理措施		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
4.1 管理措施規模		物種專屬管理措施	一般性管理措施	無	一般性管理措施	一般性管理措施
總分/等級		**1**	**2**	**3**	**2**	**2**
4.2 監測、控制與監測 (MCS)		低(1分)	中(2分)	高(3分)	紅肉丫髻鮫	
1	捕撈壓力	低	中	高	高	高
2	丟棄死亡率	低	中	高	高	高
3	體長／年齡／性別選擇性	低	中	高	低	低
4	IUU 漁業防治	低	中	高	低	低
總分/等級		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): 農業部漁業署(2025a) 修法「鮪延繩釣或鰹鮪圍網漁船赴太平洋作業管理辦法」第57條。農業部漁業署(2025b)「鮪延繩釣漁船赴大西洋作業管理辦法」第41條。農業部漁業署(2025c)「鮪延繩釣漁船赴印度洋作業管理辦法」第39條。

第五步驟：進行 NDF 判定

項目	風險等級			紅肉丫髻鮫	
	低	中	高	中西太平洋	印度洋
步驟2.1	11-17	18-26	27-33	23	26
步驟2.2	3-4	5-7	8-9	9	9
步驟3.1	1-2	3-4	5-6	3	3
步驟3.2	4-6	7-8	9-12	8	8
步驟4.1	1	2	3	2	2
步驟4.2	4-6	7-9	10-12	8	8
總分	**25-40**	**41-60**	**61-75**	**53**	**56**
NDF 評估結果	**正面**	**有條件**	**負面**	**有條件**	**有條件**

本研究針對我國中西太平洋與印度洋之紅肉丫髻鮫進行無危害評估，其結果皆為有條件之NDF。

第六步驟：管理建議

綜合紅肉丫髻鮫（*Sphyrna lewini*）於本次「有條件之無危害判定（Non-Detriment Finding, NDF）」評估結果可知，該物種於不同洋區在生物學易危性、族群恢復潛力、漁業曝露程度及保育關注層級等多項指標上，皆呈現高度保育風險特徵。尤其該物種具備晚熟、低繁殖力及群聚行為等生命史特性，使其對漁撈壓力及環境變動高度敏感，即使在漁獲量相對有限之情境下，仍可能造成族群快速衰退。本次評估亦顯示，部分關鍵評估項目因基礎生物學參數（如成長、成熟體長、死亡率）及漁業相關資料（如實際混獲率、棄捕率、放流後存活率）不足，必須以「未知即高風險」之保守原則進行判定。此結果凸顯，目前資料缺口已成為限制紅肉丫髻鮫資源精準評估與有效管理之核心瓶頸。若未能系統性補強資料蒐集與監測機制，即使現行管理措施存在，亦難以確保其長期管理效益。

基於上述風險背景，除持續落實既有「鰭連身」政策與 CITES 附錄Ⅱ相關規範外，建議臺灣針對紅肉丫髻鮫於沿近海及遠洋漁業中，逐步導入以科學評估為基礎之總容許漁獲量（Total Allowable Catch, TAC）管理制度。考量目前資料受限情境，可先透過資料受限族群評估方法（如 CMSY、SPiCT 或長度基礎模型）推估生物參考點（如 MSY 或其替代指標），並在高度不確定性下採取保守折減係數，以避免過度開發風險。TAC 應採取年度滾動式調整機制，依據最新監測結果與族群趨勢，動態調整配額、作業時段或禁漁期間，逐步建立具調適能力（adaptive management）的管理框架。

此外，建議進一步整合體長頻度與成熟資訊，評估導入最小可捕體長限制或禁捕未成熟個體之管理措施，以降低對族群補充量之直接衝擊。此類措施特別適用於紅肉丫髻鮫具明顯育幼與成長棲地之沿近海水域，可作為空間型管理（如季節性禁漁區或幼魚保護區）之科學依據。配合漁港端查驗制度，將有助於提升管理措施之可執行性與遵循度。

考量紅肉丫髻鮫於延繩釣、定置網及其他漁法中屬高頻率混獲物種，管理策略亦應由「禁止型」逐步擴充至「減量型」與「行為導向型」措施。建議持續投入資源於漁具改良與誤捕降低技術之研發與推廣，例如鉤具型式調整、作業水層與時間調整，以及降低幼魚與非目標物種混獲之操作方式。同時，透過制度化補助與技術指引，提高漁民採用友善漁法之誘因。在執行層面，應加強漁民教育訓練與現場指導，於紅肉丫髻鮫被捕且仍存活時，優先落實「科學釋放（best-practice live release）」程序，包括減少甲板暴露時間、避免不必要之傷害及適當的重播方式，以提高放流後存活率，並實質降低實際漁撈死亡率。

最後，建議持續並制度化推動「軟骨魚類資源監測計畫」，將漁撈日誌、生物採樣、觀察員或電子監測資料整合為長期監測體系。透過合理誘因機制鼓勵漁民如實填報漁獲組成與生物資訊，逐步縮小關鍵參數之不確定性。基礎資料品質的提升，將直接影響族群成長率、死亡率與補充量等核心估計結果，並決定未來 TAC 設定、禁漁設計及 NDF 判定之科學可信度與管理成效。

(二)太平洋與印度洋丫髻鮫(Smooth hammerhead) 無危害風險評估報告

第一步驟：初步資訊蒐集

物種	CITES 附錄二	RFMOs 管制措施		符合 NDF 流程
丫髻鮫	2013列入	中西太平洋	未禁捕	是
		印度洋	未禁捕	是

符合以上條件，代表該物種將進入本流程後續步驟之評估。

第二步驟：既有的生物易危性及保育關注程度

此步驟包含了既有的生物易危性及保育關注程度。

1. 既有的生物易危性

各既有生物易危性指標的判定結果如下：

項目		風險等級			丫髻鮫	
2.1生物易危性指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	成熟年齡(t_{mat})	<5	5-15	>15	10	10
2	成熟體長(L_m)	<40	40-200	>200	259.4	240
3	最大年齡(T_m)	<10	10-25	>25	未知	未知
4	極限體長(TL_∞)	<100	100-300	>300	375.2	385
5	自然死亡率(M)	>0.4	0.17-0.4	<0.17	0.178	1.39
6	產仔數(f)	>15	2-15	<2	30	33
7	族群內在增加率(r)	>0.35	0.15-0.35	<0.15	0.153	未知
8	地理分布範圍	全球性	區域性	國家性	全球性	全球性
9	資源狀態	$F<=F_{MSY}$ $B>=B_{MSY}$	$F=F_{MSY}$ $B=B_{MSY}$	$F>=F_{MSY}$ $B<=B_{MSY}$	未知	未知
10	行為因素	少數行為	部分行為	多數行為	未知	部分行為
11	營養位階	低	中	高	高	高
總分/等級		**11-17**	**18-26**	**27-33**	**27**	**25**

Remark (data source):Chen et al. (1988), Chen et al. (1990), Chou (2004), Clarke et al. (2015), Dudley and Simpfendorfer (2006), Ebert et al. (2013), Huynh and Tsai (2023), IUCN (2018), IOTC (2015), Sabarros et al. (2022), Liu (2002), Liu and Chen (1999), Liu et al. (2015), Liu et al. (2021), Martínez-Ortiz et al. (2015), Rigby et al. (2019a), Simpfendorfer et al. (2010), Temple et al. (2019), Tsai et al. (2018) ；Appukuttan and Nair (1988), Clarke et al. (2015), Dicken et al. (2018), Ebert et al. (2013), Froese and Pauly (2016), Harry et al. (2011), IOTC (2015), Jabado and Ebert (2015), Manjusha et al. (2011), Rigby et al. (2019a), Stevens (1984),Galván-Magaña et al. (2019), Li et al. (2024), Zhang et al. (2025).

生物易危性指標之評估項目計有成熟年齡（t_{mat}）、成熟體長（L_m）、最大年齡（T_m）、極限體長（TL_∞）、自然死亡率（M）、產仔數（f）、族群內在增加率（r）、地理分布、資源狀態、行為因素、營養位階等計11項。本研究參考前人研究所提供之生物學、族群統計及生態與環境適應性相關文獻，分別對丫髻鮫在中西太平洋及印度洋進行生物易危性評估與風險分級。

在本步驟中，丫髻鮫在中西太平洋之生物學參數採用 Chen et al. (1988)、 Chen et al. (1990)、 Chou (2004) Huynh and Tsai (2023)、 Chen (1999)、 Liu et al. (2015)、 Liu et al. (2021)、Tsai et al. (2018)、Liu (2002)，於印度洋之生物學參數採用 Harry et al. (2011)、IOTC (2015)、Jabado and Ebert (2015)、 Manjusha et al. (2011)、IOTC (2015)、 Stevens (1984)；生態與環境適應性參數則參考 IUCN (2019)、Froese and Pauly (2016)、Ebert et al. (2013)、IUCN (2018)、Rigby et al. (2019a)、Clarke et al. (2015)、 Dudley and Simpfendorfer (2006)、Liu and Martínez-Ortiz et al. (2015)、Sabarros et al. (2022)、 Simpfendorfer et al. (2010)、 Temple et al. (2019)、Appukuttan and Nair (1988)、 Clarke et al. (2015)、 Dicken et al. (2018)、 Ebert et al. (2013)。丫髻鮫在北太平洋觀測到具有遷徙性、季節性聚集與偏好沿岸及大陸架邊緣棲息等行為特徵（Clarke et al., 2015；Ebert et al., 2013），但這些資訊不足以全面評估整個太平洋丫髻鮫之行為因素增加其族群風險或脆弱性。多數研究亦提到，由於漁獲資料缺乏以及行為研究不完整，無法精確判斷行為因素對族群的影響，因此目前對太平洋丫髻鮫的行為因素影響層級應列為未知；在印度洋與澳洲海域丫髻鮫具有顯著的群集行為（Schooling behavior）與季節性遷徙特性（Sabarros et al., 2022; Dicken et al., 2018），這使得族群極易在特定棲地熱點（如海山或沿岸特定水域）被漁業大規模捕獲（Harry et al., 2011; Stevens, 1984），進而加劇了過度開發的風險，因此判斷為中風險程度。而資源狀態則 WCPFC 及 IOTC 尚未有該物種資源評估相關報告。

透過多項穩定同位素研究證實，遠洋鯊魚在海洋食物網中處於高營養位階（High-trophic niche），扮演不可或缺的頂級掠食者（Apex predator）角色（Galván-Magaña et al., 2019）。而熱帶遠洋鯊魚物種之間，透過營養生態位（trophic niche）的區隔與差異化利用，降低直接競爭，並使多物種能在同一生態系中共存。（Li et al., 2024）；最新研究更透過南中國海物種之多組織分析顯示，部分鯊魚之營養位置可高達 $TP_{mustle} \approx 4.6$，再次實證其位於海洋食物鏈頂端的關鍵地位（Zhang et al., 2025）。

綜合評估後，中西太平洋之生物易危性總分為 27 分，判定為中度風險；印度洋之生物易危性總分為 25 分，判定為中度風險。

2. 保育關注程度 Degree of conservation attention

各保育關注程度指標的判定結果如下：

項目		風險等級			丫髻鮫	
2.2生物易危性指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	保育與資源評估的情況	LC	NT/VU	EN/CR	VU	VU
2	族群趨勢	上升	穩定	下降	下降	上升
3	受保育關注的區域範圍	影響少數	影響部分	影響全球	影響部分	影響部分
總分/等級		**3-4**	**5-7**	**8-9**	**7**	**5**

Remark (data source): Dicken et al. (2018), Tsai et al. (2018), Rigby et al. (2019a), IUCN (2019), Huynh and Tsai (2023).

在本步驟中，丫髻鮫保育評估資料主要採用 IUCN 提供的 Rigby et al. (2019a)、 IUCN (2019)評估結果，而中西太平洋族群趨參考 Tsai et al. (2018)、Huynh and Tsai (2023)研究結果，印度洋採用 Dicken et al.(2018)對南非捕獲率（CPUE）的分析表明丫髻鮫的族群趨勢是增加的（儘管增幅輕微且在統計學上不顯著）。

第三步驟：物種承受的壓力(原貿易壓力評估列為參考)

1. 物種所受的漁業壓力

各漁業壓力指標的判定結果如下：

項目		風險等級			丫髻鮫	
3.1 貿易壓力指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	合法貿易的規模	規模小	規模中	規模大	規模小	規模小
2	非法貿易的規模	規模小	規模中	規模大	未知	未知
總分/等級		**1-2**	**3-4**	**5-6**	**3**	**3**
3.2 漁業壓力指標		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
1	漁獲死亡率	死亡率低	死亡率中等	死亡率高	未知	未知
2	丟棄活存率	活存率高	活存率中等	活存率低	活存率低	活存率低
3	漁具的選擇性	漁具選擇性高	漁具選擇性中	漁具選擇性低	漁具選擇性高	漁具選擇性高
4	IUU 漁業規模	紀錄詳細	部分記錄	紀錄不齊	紀錄詳細	紀錄詳細
總分/等級		**4-6**	**7-8**	**9-12**	**8**	**8**

Remark (data source): 漁具選擇性低表示易捕獲大量非目標物種與幼魚，對生態系影響顯著，因此為高風險；漁具選擇性高則表示漁具能有效選擇目標魚種，副捕獲少，對非目標物種及幼魚影響很小，故為低風險。

就合法貿易而言，目前丫髻鮫相關產品已可透過 CCC Code 進行申報與統計，使得官方貿易資料在產品類型與數量上具備一定程度的可辨識性。根據 CITES 與 FAO 對貿易資料應用於 NDF 的指引，當出口數量可由正式報關系統掌握，且未顯示異常快速成長或顯著偏離漁獲來源量時，通常可將「合法貿易規模」視為偏低風險（CITES, n.d.）。既有研究指出，對於已納入國家海關分類體系並持續監測之水產品項，其合法貿易本身並不必然構成對族群的主要壓力來源，除非出現貿易量與資源狀況明顯不相符的情形（Mundy-Taylor, 2014）。因此，本研究將中西太平洋與印度洋丫髻鮫之合法貿易規模均評為低（1 分）。

儘管我國已建立相對完善之 CCC Code 分類制度，並配合相關漁業與貿易管理措施，對於提升合法貿易之可追溯性與整體透明度已有相當助益；然而，依據國際文獻與 CITES 非致危判定（NDF）之相關指引，非法與 IUU 貿易行為本質上較不易完整反映於正式報關與貿易統計之中。特別是在鯊魚產品多屬加工後型態、即時物種鑑識具一定技術限制的情況下，仍存在非法來源產品混入合法供應鏈之潛在不確定性(Cardeñosa e t al. 2018；Sas-Rolfes et al., 2019) 。基於目前可取得之資訊，尚缺乏足以進一步量化非法貿易規模之查獲案件趨勢、司法裁罰統計或系統性生物鑑識資料；根據 CITES. (2023)指出，雙髻鯊魚翅因價格遠高於一般鯊魚，被非法捕撈者鎖定，即使在禁捕或 CITES 管制下，仍有非法貿易的紀錄；爰此，本研究依循國際 NDF 實務所建議之審慎原則，將我國丫髻鮫之非法貿易規模暫評為「未知」，並以中度風險（2 分）進行處理，以確保評估結果之穩健性與國際可比性。

第四步驟：評估現有的管理措施

項目		風險等級			丫髻鮫	
4 是否具備適當管理措施		低(1分)	中(2分)	高(3分)	中西太平洋	印度洋
4.1 管理措施規模		物種專屬管理措施	一般性管理措施	無	一般性管理措施	一般性管理措施
總分/等級		**1**	**2**	**3**	**2**	**2**
4.2 監測、控制與監測 (MCS)		低(1分)	中(2分)	高(3分)	丫髻鮫	
1	捕撈壓力	低	中	高	高	高
2	丟棄死亡率	低	中	高	高	高
3	體長／年齡／性別選擇性	低	中	高	低	低
4	IUU 漁業防治	低	中	高	低	低
總分/等級		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): 農業部漁業署(2025a) 修法「鮪延繩釣或鏢鮪圍網漁船赴太平洋作業管理辦法」第57條。農業部漁業署(2025b)「鮪延繩釣漁船赴大西洋作業管理辦法」第41條。農業部漁業署(2025c)「鮪延繩釣漁船赴印度洋作業管理辦法」第39條。

第五步驟：進行 NDF 判定

項目	風險等級			丫髻鮫	
	低	中	高	中西太平洋	印度洋
步驟2.1	11-17	18-26	27-33	27	25
步驟2.2	3-4	5-7	8-9	7	5
步驟3.1	1-2	3-4	5-6	3	3
步驟3.2	4-6	7-8	9-12	8	8
步驟4.1	1	2	3	2	2
步驟4.2	4-6	7-9	10-12	8	8
總分	**25-40**	**41-60**	**61-75**	**55**	**51**
NDF 評估結果	**正面**	**有條件**	**負面**	**有條件**	**有條件**

本研究針對我國中西太平洋與印度洋之丫髻鮫進行無危害評估，其結果皆為有條件之NDF。

第六步驟：管理建議

綜合本研究對丫髻鮫（*Sphyrna zygaena*）之「有條件之無危害判定（Non-Detriment Finding, NDF）」評估結果顯示，該物種於不同洋區在生物學易危性、族群恢復潛力、保育關注程度及漁業曝露風險等多項指標上，均呈現高度保育風險特徵。丫髻鮫具備成長速率相對緩慢、成熟年齡偏晚及族群補充率有限等生命史特性，使其對持續性漁撈壓力與環境變動高度敏感；在缺乏有效管控與即時監測機制之情境下，其族群衰退風險將顯著放大。本次評估亦顯示，部分關鍵指標因基礎生物學資料（如成熟體長、成長參數與自然死亡率）及漁業相關資訊（如實際混獲比例、棄捕比例與放流後存活率）取得不易，需依循預警原則（precautionary principle），以最保守之「高風險（未知）」等級進行判定。此一結果清楚指出，資料匱乏已成為限制丫髻鮫族群狀態精準判斷與管理措施改善之核心瓶頸；若未能有效補強，將持續影響 NDF 判定之穩定性與政策執行之科學可信度。

基於上述風險背景，未來管理策略宜採取多層次、互補式之「管理工具組（policy toolbox）」架構，而非倚賴單一管制手段。在產量控制方面，建議逐步導入以科學評估為基礎之總允許漁獲量（Total Allowable Catch, TAC）制度，並於資料受限情境下採取保守設定原則，透過年度滾動式調整機制，依據最新族群監測結果與風險評估，動態修正配額、作業時段或禁漁期間，以降低過度開發風險並提升管理之調適能力。在空間管理層面，鑒於丫髻鮫幼魚具備明顯之季節性遷移與群聚行為，且可能高度依賴特定沿近海或陸棚水域作為育幼棲地，建議整合臺灣周邊海域之物種分佈圖、漁獲紀錄及環境資料，系統性辨識高風險時空熱點與潛在育幼場（nursery grounds）。在具備充分科學證據支援下，可研議設定季節性禁漁區、育幼場保護區或其他區域性管控措施，以降低幼魚階段之漁撈死亡率，並強化棲地保護與族群補充功能。

同時，考量丫髻鮫於多種漁法中屬高頻率混獲物種，管理措施亦應著重於降低實際漁撈死亡率。建議持續推動漁具改良與混獲減量技術之研發與推廣，例如調整鉤具形式、作業水層與操作時段，並配合制度化補助與技術指引，鼓勵漁民於該物種被捕且仍存活時，優先採行安全放生或科學釋放程序，以實質降低累積漁業死亡壓力。

整體而言，透過結合 TAC 管控、空間型管理、混獲減量等多元管理工具，所建構之管理工具組可形成相互支援之治理架構，在符合預警原則之前提下，逐步降低資料不確定性與管理風險，並提升丫髻鮫資源永續利用與整體管理成效。

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Non-Detriment Finding Assessment for Sphyrnidae Species Caught by Taiwanese Fisheries in the Western and Central Pacific Ocean and Indian Ocean

(English version)

Fisheries Agency, Ministry of Agriculture

July 2026

中　華　民　國　1　1　5　年　7　月

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Chapter 1 INTRODUCTION

Species of the family Sphyrnidae play a key functional role in marine food webs due to their distinctive head morphology and ecological role as high-level predators. They are important for regulating the population structure of small- and medium-sized fishes and cephalopods, and for maintaining ecosystem stability. However, most hammerhead shark species possess K-selected life history characteristics, such as slow growth, late sexual maturity, low reproductive capacity, and long lifespan. These traits make them highly sensitive to fishing pressure, and once populations decline, the time required for recovery is often extremely long.

In recent decades, with the increasing global demand for shark fins and shark-related products, hammerhead sharks have frequently become bycatch species in pelagic longline and purse seine fisheries. Their population status has therefore received considerable international attention. According to international assessments, most species in the family Sphyrnidae have been listed under threatened categories by the IUCN, and their abundance has shown clear declining trends in several ocean regions. In response to this situation, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has listed most species of the family Sphyrnidae in Appendix II, requiring exporting countries to complete a Non-Detriment

Finding (NDF) before international trade can occur, in order to confirm that such trade will not have adverse impacts on wild populations.

At the level of regional fisheries management, several Regional Fisheries Management Organizations (RFMOs) in the Western and Central Pacific Ocean and the Indian Ocean have also adopted management measures for hammerhead sharks, including retention bans, mandatory release requirements, and catch reporting obligations. This indicates that hammerhead sharks have gradually shifted from traditionally treated bycatch species to high-risk resources requiring dedicated management and monitoring. However, because hammerhead sharks have broad distributions across multiple jurisdictional waters, and because fishing patterns, fishing intensity, and management measures differ among ocean regions, their stock status and risk levels are highly region-specific. Therefore, systematic assessments by ocean region are urgently needed.

Taiwan is one of the major distant-water fishing nations in the world. During fishing operations by Taiwanese pelagic tuna longline fisheries in the Western and Central Pacific Ocean and the Indian Ocean, several CITES Appendix II-listed species of the family Sphyrnidae may still be caught as bycatch. Under the premise of balancing international trade responsibilities, fisheries management compliance, and sustainable

resource utilization, establishing a science-based NDF assessment that conforms to international standards has become an important foundation of Taiwan's fisheries management.

In view of this, this report focuses on species of the family Sphyrnidae in the Western and Central Pacific Ocean and the Indian Ocean as the assessment targets. It integrates relevant domestic and international information on population status, biology, fishery utilization, international trade, and management measures. Following CITES and existing NDF guidance frameworks, this report systematically assesses the potential risks that trade utilization may pose to wild populations, with the aim of providing a scientific basis for Taiwan's implementation of NDF assessments for Sphyrnidae species and subsequent management decision-making.

Chapter 2 LITERATURE REVIEW

2.1 Overview of the stock status and management

Three hammerhead shark species have been recorded in waters surrounding Taiwan. Their main distribution range occurs in coastal and offshore waters between approximately 55°N and 55°S. According to previous fishery studies and statistical data, all three species can be caught in waters around Taiwan. Among them, the scalloped hammerhead shark has relatively higher catch production, followed by the smooth hammerhead shark, *Sphyrna zygaena*, whereas catch records of the great hammerhead shark, S. mokarran, are relatively fewer (Liu, 2002).

The scalloped hammerhead shark is a highly migratory species that mainly inhabits warm waters and tropical coastal and offshore areas. Its distribution ranges from the surface and intertidal zones to depths of at least 275 m. Juveniles and subadults use coastal and offshore waters as habitats, and the species exhibits seasonal migration and schooling behavior (Compagno et al., 2005; Fowler et al., 2005). In 1989, the annual catch of scalloped hammerhead shark in eastern Taiwan was approximately 500 metric tons. Since 2003, catches declined continuously from 525 metric tons to the lowest level of 195 metric tons in 2013, and in recent years have generally ranged between 200 and 300 metric tons.

The IUCN Shark Specialist Group assessed changes in the abundance of 31 species of pelagic sharks and rays globally over the past half-century using the Living Planet Index (LPI) and IUCN Red List Index. This assessment compiled the most complete available biological and fishery-related literature and data, while also referring to stock assessment results previously conducted by Regional Fisheries Management Organizations (RFMOs). The results were published in the journal Nature. The study showed that since 1970, due to an 18-fold increase in fishing pressure, the abundance of these pelagic sharks and rays has declined by 71%, and three-quarters of the indicator species are at risk of extinction (Pacoureau et al., 2021).

In 2018, the IUCN Shark Specialist Group reassessed the conservation status of pelagic sharks and rays. The global scalloped hammerhead shark was uplisted from Vulnerable (VU) to Critically Endangered (CR) (Rigby et al., 2019d), while the smooth hammerhead shark was uplisted from Vulnerable to Endangered (EN) (Rigby et al., 2019a). These changes indicate that the stock status of these species has clearly deteriorated in some regions over the past decade.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listed the scalloped hammerhead shark, smooth hammerhead shark, and great hammerhead shark in Appendix II in 2013. Appendix II listing does not prohibit

trade in economic species. However, a Non-Detriment Finding (NDF) must be provided for such species. An NDF is a scientific assessment used to confirm that the export of the species will not be detrimental to the stock status of its wild population. Only when such confirmation is obtained can an export permit for international trade be issued. If the species is caught beyond the 200-nautical-mile Exclusive Economic Zone, a document similar to a certificate of origin, known as Introduction from the Sea (IFS), is also required.

Mature female scalloped hammerhead sharks and smooth hammerhead sharks give birth in coastal waters around Taiwan, particularly along the western coast. These juveniles may be caught or bycaught by various coastal and offshore fishing methods. Larger individuals, greater than 150 cm total length, are caught by longline or drift gillnet fisheries operating from Nanfang'ao in Yilan and Chenggong Xingang in Taitung. Therefore, in order to ensure the sustainable utilization of hammerhead shark resources, studies on resource surveys and NDF assessments are urgently needed.

Regarding domestic studies on scalloped hammerhead shark, Chen et al. (1988) conducted a reproductive study on the scalloped hammerhead shark in the northwestern Pacific Ocean. The size at birth (L_b) was 48.5 cm, the length at 50% maturity (L_m) was 230 cm TL, the average litter size (f) was 25.8 pups, and the reproductive cycle (R_c)

was 2 years. Chen et al. (1990) conducted an age and growth study on the scalloped hammerhead shark in the northwestern Pacific Ocean. For males, the asymptotic length (L_∞) was 320.6 cm TL, the growth coefficient (k) was 0.222 year-1, and the theoretical age at zero length (t_0) was -0.75 year. For females, the asymptotic length was 319.7 cm TL, k was 0.249 year-1, and t0 was -0.41 year. The age at maturity (t_{mat}) was 4.7 years, and the maximum age (T_m) was 15 years.

Liu (2002) conducted a reproductive study on the smooth hammerhead shark in the northwestern Pacific Ocean. The size at birth (L_b) was 55 cm, the length at 50% maturity (L_m) was 259.4 cm TL, the average litter size (f) was 30 pups, and the reproductive cycle (R_c) was 2 years. Chou (2004) conducted an age and growth study on smooth hammerhead shark in the northeastern waters of Taiwan. For males, the asymptotic length (L_∞) was 358.8 cm TL, the growth coefficient (k) was 0.128 $year^{-1}$, and the theoretical age at zero length (t_0) was -0.72 year. For females, the asymptotic length was 375.2 cm TL, k was 0.111 $year^{-1}$, and t_0 was -1.31 year. The age at maturity (t_{mat}) was 11 years.

Liu et al. (2013) used age-structured analysis to estimate the biomass and fishing mortality of scalloped hammerhead shark and smooth hammerhead shark. The results showed that the biomass of scalloped hammerhead shark had been declining since 1989.

The spawning potential ratio (SPR) per recruit results indicated that, except for the periods 1991–1995 and 2000–2002, and the year 2008, during which the 95% confidence intervals of SPR included the biological reference point of SPR = 0.4, the SPR values in the other 10 years were below 0.4, with 6 years below 0.3. Therefore, it was recommended that catches should be reduced and mature individuals should be protected.

For the smooth hammerhead shark, the results indicated that its stock status was relatively good. The 95% confidence intervals of SPR in all years were above the biological reference point of 0.3, and 13 years had values higher than this reference point. However, SPR has shown a declining trend in recent years, indicating that continued monitoring of its stock status is needed.

Tsai et al. (2018) used yield-per-recruit (YPR) and spawning potential ratio (SPR) analyses to estimate the biological reference points (BRPs) and population status of smooth hammerhead shark in the northwestern Pacific Ocean. The YPR results showed that the current fishing mortality rate (Fcur) for males was lower than the $F_{0.1}$ biological reference point, but higher than the female F0.1. In addition, the SPR analysis indicated that the current SPR (SPRcur) was substantially lower than both the target reference point (SPR35%) and the threshold reference point (SPR30%). This finding suggests

that, under the current fishing level, female smooth hammerhead sharks in the northwestern Pacific Ocean are overexploited. It was recommended that the population status of smooth hammerhead shark should be continuously monitored to ensure its sustainability.

Based on demographic analysis, Liu et al. (2015) estimated that, under an unfished condition, the intrinsic population growth rate (λ) of scalloped hammerhead shark was 1.275, the population doubling time was 2.9 years, and the generation time was 7.1 years. For smooth hammerhead shark, the intrinsic population growth rate (λ) was 1.166, the population doubling time was 4.5 years, and the generation time was 15.6 years.

Liu et al. (2021) conducted an ecological risk assessment for 11 pelagic shark species in Taiwan. The study estimated productivity indicators using the intrinsic rate of population increase method and estimated susceptibility indicators using catch percentage, selectivity, and post-capture mortality. These results were then integrated with the endangered status of the species, trends in catch size composition, and the inflection point of the population growth curve to conduct an integrated ecological risk assessment. The scalloped hammerhead shark was classified in the highest-risk group.

Because the scalloped hammerhead shark has life history characteristics such as a long life cycle, late sexual maturity, and large body size, although its litter size is

relatively higher than that of some other large shark species, its reproductive cycle is long. Therefore, the northwestern Pacific scalloped hammerhead shark cannot tolerate long-term high exploitation of young individuals. Once its abundance declines, recovery will be extremely difficult. Stock assessment and fisheries management for this species are therefore urgently needed (Liu and Chen, 1999).

Liu (2015) proposed Taiwan's NDF assessment procedure and completed an NDF assessment for scalloped hammerhead shark. However, the stock status of scalloped hammerhead shark showed a declining and overfished trend. Therefore, at present, an NDF certificate should not be issued for scalloped hammerhead shark, and export should not be permitted. Zhu (2020) conducted an NDF assessment for smooth hammerhead shark in Taiwan. The result was a "conditional NDF," indicating that management must be implemented and certain new conditions must be met before a positive NDF can be granted.

In response to the listing of hammerhead sharks in CITES Appendix II and their IUCN conservation status as Critically Endangered and Endangered, as well as the current lack of specific management measures for hammerhead sharks in Taiwan, this study attempts to conduct data surveys and NDF assessments for hammerhead sharks caught in Taiwan's coastal and offshore fisheries. The study further proposes

management measures and recommendations for hammerhead sharks in Taiwan as references for administrative authorities.

2.2 Overview of the development of Non-Detriment Findings (NDF)

Non-Detriment Findings (NDFs) are a core procedure required under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) before international trade of Appendix-listed species can be authorized by the Management Authority of a Party. The purpose of an NDF is to assess whether trade in the species will have a negative impact on the survival of its wild populations. In other words, export permits may be issued only when scientific evidence supports that export will not be detrimental to the stock status of the species.

To assist countries in establishing standardized and consistent assessment procedures, the German Federal Agency for Nature Conservation (BfN) convened shark conservation scientists and fisheries management experts from 14 countries in 2014 to develop the Guidance for CITES Scientific Authorities： Checklist to assist in making Non-Detriment Findings for sharks (Mundy-Taylor et al., 2014). The guidance proposed a six-step assessment process and an operational indicator framework, which have become important references for the development of shark NDF systems in several countries (Mundy-Taylor, 2014). Subsequently, CITES Parties have also developed

their own NDF assessment guidelines. For example, Japan published guidance for non-detriment risk assessment in 2016. Sri Lanka, following the guidance of Mundy-Taylor et al. (2014), completed NDF assessments for silky shark and three hammerhead shark species in 2017, with the results classified as "conditional NDF" and assigned a validity period of two years (Abernethy, 2017; Pierce, 2017). Australia conducted NDF analyses for five large shark species, including scalloped hammerhead shark, winghead shark, smooth hammerhead shark, porbeagle shark, and silky shark, and proposed specific fishery management recommendations (Australian Government, 2014). New Zealand also completed an NDF assessment for shortfin mako shark within its Exclusive Economic Zone (EEZ) to confirm the legality and sustainability of its exports. India established NDF procedures for CITES Appendix II-listed hammerhead sharks, silky shark, scalloped hammerhead shark, and two species of mobulid rays (Zacharia et al., 2017; Kizhakudan et al., 2019), indicating that NDFs have gradually become an important tool for the international trade management of sharks.

In Taiwan, earlier NDF assessments referred to the assessment frameworks developed by Germany and Australia. Assessments were conducted for the northwestern Pacific scalloped hammerhead shark, smooth hammerhead shark, bigeye thresher shark, and shortfin mako shark. The results showed that, except for shortfin

mako shark, the stock status of the other species was generally not optimistic (Liu, 2015, 2016, 2017, 2019). In 2018, the Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC) and the German BfN jointly established the electronic Non-Detriment Finding (e-NDF) system. This system transformed the original steps and indicators into a systematic process with predefined calculation formulas. Users only need to enter the required data to obtain corresponding risk assessments and NDF determinations, including positive, negative, or conditional NDF. This greatly improved the transparency and consistency of practical NDF implementation.

In recent years, Taiwan has also applied the e-NDF framework to several assessments. Chang (2016) conducted an e-NDF assessment for the Pacific scalloped hammerhead shark, and Zhu (2020) conducted an assessment for the Pacific smooth hammerhead shark. Both studies identified areas where Taiwan still needs to strengthen data collection, monitoring systems, and supporting management measures. Liu (2022) further integrated previous results and revised the shark NDF assessment steps for Taiwan. To date, Taiwan has completed assessments for species including the northwestern Pacific scalloped hammerhead shark, smooth hammerhead shark, bigeye thresher shark, silky shark, and shortfin mako shark. In the Indian Ocean, Tsai (2019), Zhang (2022), and Huang (2024) also completed NDF studies. The results showed that

silky shark and shortfin mako shark were generally classified as conditional NDF, whereas blue shark could be granted a positive NDF. Overall, these NDF studies have become important scientific bases for Taiwan's fisheries authorities when reviewing the export trade of these species, and have also clearly identified aspects requiring strengthened management in the future.

Within this context, this project will collect and analyze relevant domestic and international information in order to establish the NDF assessment procedures and methods for important trade-regulated shark species in Taiwan's fisheries across different ocean regions. Data sources include domestic and international academic papers and journals, official government information, publications, conference materials, and relevant industry websites. The contents cover the life history parameters, stock abundance, international trade status, and management measures of the assessed species. In addition, the project will refer to the procedures and assessment results of Scientific Authorities and management agencies in Germany, Australia, Japan, Sri Lanka, India, and New Zealand for CITES Appendix II-listed shark species. Their assessment indicators and management practices will be analyzed, and previous research results from Taiwan's NDF assessments of shark species in different ocean regions will be compiled. These materials will serve as the basis for developing

Taiwan's NDF framework for important trade-regulated shark species in fisheries and for proposing subsequent management recommendations.

Chapter 3 RESEARCH PURPOSES

Non-Detriment Findings (NDFs) remain a relatively emerging management tool internationally. Their institutionalization and practical implementation are still under continuous development, and only a limited number of countries have established practical implementation cases to date. Species of the family Sphyrnidae are common shark bycatch groups in pelagic tuna longline fisheries operating in the Western and Central Pacific Ocean and the Indian Ocean. Due to population risks and international trade pressure, most species have been listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Therefore, an NDF must be completed before export to ensure that trade activities will not be detrimental to wild population resources.

Given that species of the family Sphyrnidae are widely distributed, frequently encountered in cross-ocean fishing operations, and subject to different fishery patterns and management measures among ocean regions, it is necessary to conduct region-specific assessments for the major fishing areas. Therefore, this project will follow Taiwan's existing shark NDF assessment steps and framework to conduct a systematic NDF risk assessment for Sphyrnidae species bycaught by Taiwanese tuna longline vessels during fishing operations in the Western and Central Pacific Ocean and the

Indian Ocean. Based on the integrated assessment results, specific management and policy recommendations will be proposed as references for Taiwan's subsequent implementation of NDF reviews and adjustment of management measures for Sphyrnidae species.

Chapter 4 ELECTRONIC NDF ASSESSMENT METHOD

Step 1： Primary information collection

This step serves as the pre-assessment preparation. Basic preliminary information on the species must be collected and compiled to confirm whether an NDF assessment is required for export. The assessed species must be listed in CITES Appendix II, and the specimens must be legally obtained. Subsequently, information from Regional Fisheries Management Organizations (RFMOs) is collected to determine whether the species is listed as a prohibited shark species. If the species is listed as prohibited for retention, the NDF determination does not need to proceed and the assessment is stopped. If the above conditions are met, the species then proceeds to the following assessment steps.

Step 2： Biological Vulnerability and Conservation Concern

This step consists of two parts.

2.1 Existing biological vulnerability

This part evaluates whether the species would face difficulties in resource recovery after exploitation due to its biological characteristics. A total of 11 indicators are included： age at maturity (t_{mat}), length at maturity (L_m), maximum age (T_m), asymptotic length (TL_∞), natural mortality rate (M), litter size (f), intrinsic rate of population increase (r), geographic distribution range, stock assessment, behavioral factors, and trophic position. The criteria and scores for each indicator follow the original table. The final score is obtained by summing the scores of all indicators. A total score of 11–17 indicates low risk, 18–26 indicates medium risk, and 27–33 indicates high risk. A higher risk level indicates a greater risk that the species will be difficult to recover after exploitation.

The criteria for “existing biological vulnerability” are as follows：

(1)Age at maturity (t_{mat})

If age at maturity is less than 5 years, the risk level is low and the score is 1. If age at maturity is between 5 and 15 years, the risk level is medium and the score is 2. If age at maturity is greater than 15 years, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(2) Length at maturity (L_m)

If length at maturity is less than 40 cm, the risk level is low and the score is 1. If length at maturity is between 40 and 200 cm, the risk level is medium and the score is 2. If length at maturity is greater than 200 cm, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(3)Maximum age (T_m)

If maximum age is less than 10 years, the risk level is low and the score is 1. If maximum age is between 10 and 25 years, the risk level is medium and the score is 2. If maximum age is greater than 25 years, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(4)Asymptotic length (TL_∞)

If asymptotic length is less than 100 cm, the risk level is low and the score is 1. If asymptotic length is between 100 and 300 cm, the risk level is medium and the score is 2. If asymptotic length is greater than 300 cm, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(5)Natural mortality rate (M)

If the natural mortality rate M is greater than 0.4, the risk level is low and the score is 1. If M is between 0.17 and 0.4, the risk level is medium and the score is 2. If M is less than 0.17, the risk level is high and the score is 3. If data for this

item are lacking, the risk level is unknown and the score is 3.

(6)Litter size (f)

If litter size f is greater than 15, the risk level is low and the score is 1. If f is between 2 and 15, the risk level is medium and the score is 2. If f is less than 2, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(7)Intrinsic rate of population increase (r)

If the intrinsic rate of population increase r is greater than 0.35, the risk level is low and the score is 1. If r is between 0.15 and 0.35, the risk level is medium and the score is 2. If r is less than 0.15, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(8)Geographic distribution range

If the species has a global distribution, the risk level is low and the score is 1. If the species has a regional distribution, the risk level is medium and the score is 2. If the species has a national distribution, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(9)Stock assessment

If $F <= F_{MSY}$ and $B >= B_{MSY,}$ the risk level is low and the score is 1. If $F = F_{MSY}$ and $B = B_{MSY,}$ the risk level is medium and the score is 2. If $F >= F_{MSY}$ and $B <= B_{MSY}$, the risk level is high and the score is 3.

(10) Behavioral factors

The term “behavioral factors” in this item refers to behavioral characteristics related to the species’ ecology and behavior that may affect its probability of

capture, survival rate, or population recovery capacity, such as schooling behavior, vertical or horizontal migration patterns, and tendency to interact with fishing gear. It does not refer broadly to all biological characteristics. If only a few behavioral factors increase stock risk, the risk level is low and the score is 1. If some behavioral factors increase stock risk, the risk level is medium and the score is 2. If multiple behavioral factors increase stock risk, the risk level is high and the score is 3. If sufficient behavioral data are lacking, the risk level is regarded as unknown and, based on the precautionary principle, the score is 3. This classification reflects the relative risk differences among species caused by behavioral characteristics and is consistent with the basic principle of CITES NDF assessments, which adopt a conservative approach when data are limited.

(11) Trophic position

If the species is located at a low trophic position, the risk level is low and the score is 1. If the species is located at an intermediate trophic position, the risk level is medium and the score is 2. If the species is located at a high trophic position, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

2.2. Degree of conservation concern

This part further assesses key conservation factors, including conservation and stock assessment status, population trend, and the regional range of conservation concern. Each indicator is determined according to the original table. A total score of 3–4 indicates low risk, 5–7 indicates medium risk, and 8–9 indicates high risk. In theory, species with higher biological vulnerability are also expected to receive higher conservation concern. This is particularly true for many shark species, which exhibit K-selected life history traits and whose populations are highly sensitive to fishing impacts.

The criteria for “degree of conservation concern” are as follows：

(1)Conservation and stock assessment status

If the species stock is not overfished and is currently listed by IUCN as Least Concern (LC), the risk level is low and the score is 1. If the species stock is subject to overfishing or has been overfished, and is currently listed by IUCN as Near Threatened (NT) or Vulnerable (VU), the risk level is medium and the score is 2. If the species stock is subject to overfishing and has been overfished, and is currently listed by IUCN as Endangered (EN) or Critically Endangered (CR), the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(2) Population trend

If the species population shows an increasing trend, the risk level is low and the score is 1. If the species population is stable, the risk level is medium and the score is 2. If the species population shows a decreasing trend, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(3)Regional range of conservation concern

The focus of this assessment is to determine whether the main threats in the assessed ocean region may affect the overall stock status of the species or its important reproductive, recruitment, and migration processes. If the main threats faced by the species affect only a few stocks, the risk level is low and the score is 1. If the main threats affect some stocks, the risk level is medium and the score is 2. If the main threats affect global stocks, the risk level is high and the score is 3. If the stock structure has not yet been clearly resolved, the

precautionary principle adopted by CITES NDF assessments is followed. Such threats are regarded as having potential trans-regional impacts, the risk level is considered unknown, and the score is 3.

Step 3： Pressures on species, with emphasis on fishing pressure

The IUCN Global Shark Red List Assessment indicated that fishing mortality, including targeted fishing and bycatch, is the single greatest cause of shark population declines, and that international trade drives a substantial proportion of this mortality. Therefore, Step 3 focuses on the impacts of fishery exploitation on shark populations, because fishing-induced mortality is a core factor that must be considered when making CITES Non-Detriment Findings.

However, the first part of this step, Section 3.1, also considers trade dynamics, because trade can drive fishing activities and provides important context for understanding the fishing pressure assessed in Section 3.2. When fishery-dependent or fishery-independent data are lacking, trade data may also serve as an alternative indicator for assessing the severity of fishing pressure.

Compared with fishery exploitation, other threats to sharks, such as habitat loss and degradation, pollution, reduction in food resources, and climate change, usually have only secondary impacts on their status. Therefore, Step 3 does not specifically discuss these threats. However, if a particular stock is indeed affected by such threats, the need for a higher level of precaution should be considered when determining whether a positive or negative NDF should be issued.

3.1 Evaluation of trade pressures

Trade activities may have significant adverse impacts on the survival of a

species, mainly because they can increase fishing pressure and unsustainable harvest rates, thereby increasing total population mortality. This is one of the core threats of concern under CITES. Scientific Authorities may identify and assess the impacts on populations by understanding the scale and trends of legal and illegal trade, including both domestic and international trade.

Analysis of trade dynamics helps to understand the formation of fishing pressure and patterns of exploitation. When fishery data are lacking, relevant trade information may also serve as an alternative basis. Nevertheless, the ultimate purpose of this step remains the assessment of overall fishery mortality, which is further described in Step 3.2.

Although Step 3.2 examines the impacts of all fishing activities on populations, regardless of whether the products ultimately enter domestic or international markets, it is still necessary to compare the relative pressure caused by international and domestic trade, including both legal and illegal trade. If certain shark products have high economic value in international markets, such demand may promote increased catches, especially in stocks with insufficient management (Lack et al., 2014). In addition, higher international prices may increase the risk of products being laundered into legal trade systems.

This section follows the CITES guidance and divides trade pressure into two main factors：

(a) Magnitude of legal trade：

If the trade volume is very small relative to the abundance of the species, trade volume or market demand is declining, and there is no product shortage in the market, the risk level is low and the score is 1. If the trade volume is moderate relative to the abundance of the species, and trade volume or demand is stable or slowly increasing, the risk level is medium and the score is 2. If the species has

multiple commercial uses, involves various products and markets, the trade volume is high relative to species abundance or utilized parts, trade volume is rapidly increasing or declining because of limited resources, product prices are high or rising rapidly, market shortages occur, or there is insufficient information for assessment, the risk level is high and the score is 3.

(b) Magnitude of illegal trade：

This assessment item highlights the importance of Taiwan's current establishment of detailed commodity classification codes, namely CCC Codes. By subdividing commodity codes to the species level, the identification and accuracy of specific species in legal trade declarations and statistical data can be effectively improved, providing substantial benefits for trade management. However, the tracking of illegal trade activities often relies on information from seizure records, judicial cases, or law enforcement cases. Due to limitations in data availability and case disclosure, such information is unlikely to fully reflect actual trade flows ('t Sas-Rolfes et al., 2019; UNODC, 2024). In the future, gradually integrating risk-based inspection mechanisms, cross-national trade data comparisons, species identification techniques, and law enforcement information will help reduce uncertainty in the assessment process and strengthen the analytical basis. Although illegal trade may still occur through non-declaration, misreporting, transshipment, or other means of evading regulation, and may not be included in official trade statistics, the establishment of export commodity codes has positive and important institutional significance for strengthening trade management mechanisms and deterring illegal trade activities. This is particularly important because transnational re-export activities and differences in national reporting systems may create discrepancies between trade routes and actual sources, thereby increasing uncertainty in interpreting the scale of illegal trade.

If domestic and international trade records are complete, trade chains are transparent, concerns regarding substitution by similar species are low, and catch volume is consistent with legal domestic transaction volume and reported export volume, the risk level is low and the score is 1. If trade records are partially complete, trade chains are difficult to trace, there are concerns regarding substitution by similar species, or there are inconsistencies between catch volume and legally reported volume, the risk level is medium and the score is 2. If there are records of illegal trade, trade records are insufficient or of poor quality, trade chains are not transparent, the risk of substitution by similar species is high, or legal export volumes are significantly lower than the import volumes reported by importing countries, the risk level is high and the score is 3. Due to the nature and limitations of the available data for assessment, if sufficient information is lacking, the risk level is regarded as unknown and a conservative score of 3 is assigned.

3.2 Evaluation of fishing pressures on the species

The assessment includes four indicators： fishing mortality, survival rate after discard, fishing gear selectivity, and the scale of IUU fishing. Since Taiwan has only recently established species-specific commodity classification codes, or CCC Codes, for hammerhead sharks, thresher sharks, and other shark species, it is currently difficult to obtain detailed export quantities and transaction price data to assess trade pressure. Therefore, this study treats trade pressure as a reference for future management recommendations, and Step 3 focuses primarily on the evaluation of fishing pressure. Each indicator is determined according to the original table. A total score of 4–6 indicates low pressure, 7–9 indicates moderate pressure, and 10–12 indicates high pressure.

The criteria for “pressures on species” are as follows：

(1)Fishing mortality

If fishing activities reduce a low proportion of the population, the risk level is low and the score is 1. If fishing activities reduce some proportion of the population, the risk level is medium and the score is 2. If fishing activities reduce a high proportion of the population, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(2)Survival rate after discard

If only a small proportion of the species catch is discarded and the survival rate after release is high, the risk level is low and the score is 1. If some proportion of the species catch is discarded and the survival rate after release is moderate, the risk level is medium and the score is 2. If most of the species catch is discarded and the survival rate after release is low, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

(3)Fishing gear selectivity

If the fishing gear is highly selective and can effectively target individuals of specific ages, sizes, or sexes, its disturbance to population structure is relatively small. The risk level is low and the score is 1. If the fishing gear has moderate selectivity, it may restrict the capture of certain components of the population to some extent, but may still have a moderate impact on population structure. The risk level is medium and the score is 2. If the fishing gear has low selectivity and cannot effectively distinguish or exclude individuals of specific ages, sizes, or sexes, it may have a greater impact on population structure. The

risk level is high and the score is 3. If relevant data are lacking to assess fishing gear selectivity, the risk level is regarded as unknown and the score is also 3 to reflect potential uncertainty.

(4)Scale of IUU fishing

If there are detailed trade records for the species, the trade chain is transparent and publicly available, and trade volume roughly corresponds to catch volume, the risk level is low and the score is 1. If there are adequate trade records for the species, the trade chain is difficult to trace, and trade volume partially corresponds to catch volume, the risk level is medium and the score is 2. If trade records for the species are incomplete, the trade chain is not transparent or publicly available, and there is a large discrepancy between trade volume and catch volume, the risk level is high and the score is 3. If data for this item are lacking, the risk level is unknown and the score is 3.

Step 4： Evaluation of existing management measures

This step aims to confirm whether CITES Appendix II species are subject to appropriate management measures that reduce utilization risk and achieve sustainability objectives. This step identifies the various management measures currently implemented for the assessed species or stock. These measures may be derived from national, regional, or international levels, and can be divided into two major categories：

(1) Generic fisheries management measures：

These measures are not specifically designed for a particular species, but may still provide certain benefits to its population. Examples include limited entry, catch limits or fishing effort controls for other species, regulations for specific species groups such as shark finning bans or requirements for sharks to

be landed with fins naturally attached, and restrictions on the use of certain fishing gears. Although such measures are not specifically designed for the assessed species, they may indirectly reduce fishing pressure.

(2) Species-specific management measures：

These measures are directly designed for the assessed species. Examples include species-specific catch quotas, effort controls for target fisheries of the species, spatial closures established to protect specific life history stages, and retention bans for certain non-target shark species adopted by some Regional Fishery Bodies (RFBs). Such measures may also require that bycaught individuals be immediately and safely released at sea to improve their survival rate (Lack et al., 2014).

This step evaluates whether current management measures are sufficient, in terms of both “design” and “implementation,” to mitigate the fishing and trade pressures affecting the target species population. Whether these measures are actually effective is further assessed in Question 4.1(b).

(a) Management design：

To determine whether management measures are properly designed, the “generic fisheries management measures” and “species-specific management measures” compiled during the preparatory stage of Step 4 must be compared with the fishing and trade pressures identified in Step 3. Existing management measures are evaluated in terms of which fishing or trade pressures they can mitigate. For example, whether a measure can reduce bycatch pressure and thereby protect the species is considered. This section mainly assesses whether the types of measures are appropriate. Whether the measures are consistent with scientific advice is discussed later when their effectiveness is assessed in Question 4.1(b).

(b) Management implementation：

This part evaluates whether monitoring, control, and surveillance (MCS) systems are sufficient to ensure the implementation of and compliance with management measures. MCS is an important mechanism for ensuring the implementation of fishery management policies, plans, and strategies, and is an indispensable foundation of management systems. For all management measures described above, it is necessary to determine which MCS measures can ensure their implementation and compliance.

The higher the biological vulnerability, conservation concern, and fishing pressure risk of a species, the stricter the management measures required to mitigate the impacts. To systematically evaluate the actual mitigation effect of existing management measures on the pressures faced by the population, this study establishes a risk-based scoring framework. Each management tool is classified into three levels according to the directness and strength with which it can reduce pressure： low risk, scored as 1; medium risk, scored as 2; and high risk, scored as 3. The overall principle is that management measures capable of directly and effectively limiting catch or reducing mortality are assigned lower risk. Measures that are more indirect or highly dependent on implementation are assigned medium risk. If relevant management measures are completely lacking, the risk is regarded as high.

For fishing pressure, quota systems such as TAC or ITQ that directly limit total catch are regarded as the lowest risk, scored as 1, because they can clearly establish an acceptable catch limit. Effort controls, limited entry systems, and catch data collection can regulate fishing capacity or support subsequent management, but their effects are relatively indirect. Therefore, they are classified as medium risk, scored as 2. If management measures are lacking for

this source of pressure, the risk is scored as 3.

For discard mortality, bycatch mitigation measures, safe release requirements, and studies on post-release survival can directly reduce the mortality risk of released individuals. These are therefore classified as low risk, scored as 1. Observer or electronic monitoring systems, port inspections, and biological sampling can improve data quality and provide mortality estimates, but they cannot directly reduce mortality. These are therefore classified as medium risk, scored as 2. If no relevant measures are in place, the risk is scored as 3.

For management of size, age, and sex selectivity, minimum catch size limits, mesh size regulations, and spatial or temporal closures targeting juveniles or spawning grounds can directly protect specific life history stages. These are therefore classified as low risk, scored as 1. Measures that indirectly affect population structure, such as restrictions on fishing depth or areas, are classified as medium risk, scored as 2. The absence of such measures is regarded as high risk, scored as 3.

The scoring of risks related to illegal, unreported, and unregulated (IUU) fishing reflects transparency and enforcement strength. Vessel monitoring systems (VMS/AIS), white-list management, port State measures, and bans on transshipment at sea can directly improve traceability and suppress unauthorized fishing operations. These are therefore classified as low risk, scored as 1. Deterrent penalty systems, observer and electronic monitoring, traceability systems, and national plans of action with IUU measures can strengthen governance, but their actual effectiveness depends heavily on enforcement. These are therefore classified as medium risk, scored as 2. If no measures exist for this source of pressure, the risk is scored as 3.

Step 5：Non-Detriment Finding determination

The risk scores from Steps 2 to 4 are summed to determine the NDF result：

(1) A total score of 25–40 indicates a positive NDF, and certification may be issued for export.

(2) A total score of 41–60 indicates a conditional NDF, and certification may be issued only after the attached conditions are fulfilled.

(3) A total score of 61–75 indicates a negative NDF, and management improvements are required.

Step 6： Management recommendations

Step 6 aims to propose monitoring plans and management recommendations suitable for implementation by Taiwan, based on the preceding assessment results. These recommendations serve as a basis for subsequent management improvement and resource enhancement. This step is not only applicable to species with negative NDF results, but may also be applied, depending on the risk level and management needs of the species, to conditional NDF species or other species for which management adjustments are needed. Corresponding management recommendations and monitoring measures can therefore be proposed.

Through the management and monitoring mechanisms established in Step 6, implementing agencies can gradually improve data quality, reduce management uncertainty, and systematically review the effectiveness of relevant management measures during future reassessments. The latest NDF determination results can then be revised and updated accordingly, forming an

adaptive management cycle with feedback capacity.

Referring to the guidance of the German BfN (Mundy, 2014), the validity period of an NDF is one year. After expiration, the NDF must be reviewed and updated based on the latest stock status in order to effectively manage the species resource.

Chapter 5 TABLE VISUALIZATION RESULTS OF NDF

I. Non-Detriment Finding Risk Assessment Report for Scalloped Hammerhead in the Pacific and Indian Oceans

Step 1： Primary information collection

Species	CITES Appendix II	RFMOs control measures		Comply with NDF process
Scalloped Hammerhead	2013 Included	Western and Central Pacific Ocean	Non-Prohibited	Yes
		Indian	Non-Prohibited	Yes

The species meets the above criterion; it indicates that it will proceed to the subsequent steps of the assessment process.

Step 2： Biological Vulnerability and Conservation Concern

2.1 Existing Vulnerability:

Item		Risk level			Scalloped Hammerhead	
2.1 Existing Vulnerability		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Size at maturity (t_{mat})	<5	5-15	>15	4.7	13.2
2	Length at maturity (L_m)	<40	40-200	>200	230	220.5
3	Maximum age (T_m)	<10	10-25	>25	15	35
4	Asymptotic length (TL_∞)	<100	100-300	>300	319	399
5	Natural mortality (M)	>0.4	0.17-0.4	<0.17	0.4185	0.18
6	Little size (f)	>15	2-15	<2	25.8	26.5
7	Intrinsic rate of population increase (r)	>0.35	0.15-0.35	<0.15	0.243	0.175
8	Geographic distribution range	Global	Regional	National	National	National
9	Stock assessment	$F<=F_{MSY}$ $B>=B_{MSY}$	$F=F_{MSY}$ $B=B_{MSY}$	$F>=F_{MSY}$ $B<=B_{MSY}$	None	None
10	Behavior factor	Few behavioral factors	Some behavioral factors	Multiple behavioral factors	Multiple behavioral factors	Multiple behavioral factors
11	Trophic position	Low	Median	High	High	High
Total/Rank		**11-17**	**18-26**	**27-33**	**23**	**26**

Remark (data source): Chen et al. (1988), Chen et al. (1990), Chodrijah and Faizah (2021), Geng et al. (2021), Hearn et al. (2010), Huynh and Tsai (2023), IOTC Secretariat. (2015), Geng (2022), Jacoby et al. (2012), Jacoby et al. (2022), Klimley (1985), Liu and Chen (1999), Liu et al. (2021), Thomas et al. (2022), Galván-Magaña et al. (2019), Li et al. (2024), Zhang et al. (2025).

The assessment items for biological vulnerability indicators include 11 parameters: age at maturity (t_{mat}), length at maturity (L_m), maximum age (T_m), asymptotic length (TL_∞), natural mortality rate (M), litter size (f), intrinsic rate of population increase (r), geographic distribution, stock status, behavioral factors, and trophic position. In this study, biological, demographic, ecological, and environmental adaptability-related literature provided by previous studies was reviewed to conduct biological vulnerability assessments and risk classifications for Scalloped Hammerhead Shark in Western and Central Pacific Ocean.

In this step, biological parameters for scalloped hammerhead shark in the Western and Central Pacific Ocean were adopted from Chen et al. (1988), Chen et al. (1990), Liu and Chen (1999), and Liu et al. (2021). Biological parameters for the Indian Ocean were adopted from Chodrijah and Faizah (2021), Geng et al. (2021), IOTC Secretariat (2015), Jacoby et al. (2022), and Thomas et al. (2022). For ecological and environmental adaptability parameters, references for the Western and Central Pacific Ocean included Huynh and Tsai (2023), Rigby et al. (2019d), Klimley (1985), Hearn et al. (2010), and Jacoby et al. (2012). For the Indian Ocean, references included Geng et al. (2021), IOTC Secretariat (2015), Geng (2022), and Jacoby et al. (2022). Together with the IOTC–2015–SC18–ES19[E] report, these sources indicate that the aggregation behavior of scalloped hammerhead shark and the occupation of coastal nursery grounds by juveniles are key behavioral factors contributing to high vulnerability in the Indian Ocean.

The stock status was based on the latest review results released by the Scientific Committee at the 21st Regular Session of the Western and Central Pacific Fisheries Commission (WCPFC SC21) and the WCPFC Secretariat in October 2025. At present, the stock status of this species is assessed as “unknown.” Because catch data are often confused with those of other hammerhead shark species, such as *Sphyrna zygaena* and Sphyrna mokarran, and because historical catch and biological data are incomplete, it is currently not possible to conduct a conventional age-structured stock assessment. In addition, due to insufficient information for establishing clear target reference points for scalloped hammerhead shark, its stock status cannot yet be quantitatively determined.

For the Indian Ocean, according to the report presented by the IOTC Working Party on Ecosystems and Bycatch (WPEB) in 2022 (IOTC–2022–WPEB18–R[E]) and Appendix IX of the

2025 Scientific Committee report (IOTC-2025-SC28-ES19_SPLE), the official qualitative assessment for this species remains “data-poor, with highly uncertain stock status.” Multiple stable isotope studies have confirmed that pelagic sharks occupy a high-trophic niche in marine food webs and play an indispensable role as apex predators (Galván-Magaña et al., 2019). Studies have indicated that tropical pelagic shark assemblages maintain ecosystem functions through trophic niche partitioning (Li et al., 2024). Recent studies using multi-tissue analyses of species from the South China Sea further showed that the trophic position of some sharks may reach TPmuscle ≈ 4.6, again confirming their key position at the top of marine food chains (Zhang et al., 2025).

Based on the comprehensive assessment, the total biological vulnerability score was 23 for the Western and Central Pacific Ocean and 26 for the Indian Ocean. Overall, both ocean regions were classified as medium risk.

2.2 Degree of conservation attention

Item		Risk level			Scalloped Hammerhead	
2.2 Degree of conservation attention		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Conservation and Stock Status	LC	NT/VU	EN/CR	CR	CR
2	Population Trend	Increasing	Stable	Decreasing	None	Decreasing
3	Conservation Concern in Regional Range	Few	Some	Global	Global	Global
Total/Rank		**3-4**	**5-7**	**8-9**	**9**	**9**

Remark (data source): Camhi et al. (2008), Clarke et al. (2006a), Clarke et al. (2006b), Dent and Clarke (2015), Dudley and Simpfendorfer (2006), Fields et al. (2018), Martínez-Ortiz et al. (2015), Rigby et al. (2019d), Simpfendorfer et al. (2010), Temple et al. (2019)

In this step, the assessment information for scalloped hammerhead shark was mainly based on the assessment results provided by IUCN in Rigby et al. (2019d). Except for the Northwest Atlantic and the Gulf of Mexico, where populations have shown signs of stability or recovery due to the implementation of management measures, populations in other regions have continued to decline. Based on the global assessment results weighted by population trends across different ocean regions, the median global population decline over three generation lengths, approximately 72.3 years, ranged from 76.9% to 97.3%, with the highest probability indicating a decline of more than 80%.

Relevant regional studies have also shown similar trends, including those in the South Pacific (Simpfendorfer et al., 2010) and the Indian Ocean (Dudley and Simpfendorfer, 2006). For the Western and Central Pacific Ocean, relevant literature is lacking; therefore, the population trend is considered unknown.

The species is subject to fishing pressure globally, both as a target catch and as bycatch (Camhi et al., 2008). It is also threatened across different regions, particularly in coastal environments (Camhi et al., 2008; Martinez-Ortiz et al., 2015; Temple et al., 2019). In

addition, the species has commercial value, especially in relation to shark products traded internationally (Clarke et al., 2006a; Clarke et al., 2006b; Dent and Clarke, 2015; Fields et al., 2018).

Step 3： Pressures on species, with emphasis on fishing pressure

Item		Risk level			Scalloped Hammerhead	
3.1 Evaluation of trade pressures		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Magnitude of legal trade	Small scale	Medium scale	Large scale	Small scale	Small scale
2	Magnitude of illegal trade	Small scale	Medium scale	Large scale	None	None
Total/Rank		1-2	3-4	5-6	3	3
3.2 Evaluation of fishing pressures on the species		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Fishing Mortality	Mortality Low	Mortality Median	Mortality High	None	None
2	Survival rate of discarded	High Survival	Median Survival	Low Survival	Low Survival	Low Survival
3	Fishing Gear Selectivity	High gear selectivity	Moderate gear selectivity	Low gear selectivity	High gear selectivity	High gear selectivity
4	IUU Fishing Scale	Detailed records	Appropriate records	Incomplete	Detailed records	Detailed records
Total/Rank		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): Cortés et al. (2010), de Bruyn et al. (2005), Casper et al. (2005), Murua et al. (2018), Bhanja and Mandal (2024).

Low fishing gear selectivity indicates that the gear is likely to capture large numbers of non-target species and juveniles, resulting in significant impacts on the ecosystem. Therefore, it is classified as high risk. In contrast, high fishing gear selectivity indicates that the gear can effectively target the intended species, with limited bycatch and minimal impacts on non-target species and juveniles. It is therefore classified as low risk.

In terms of legal trade, since April 2023, scalloped hammerhead shark-related products have been eligible for declaration and statistical compilation through more detailed CCC Codes. This has provided official trade data with a certain degree of identifiability in terms of product types and quantities. According to CITES and FAO guidance on the use of trade data in NDF assessments, when export quantities can be monitored through the formal customs declaration system and do not show abnormally rapid growth or significant deviation from catch source volumes, the “magnitude of legal

trade" can generally be regarded as relatively low risk (CITES, n.d.). Existing studies have indicated that, for aquatic products that have been incorporated into national customs classification systems and are subject to continuous monitoring, legal trade itself does not necessarily constitute the main source of pressure on populations, unless trade volume clearly does not correspond with resource status (Mundy-Taylor, 2014). Therefore, this study assessed the magnitude of legal trade for scalloped hammerhead shark in both the Western and Central Pacific Ocean and the Indian Ocean as low, with a score of 1.

Although Taiwan has established a relatively comprehensive CCC Code classification system and implemented related fishery and trade management measures, which have substantially improved the traceability and overall transparency of legal trade, international literature and CITES NDF guidance indicate that illegal and IUU trade activities are inherently difficult to fully reflect in formal customs declarations and trade statistics. In particular, because shark products are often traded in processed forms and real-time species identification has certain technical limitations, there remains potential uncertainty that products from illegal sources may enter legal supply chains (Cardeñosa et al., 2017, 2018; Sas-Rolfes et al., 2019).

Based on currently available information, there is still insufficient evidence, such as trends in seizure cases, judicial penalty statistics, or systematic forensic species identification data, to further quantify the magnitude of illegal trade. However, according to CITES (2023), hammerhead shark fins are targeted by illegal fishers because their prices are much higher than those of ordinary shark fins, and records of illegal trade still exist even under fishing bans or CITES controls. Therefore, following the precautionary principle recommended in international NDF practice, this study temporarily assesses the magnitude of illegal trade in scalloped hammerhead shark in Taiwan as "unknown" and treats it as medium risk, with a score of 2, in order to ensure the robustness and international comparability of the assessment results.

According to the practical principles of CITES NDF assessments, when the magnitude of illegal trade lacks quantifiable evidence, it should be classified as "unknown" rather than being directly

equated with a specific scale. The determination of risk level should comprehensively consider international market demand for the species, product processing forms, difficulty of species identification, and existing literature identifying illegal trade hotspots. In situations where market incentives and supply chain opacity are relatively high, a more precautionary medium to high risk treatment should be adopted. Conversely, if the incentive for illegal trade is limited, it may be reasonably assessed as low risk.

Step 4： Evaluation of existing management measures

Item		Risk level			Scalloped Hammerhead	
Presence of appropriate management measures		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
4.1 Scale of management measures		Species-specific management measures	Generic fisheries management measures	None	Generic fisheries management measures	Generic fisheries management measures
Total/Rank		**1**	**2**	**3**	**2**	**2**
4.2 monitoring, control, and surveillance (MCS)		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Fishing pressure (F/Fmsy)	Low	Median	High	High	High
2	Discard mortality	Low	Median	High	High	High
3	Size/age/sex selectivity	Low	Median	High	Low	Low
4	IUU fishing prevention and control	Low	Median	High	Low	Low
Total/Rank		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): 農業部漁業署(2025a) 修法「鮪延繩釣或鰹鮪圍網漁船赴太平洋作業管理辦法」第57條。農業部漁業署(2025b)「鮪延繩釣漁船赴大西洋作業管理辦法」第41條。農業部漁業署(2025c)「鮪延繩釣漁船赴印度洋作業管理辦法」第39條。

Step 5：Non-Detriment Finding determination

Item	Risk level			Scalloped Hammerhead	
	Low risk	Median risk	High risk	Western and Central Pacific Ocean	Indian
Step 2.1	11-17	18-26	27-33	23	26
Step 2.2	3-4	5-7	8-9	9	9
Step 3.1	1-2	3-4	5-6	3	3
Step 3.2	4-6	7-8	9-12	8	8
Step 4.1	1	2	3	2	2
Step 4.2	4-6	7-9	10-12	8	8
Total	**25-40**	**41-60**	**61-75**	**53**	**56**
NDF assessment	**Positive**	**Conditional**	**Negative**	**Conditional**	**Conditional**

This study conducted a Non-Detriment Finding (NDF) assessment for scalloped hammerhead shark in the Western and Central Pacific Ocean and the Indian Ocean by Taiwan. The results for both ocean regions were classified as conditional NDF.

Step 6： Management recommendations

Based on the results of the present "conditional Non-Detriment Finding (NDF)" assessment for the scalloped hammerhead shark, *Sphyrna lewini*, the species shows characteristics of high conservation risk across multiple indicators in different ocean regions, including biological vulnerability, population recovery potential, fishery exposure, and degree of conservation concern. In particular, its life history traits, including late maturity, low reproductive capacity, and schooling behavior, make the species highly sensitive to fishing pressure and environmental changes. Even under conditions of relatively limited catch volume, population decline may still occur rapidly.

The present assessment also showed that several key assessment items had to be determined based on the conservative principle of "unknown equals high risk" due to insufficient basic biological parameters, such as growth, length at maturity, and mortality rate, as well as inadequate fishery-related data, including actual bycatch rate, discard rate, and post-release survival rate. This result highlights that current data gaps have become a core bottleneck limiting accurate stock assessment and effective management of scalloped hammerhead shark. If data collection and monitoring mechanisms are not systematically strengthened, it will be difficult to ensure the long-term effectiveness of management measures, even if current measures are already in place.

Based on the above risk context, in addition to continuing the implementation of the existing "fins naturally attached" policy and relevant CITES Appendix II requirements, it is recommended that Taiwan gradually introduce a science-based Total Allowable Catch (TAC) management system for scalloped hammerhead shark in both coastal/offshore and distant-water fisheries. Considering the current limitations in available data, data-limited stock assessment methods, such as CMSY, SPiCT, or length-based models, may first be applied to estimate biological reference points, such as MSY or alternative indicators. Under conditions of high uncertainty, conservative reduction coefficients

should be adopted to avoid the risk of overexploitation. The TAC should be adjusted through an annual rolling review mechanism, with quotas, fishing seasons, or closed periods dynamically adjusted according to the latest monitoring results and population trends. This would gradually establish an adaptive management framework.

In addition, it is recommended that length-frequency data and maturity information be further integrated to evaluate the introduction of minimum catch size limits or measures prohibiting the catch of immature individuals, in order to reduce direct impacts on population recruitment. Such measures are particularly applicable to coastal and offshore waters where scalloped hammerhead sharks have distinct nursery and growth habitats, and may serve as a scientific basis for spatial management measures, such as seasonal closures or juvenile protection areas. When combined with port inspection systems, these measures would help improve the enforceability of management actions and compliance.

Considering that scalloped hammerhead shark is a frequently bycaught species in longline, set-net, and other fisheries, management strategies should gradually expand from “prohibition-based” measures to “reduction-based” and “behavior-oriented” measures. It is recommended that resources continue to be invested in the development and promotion of fishing gear modifications and bycatch reduction techniques, such as adjustments to hook type, fishing depth, and operation time, as well as operational practices that reduce bycatch of juveniles and non-target species. At the same time, institutionalized subsidies and technical guidelines should be used to increase incentives for fishers to adopt more shark-friendly fishing practices.

At the implementation level, fisher education, training, and on-site guidance should be strengthened. When scalloped hammerhead sharks are captured and still alive, “best-practice live

release" procedures should be prioritized, including reducing deck exposure time, avoiding unnecessary injury, and applying appropriate release methods. These practices would improve post-release survival rates and substantially reduce actual fishing mortality.

Finally, it is recommended that the "chondrichthyan resource monitoring program" continue to be promoted and institutionalized. Fishing logbooks, biological sampling, observer data, and electronic monitoring data should be integrated into a long-term monitoring system. Through reasonable incentive mechanisms, fishers should be encouraged to accurately report catch composition and biological information, thereby gradually reducing uncertainty in key parameters. Improvement in the quality of basic data will directly affect core estimates such as population growth rate, mortality rate, and recruitment, and will determine the scientific credibility and management effectiveness of future TAC settings, closure designs, and NDF determinations.

II. Non-Detriment Finding Risk Assessment Report for Smooth hammerhead in the Pacific and Indian Oceans

Step 1： Primary information collection

Species	CITES Appendix II	RFMOs control measures		Comply with NDF process
Smooth hammerhead	2013 Included	Western and Central Pacific Ocean	Non-Prohibited	Yes
		Indian	Non-Prohibited	Yes

The species meets the above criterion; it indicates that it will proceed to the subsequent steps of the assessment process.

Step 2： Biological Vulnerability and Conservation Concern

2.1 Existing Vulnerability:

Item		Risk level			Smooth hammerhead	
2.1 Existing Vulnerability		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Size at maturity (t_{mat})	<5	5-15	>15	10	10
2	Length at maturity (L_m)	<40	40-200	>200	259.4	240
3	Maximum age (T_m)	<10	10-25	>25	None	None
4	Asymptotic length (TL_∞)	<100	100-300	>300	375.2	385
5	Natural mortality (M)	>0.4	0.17-0.4	<0.17	0.178	1.39
6	Little size (f)	>15	2-15	<2	30	33
7	Intrinsic rate of population increase (r)	>0.35	0.15-0.35	<0.15	0.153	None
8	Geographic distribution range	Global	Regional	National	全球性	全球性
9	Stock assessment	$F<=F_{MSY}$ $B>=B_{MSY}$	$F=F_{MSY}$ $B=B_{MSY}$	$F>=F_{MSY}$ $B<=B_{MSY}$	未知	未知
10	Behavior factor	Few behavioral factors	Some behavioral factors	Multiple behavioral factors	未知	部分行為
11	Trophic position	Low	Median	High	高	高
Total/Rank		**11-17**	**18-26**	**27-33**	27	25

Remark (data source): Chen et al. (1988), Chen et al. (1990), Chou (2004), Clarke et al. (2015), Dudley and Simpfendorfer (2006), Ebert et al. (2013), Huynh and Tsai (2023), IUCN (2018), IOTC (2015), Sabarros et al. (2022), Liu (2002), Liu and Chen (1999), Liu et al. (2015), Liu et al. (2021), Martinez-Ortiz et al. (2015), Rigby et al. (2019a), Simpfendorfer et al. (2010), Temple et al. (2019), Tsai et al. (2018) ；Appukuttan and Nair (1988), Clarke et al. (2015), Dicken et al. (2018), Ebert et al. (2013), Froese and Pauly (2016), Harry et al. (2011), IOTC (2015), Jabado and Ebert (2015), Manjusha et al. (2011), Rigby et al. (2019a), Stevens (1984),Galván-Magaña et al. (2019), Li et al. (2024), Zhang et al. (2025).

The assessment items for biological vulnerability indicators include 11 parameters: age at maturity (t_{mat}), length at maturity (L_m), maximum age (T_m), asymptotic length (TL_∞), natural mortality rate (M), litter size (f), intrinsic rate of population increase (r), geographic distribution, stock status, behavioral factors, and trophic position. In this study, biological, demographic, ecological, and environmental adaptability-related literature provided by previous studies was reviewed to conduct biological vulnerability assessments and risk classifications for Smooth hammerhead in Western and Central Pacific Ocean.

In this step, biological parameters for smooth hammerhead shark in the Western and Central Pacific Ocean were adopted from Chen et al. (1988), Chen et al. (1990), Chou (2004), Huynh and Tsai (2023), Chen (1999), Liu et al. (2015), Liu et al. (2021), Tsai et al. (2018), and Liu (2002). Biological parameters for the Indian Ocean were adopted from Harry et al. (2011), IOTC (2015), Jabado and Ebert (2015), Manjusha et al. (2011), IOTC (2015), and Stevens (1984). Ecological and environmental adaptability parameters were referenced from IUCN (2019), Froese and Pauly (2016), Ebert et al. (2013), IUCN (2018), Rigby et al. (2019a), Clarke et al. (2015), Dudley and Simpfendorfer (2006), Liu and Martínez-Ortiz et al. (2015), Sabarros et al. (2022), Simpfendorfer et al. (2010), Temple et al. (2019), Appukuttan and Nair (1988), Clarke et al. (2015), Dicken et al. (2018), and Ebert et al. (2013).

In the North Pacific, smooth hammerhead shark has been observed to exhibit behavioral characteristics such as migration, seasonal aggregation, and preference for coastal waters and continental shelf edges (Clarke et al., 2015; Ebert et al., 2013). However, this information is insufficient to comprehensively evaluate whether behavioral factors increase population risk or vulnerability for smooth hammerhead shark across the entire Pacific Ocean. Many studies have also noted that, due to limited catch data and incomplete behavioral studies, the impact of behavioral factors on the population cannot be precisely determined. Therefore, the influence level of behavioral factors for smooth hammerhead shark in the Pacific Ocean should currently be classified as unknown.

In the Indian Ocean and Australian waters, smooth hammerhead shark exhibits pronounced schooling behavior and seasonal migration characteristics (Sabarros et al., 2022; Dicken et al., 2018). These behaviors make the population highly susceptible to large-scale capture by fisheries in specific habitat hotspots, such as seamounts or particular coastal waters (Harry et al., 2011; Stevens, 1984), thereby increasing the risk of overexploitation. Therefore, this item is classified as medium risk. With regard to stock status, neither WCPFC nor IOTC has yet released a stock assessment report for this species.

Multiple stable isotope studies have confirmed that pelagic sharks occupy a high-trophic niche in marine food webs and play an indispensable role as apex predators (Galván-Magaña et al., 2019). Among tropical pelagic shark species, trophic niche partitioning and differentiated resource use reduce direct competition and allow multiple species to coexist within the same ecosystem (Li et al., 2024). Recent studies using multi-tissue analyses of species from the South China Sea further showed that the trophic position of some sharks may reach TPmuscle ≈ 4.6, again confirming their key position at the top of marine food chains (Zhang et al., 2025).

Based on the comprehensive assessment, the total biological vulnerability score was 27 for the Western and Central Pacific Ocean, which was classified as medium risk. The total biological vulnerability score for the Indian Ocean was 25, which was also classified as medium risk.

2.2 Degree of conservation attention

Item		Risk level			Smooth hammerhead	
2.2 Degree of conservation attention		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Conservation and Stock Status	LC	NT/VU	EN/CR	VU	VU
2	Population Trend	Increasing	Stable	Decreasing	Decreasing	Increasing
3	Conservation Concern in Regional Range	Few	Some	Global	Some	Some
Total/Rank		**3-4**	**5-7**	**8-9**	7	5

Remark (data source): Dicken et al. (2018), Tsai et al. (2018), Rigby et al. (2019a), IUCN (2019), Huynh and Tsai (2023).

In this step, conservation assessment information for smooth hammerhead shark was mainly based on the assessment results provided by IUCN in Rigby et al. (2019a) and IUCN (2019). For the Western and Central Pacific Ocean, population trends were referenced from the results of Tsai et al. (2018) and Huynh and Tsai (2023). For the Indian Ocean, the analysis of catch per unit effort (CPUE) in South Africa by Dicken et al. (2018) was adopted. Their results indicated that the population trend of smooth hammerhead shark was increasing, although the increase was slight and not statistically significant.

Step 3： Pressures on species, with emphasis on fishing pressure

Item		Risk level			Smooth hammerhead	
3.1 Evaluation of trade pressures		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Magnitude of legal trade	Small scale	Medium scale	Large scale	Small scale	Small scale
2	Magnitude of illegal trade	Small scale	Medium scale	Large scale	None	None
Total/Rank		1-2	3-4	5-6	3	3
3.2 Evaluation of fishing pressures on the species		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Fishing Mortality	Mortality Low	Mortality Median	Mortality High	None	None
2	Survival rate of discarded	High Survival	Median Survival	Low Survival	Low Survival	Low Survival
3	Fishing Gear Selectivity	High gear selectivity	Moderate gear selectivity	Low gear selectivity	High gear selectivity	High gear selectivity
4	IUU Fishing Scale	Detailed records	Appropriate records	Incomplete	Detailed records	Detailed records
Total/Rank		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): Low fishing gear selectivity indicates that the gear is likely to capture large numbers of non-target species and juveniles, resulting in significant impacts on the ecosystem. Therefore, it is classified as high risk. In contrast, high fishing gear selectivity indicates that the gear can effectively target the intended species, with limited bycatch and minimal impacts on non-target species and juveniles. It is therefore classified as low risk.

In terms of legal trade, smooth hammerhead shark-related products can currently be declared and statistically compiled through CCC Codes. This has provided official trade data with a certain degree of identifiability in terms of product types and quantities. According to CITES and FAO guidance on the use of trade data in NDF assessments, when export quantities can be monitored through the formal customs declaration system and do not show abnormally rapid growth or significant deviation from catch source volumes, the “magnitude of legal trade” can generally be regarded as relatively low risk (CITES, n.d.). Existing studies have indicated that, for aquatic products that have been incorporated into national customs classification systems and are subject to continuous

monitoring, legal trade itself does not necessarily constitute the main source of pressure on populations, unless trade volume clearly does not correspond with resource status (Mundy-Taylor, 2014). Therefore, this study assessed the magnitude of legal trade for smooth hammerhead shark in both the Western and Central Pacific Ocean and the Indian Ocean as low, with a score of 1.

Although Taiwan has established a relatively comprehensive CCC Code classification system and implemented related fishery and trade management measures, which have substantially improved the traceability and overall transparency of legal trade, international literature and relevant CITES NDF guidance indicate that illegal and IUU trade activities are inherently difficult to fully reflect in formal customs declarations and trade statistics. In particular, because shark products are often traded in processed forms and real-time species identification has certain technical limitations, there remains potential uncertainty that products from illegal sources may enter legal supply chains (Cardeñosa et al., 2018; Sas-Rolfes et al., 2019).

Based on currently available information, there is still insufficient evidence, such as trends in seizure cases, judicial penalty statistics, or systematic forensic species identification data, to further quantify the magnitude of illegal trade. According to CITES (2023), hammerhead shark fins are targeted by illegal fishers because their prices are much higher than those of ordinary shark fins, and records of illegal trade still exist even under fishing bans or CITES controls. Therefore, following the precautionary principle recommended in international NDF practice, this study temporarily assesses the magnitude of illegal trade in smooth hammerhead shark in Taiwan as “unknown” and treats it as medium risk, with a score of 2, in order to ensure the robustness and international comparability of the assessment results.

Step 4： Evaluation of existing management measures

Item		Risk level			Smooth hammerhead	
Presence of appropriate management measures		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
4.1 Scale of management measures		Species-specific management measures	Generic fisheries management measures	None	Generic fisheries management measures	Generic fisheries management measures
Total/Rank		**1**	**2**	**3**	**2**	**2**
4.2 monitoring, control, and surveillance (MCS)		Low risk (S=1)	Median risk (S=2)	High risk (S=3)	Western and Central Pacific Ocean	Indian
1	Fishing pressure (F/Fmsy)	Low	Median	High	High	High
2	Discard mortality	Low	Median	High	High	High
3	Size/age/sex selectivity	Low	Median	High	Low	Low
4	IUU fishing prevention and control	Low	Median	High	Low	Low
Total/Rank		**4-6**	**7-9**	**10-12**	**8**	**8**

Remark (data source): 農業部漁業署(2025a) 修法「鮪延繩釣或鰹鮪圍網漁船赴太平洋作業管理辦法」第57條。農業部漁業署(2025b)「鮪延繩釣漁船赴大西洋作業管理辦法」第41條。農業部漁業署(2025c)「鮪延繩釣漁船赴印度洋作業管理辦法」第39條。

Step 5：Non-Detriment Finding determination

Item	Risk level			Smooth hammerhead	
	Low risk	Median risk	High risk	Western and Central Pacific Ocean	Indian
Step 2.1	11-17	18-26	27-33	27	25
Step 2.2	3-4	5-7	8-9	7	5
Step 3.1	1-2	3-4	5-6	3	3
Step 3.2	4-6	7-8	9-12	8	8
Step 4.1	1	2	3	2	2
Step 4.2	4-6	7-9	10-12	8	8
Total	**25-40**	**41-60**	**61-75**	55	51
NDF assessment	**Positive**	**Conditional**	**Negative**	**Conditional**	**Conditional**

This study conducted a Non-Detriment Finding (NDF) assessment for Smooth hammerhead shark in the Western and Central Pacific Ocean and the Indian Ocean by Taiwan. The results for both ocean regions were classified as conditional NDF.

Step 6： Management recommendations

Based on the results of the present "conditional Non-Detriment Finding (NDF)" assessment for the smooth hammerhead shark, *Sphyrna zygaena*, the species shows characteristics of high conservation risk across multiple indicators in different ocean regions, including biological vulnerability, population recovery potential, degree of conservation concern, and fishery exposure risk. The smooth hammerhead shark is characterized by a relatively slow growth rate, late maturity, and limited population recruitment. These life history traits make the species highly sensitive to sustained fishing pressure and environmental changes. In the absence of effective control and real-time monitoring mechanisms, the risk of population decline may increase substantially.

The present assessment also showed that several key indicators had to be assessed at the most conservative "high risk (unknown)" level under the precautionary principle, because basic biological information, such as length at maturity, growth parameters, and natural mortality rate, as well as fishery-related information, including actual bycatch proportion, discard proportion, and post-release survival rate, are difficult to obtain. This result clearly indicates that data deficiency has become a core bottleneck limiting accurate determination of the population status of smooth hammerhead shark and improvement of management measures. If such data gaps are not effectively addressed, they will continue to affect the stability of NDF determinations and the scientific credibility of policy implementation.

Based on the above risk context, future management strategies should adopt a multi-level and complementary "policy toolbox" framework rather than relying on a single regulatory measure. In terms of catch control, it is recommended that a science-based Total Allowable Catch (TAC) system be gradually introduced. Under data-limited conditions, conservative setting principles should be adopted. Through an annual rolling adjustment mechanism, quotas, fishing seasons, or closed periods should be dynamically revised based on the latest population monitoring results and risk assessments. This would help reduce the risk of overexploitation and improve the adaptive capacity of management.

In terms of spatial management, considering that juvenile smooth hammerhead sharks exhibit clear seasonal migration and aggregation behavior and may rely heavily on specific coastal, offshore, or continental shelf waters as nursery grounds, it is recommended that species distribution maps, catch records, and environmental data from waters surrounding Taiwan be integrated to systematically identify high-risk spatiotemporal hotspots and potential nursery grounds. When sufficient scientific evidence is available, the establishment of seasonal closures, nursery ground protection areas, or other area-based management measures may be considered, in order to reduce fishing mortality during the juvenile stage and strengthen habitat protection and population recruitment functions.

At the same time, considering that smooth hammerhead shark is a frequently bycaught species in multiple fisheries, management measures should also focus on reducing actual fishing mortality. It is recommended that the development and promotion of fishing gear modifications and bycatch reduction techniques continue, such as adjustments to hook type, fishing depth, and operation time. These should be combined with institutionalized subsidies and technical guidelines to encourage fishers to prioritize safe release or best-practice live release procedures when the species is captured and still alive. Such measures would substantially reduce cumulative fishing mortality pressure.

Overall, by combining multiple management tools, including TAC control, spatial management, and bycatch reduction, the proposed policy toolbox can form a mutually supportive governance framework. Under the precautionary principle, this framework would gradually reduce data uncertainty and management risk, while improving the sustainable utilization and overall management effectiveness of smooth hammerhead shark resources.

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