A practical approach to meeting national obligations for sustainable trade under CITES

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A practical approach to meeting national obligations for sustainable trade under CITES

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Abstract

Reconciling conservation and resource use requires adaptive management. The Convention on International Trade of Endangered Species (CITES) is a key tool in species conservation, regulating international trade for a list of species (Appendix II) that are or may become threatened by trade. To export such species, CITES member countries are required to evaluate if their exports are damaging wild populations (dubbed making a non-detriment finding or NDF). When countries find this challenge too great, they often default to banning international trade, thus imposing economic costs on stakeholders and/or driving the trade underground where it is more difficult to control. What, then, are the easiest ways for countries to make NDFs? We propose a simplified spatial approach to making NDFs using the case study of India, which has banned catch and trade of seahorses (Hippocampus spp.), but where rampant illegal trade continues. Our approach involves mapping the answers to four questions: (1) where are the species found?; and then, for those areas, (2) what pressures do the species face?; (3) what measures are in place to manage the pressures?; and (4) how well are the measures working? Information came from fishers’ knowledge and published literature. Overall, reported seahorse presence was greatest in the southern Palk Bay region. This region theoretically offered protection to seahorses through a 3 nm bottom trawl exclusion zone and a 60 day closed season. Implementation was problematic. Both bottom trawl and dragnet fishers reported respecting the closed season but three-quarters of bottom trawl fishers reportedly catching seahorses in the trawl exclusion zone. Our conservation assessment identified the opportunity to better implement existing management measures as well as the need for further management action (that would do more than simply banning capture). This pragmatic geographic analysis provides managers in India with a tractable route towards regulating exports at sustainable levels. Our assessment approach can be deployed broadly in assessing sustainability of exploitation and provides an alternative to the current futile bans.
1. Introduction

When governments struggle to reconcile species conservation and resource use, they may default to bans on exploitation and/or trade, but such bans may not achieve the conservation gains that were intended. Bans may take many forms: i) the creation of fully protected areas (e.g., Lubchenco & Grorud-Colvert, 2015); ii) precluding certain extractive activities such as hunting and logging (e.g., Blackie, 2019); iii) preventing any harmful methods of extraction (e.g., McConnaughey et al., 2020); or iv) protecting certain threatened species even while allowing more extensive exploitative activities (e.g., Collins et al., 2020). Though bans may appear to be a pragmatic approach to addressing problems associated with species population declines, rarely is it so straightforward (Moyle, 2003). Bans on extraction and/or trade are often met with resistance where they result in a loss of revenue to local communities and/or reduced revenue for conservation (e.g., Broad et al., 2003; Lindsey, 2010; Mbaiwa, 2018). Bans can also provoke or strengthen underground markets, where increased prices further incentivize exploitation and trade in spite of the prohibitions (Abensperg-Traun, 2009; Lemieux & Clarke, 2009). Such underground markets are more difficult to monitor and regulate than legal trade (Martin, 2000), exacerbating sustainability challenges rather than addressing them.

The Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a key instrument used to reconcile conservation and resource use (www.cites.org). CITES aims to ensure that international trade in specimens of animals and plants does not threaten the species’ survival in the wild by providing a framework that directs all member States (Parties, 184 at the time of writing; CITES, 2022a). International trade for commercial purposes is banned for species listed on Appendix I, whereas it must be regulated to ensure sustainability and legality for those on Appendix II. Parties wanting to export an Appendix II species must first provide evidence that such exports will not be detrimental to wild populations, called making a non-detriment finding (NDF; CITES, 2016). Making an NDF requires data on factors such as the magnitude of trade, the population status, pressures faced at the level of the species and on their habitats, and management possibilities (e.g., CITES, 2013; Foster & Vincent, 2016; Leaman & Oldfield, 2014; Mundy-Taylor et al., 2014; Rosser & Haywood, 2002). However, Parties often lack the resources, capacity, and information to undertake the detailed work required under most NDF framework protocols.

Parties that struggle to meet the CITES requirement for an NDF prior to allowing export sometimes choose to end international trade altogether, rather than trying to manage it for sustainability (Foster & Vincent, 2021). In a first set of cases, CITES Parties may legislate or declare stricter domestic measures than required by CITES (examples in Vincent et al., 2014). In a second set of cases, Parties that are asked to justify the scale and nature of their exports (in a CITES compliance process called the Review of Significant Trade – RST; CITES, 2022d) sometimes turn to bans as a way of deflecting scrutiny of their exports (e.g., Foster & Vincent, 2021). In a third set of countries, a Party’s difficulties in meeting its obligations for defensible NDFs may lead CITES to impose an export ban as a consequence of the RST (called a suspension: e.g., Foster & Vincent, 2021). Although trade suspensions have sometimes been effective in improving the implementation of CITES listings (UNEP-WCMC, 2016), incomplete enforcement of such bans often leads to illegal trade and higher black-market prices (Abensperg-Traun, 2009). Compounding this is the reality that Parties that end export (whether through a zero quota, legislated ban, or temporary suspension) tend to do little else, feeling that they have met the provisions of CITES, and thus generally fail to address any illegal trade.
Seahorses (46 species of *Hippocampus*) provide a well-documented example of how ending exports may not translate into effective implementation of CITES. Seahorses were the first marine fishes to be included on Appendix II of CITES since its inception (Vincent et al., 2014), the first marine fish for which an NDF framework was created (Foster & Vincent, 2016), and the first to go through the RST (Foster & Vincent, 2021). Further capacity building has included the development of monitoring protocols, simplified identification guides, and the generation of information on seahorse distribution, fisheries, and trade in most key source countries, *inter alia* (as reviewed in CITES, 2018). Nonetheless, while the CITES listing for seahorses appears to have reduced any pressure of international trade for aquarium display (Foster et al., 2022) the much larger trade in dried seahorses continues to pose a significant threat to seahorse species, involving millions of smuggled seahorses (Foster et al., 2019; Foster & Vincent, 2021; Vincent et al., 2022). The RST for seahorses has ultimately resulted in export bans or suspensions in most countries that had historically exported the most dried seahorses (Foster & Vincent, 2021). The worry is that, although jurisdictions have declared an end to exports instead of making NDFs, most have not actively enforced their rules... and the result is vast illegal international trade (as reviewed in Vincent et al., 2022). For example, it was estimated that about 95% of dried seahorses in Hong Kong SAR in 2016-17 had been imported from source countries with export bans in place, indicating a widespread lack of enforcement (Foster et al., 2019).

As the seahorse example reveals, an important step toward sustainable trade under CITES will be to improve Parties’ willingness to make NDFs that restrict exports usefully. This can be partly achieved by simplifying advice on how Parties might more easily balance export of animals (or plants) and the health of wild populations. We propose that governments could achieve adequate analysis of NDFs – helpful, even if not perfect – by mapping the answers to four questions: (1) where are the species found?; then, for those areas, (2) what pressures do the species face?; (3) what measures are in place to manage the pressures?; and (4) how well are the management measures working? (Figure 1). Core data on the first two sets of information – spatial distribution of species and pressures – can be generated relatively rapidly, cheaply, and with few technical challenges using local/traditional ecological knowledge (Berkes, 1993; Huntington, 2000). For the third and fourth sets of information, governments can draw on their own management protocols and experiences in time and space (Aylesworth et al., 2020; Mundy-Taylor et al., 2014). The resulting NDF evaluation, although imperfect, should enable Parties to make progress in assessing the status of wild populations under their regulatory regimes and to move towards adaptive management (Meffe & Viederman, 1995; Smith et al., 2011).

We used a case study in India for testing our concept of simplified NDFs, as a country with an export ban on seahorses that isn’t working to support the species’ conservation. India banned all exploitation and trade of seahorses in 2001, under Schedule I of its Wild Life Protection Act, 1972,¹ as a result of its involvement in the consultations that led to the CITES Appendix II listing for these fishes in 2002 (A.C.J. Vincent, personal communication). Nonetheless, the catch and trade of seahorses has continued virtually unabated (Vaidyanathan et al., 2021; Vinod et al., 2018). The take of seahorses, an estimated 13 million individuals per year (Vaidyanathan et al., 2021), is primarily landed as bycatch from non-selective gear such as bottom trawls and dragnets (modified wind powered shrimp trawls; Perry et al., 2010; Salin et al., 2005; Vaidyanathan et al., 2021; Vinod et al., 2018). A large proportion of the seahorse catch (30-90%) was reportedly still exported (Perry et al., 2010; Salin et al., 2005; Vaidyanathan et al., 2021). Fisher compliance with the ban on exploitation was low, partly because they were not involved in the decision-

¹ https://legislative.gov.in/sites/default/files/A1972-53_0.pdf

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making process and questioned the legitimacy of the law, but mostly because the seahorses were caught incidentally during their other fishing activities (Vaidyanathan, 2021). The seahorses are no better off in spite of the ban – available data suggest a marked decline in catch per unit effort between 1999 and 2017 (Vaidyanathan & Vincent, 2021). As such, India is a perfect case study for exploring how a country might work toward making positive NDFs – and permitting ongoing trade – should they choose to consider adaptive management instead of an ineffective blanket ban.

Figure 1. Pictorial depiction of the core questions of a simplified NDF. From left to right: (1) where are the species found? (distribution); then, for those areas, (2) what pressures do the species face? (e.g., fisheries, coastal development); (3) what measures are in place to manage the pressures? (e.g., fisheries regulations, MPAs); and (4) how well are the management measures working? (e.g. is there evidence of increased or decreased abundance). (R. Bestbier/Project Seahorse).

2. Methods
Using data generated from fisher interviews we conducted and from existing published literature, we probed the viability of our proposed four step mapping approach to making NDFs in India. First, we identified seahorse locations by generating distribution maps based on fishers reports of seahorse presence/absence in their catches, and then overlayed these maps with spatial information on seahorse habitats. Second, we identified threats to seahorses from fishing by generating a map of fishing effort using the active number of fishing hours per day by different boat types. Third, we
overlaid the distribution of existing spatial management efforts. Finally, we evaluated whether existing management was sufficient to mitigate the pressures on the seahorses.

2.1 Study Area
Our research is anchored in an area of the southeastern state of Tamil Nadu called Ramanathapuram District (Figure 2), a hotspot for illegal seahorse catch and trade (e.g., Murugan et al., 2011; Perry et al., 2010; Salin et al., 2005; Vaidyanathan et al., 2021; Vinod et al., 2018). Around 10 million seahorses were caught annually between 2015 and 2017 from Tamil Nadu alone (Vaidyanathan et al., 2021; Vinod et al., 2018). Tracking this illegal trade is challenging because of the organized and underground operations of the smuggling activities, but exports were estimated to be in the range of ~3.4 to 9.2 million individuals (Vaidyanathan et al., 2021).

2.2 Data sources
Information on seahorses for the Ramanathapuram District came from fishers' knowledge and published literature. We used information at the genus level (*Hippocampus* spp.) because i) that was the level at which fishers' knowledge was expressed, and ii) all species of *Hippocampus* are protected under India’s WLPA and listed in CITES Appendix II.

![Figure 2](image-url)

**Figure 2.** Locations where fisher interviews were carried out between 2015-2017 at coastal villages and fish landing centres of the Ramanathapuram District. Major bottom trawl landing centres and drag net landing sites are labeled. Bottom trawl centres along the Rameswaram Peninsula have been numbered (from west to east): 1. Mandapam North; 2. Mandapam South; 3. Pamban; 4. Rameswaram Fishing Harbour. Note that although Thondi is a major drag net centre, the few drag-netters interviewed in the region did not provide information about locations in which they caught seahorses.
2.2.1 Fishers’ knowledge
We obtained fisher knowledge for this study from interviews conducted along the Tamil Nadu coast to understand the extent of seahorse occurrence, fisheries and trade in the state after the ban. Our sampling methodology involved maximizing geographical coverage as well as respondents interviewed to increase the reliability of our estimates. To obtain fishers’ knowledge, we conducted semi-structured interviews at 56 locations, including fish landing centres and fishing villages, eight of which were bottom trawl landing centres, along the Ramanathapuram District coast (Figure 2). We obtained information on seahorse species distribution and fishing pressure from 118 interviews conducted between 2015 and 2017 across 29 locations in the district. Fishers from 19 locations reported primarily fishing in the shallow, seagrass rich Palk Bay region of the state, and fishers from 15 locations reported fishing along the highly biodiverse Gulf of Mannar region (Figure 2). Note that some fishers in the Ramanathapuram peninsula reported fishing in both the Gulf of Mannar and Palk Bay regions. Over half of our interview data came from bottom trawl fishers (n=69 interviews) because our second field season, beginning in 2016, focused on the pressures of bottom trawl fisheries in Tamil Nadu.

We chose interview locations based on where seahorses could be found according to published literature (Marichamy et al., 1993; Murugan et al., 2008; Perry et al., 2010), information from local colleagues, and from snowball sampling (in which one respondent indicated other potential locations). At each location, we spoke with respondents recommended by local researchers and those we encountered haphazardly. We conducted our interviews with fishing crew, boat drivers and boat owners across five types of fishing methods: bottom trawls (n=69 interviews), gillnets (including trammel nets and bottom-set gillnets; n=20), dragnets (n=16), shore seines (n=12) and diving (n=4). Gillnets, dragnets, shore seines and diving are considered traditional gears in India because they are non-motorized; we retained this classification in our analysis. However, we sometimes separated dragnets from other traditional gear in our analysis, as they are one of the most significant fishing pressures on seahorses in this district. We conducted all interviews at landing sites, such that multiple fishers from the same boat often participated in a single interview. In some landing sites, fishers from different boats took part in the mapping process, allowing for cross-validation amongst fishers. All research received approval from the University of British Columbia’s Human Behavioural Research Ethics Board (H12-02731 and H15-00160).

During interviews, we asked fishers to draw regions where they caught and did not catch seahorses on nautical charts. We sometimes guided mapping efforts by pointing out features on the map (e.g., islands). In interviews where fishers could not draw because of time constraints or other reasons, we used their narrated details to draw polygons for seahorse presence or absence (as per Zhang & Vincent, 2017). We asked fishers to identify locations in which they (a) fished and caught seahorses (i.e., presences) and (b) fished but did not catch seahorses (i.e., absences). We also asked about the depth, distance from shore and habitat in which they caught seahorses, and the fishing gear, fishing effort and fishing seasons. We mapped and analysed the data using ArcGIS, with coordinates measured by the WGS84 spatial referencing system.

2.2.2 Published literature
We extracted available data about seahorse distributions and fishing effort in the Ramanathapuram District from the published literature (Table 1). If specific localities were not documented, we included the entire study/sampling area described in the paper as part of the species’ range. All species maps from the validated records in literature were digitized using ArcGIS Pro.
We attempted to obtain seahorse sightings (SS) from online biogeographic databases including the Global Biodiversity Information Faculty (GBIF, www.gbif.org), Oceanic Biodiversity Information System (OBIS, www.iobis.org), FishNet2 (www.fishnet2.net), FishBase (www.fishbase.org) and iSeahorse (www.iseahorse.org). However, the only records of seahorse sighting within the coordinates of our study sites were located on land and hence could not be used for this study.

The published literature was also a source for information on the spatial distribution of documented seahorse habitats, which include corals, dead corals and seagrass (Murugan et al., 2008; Vinod et al., 2018). We extracted seagrass occurrence data originally published by Geevarghese et al. (2018) that used Landsat 8 LI imagery to map seagrass distribution in the Palk Bay region (Geevarghese et al., 2018). For the Gulf of Mannar Marine National Park, we used habitat data (coral and dead coral with algae, dead corals and seagrass beds) from (Mathews et al., 2010), which used line intercept transect methods to map the habitats.

Table 1. Peer reviewed literature used in our study to map seahorse presence in the Ramanathapuram District of southern India.

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<tr>
<th>Location</th>
<th>Objectives</th>
<th>Study</th>
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<td>Multiple locations in the Palk Bay region</td>
<td>First estimate of extent of seahorse fisheries in the Palk Bay region</td>
<td>Marichamy et al., 1993</td>
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<tr>
<td>Palk Bay region</td>
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<tr>
<td>Thondi, Palk Bay</td>
<td>Estimates of the volumes of seahorses exported until the imposition of an exploitation ban</td>
<td>Salin et al., 2005</td>
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<td>Mullimunai, Palk Bay</td>
<td>First reported occurrence of \textit{H. mohnikei} from the Palk Bay region from bycatch</td>
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<tr>
<td>Multiple locations in both the Palk Bay and Gulf of Mannar region</td>
<td>Identification of seahorses and pipefishes, and estimation of their catches in fishing gear</td>
<td>Murugan et al., 2008</td>
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<tr>
<td>Three locations in the Gulf of Mannar</td>
<td>Estimation of seahorse catches from the Gulf of Mannar</td>
<td>Murugan et al., 2011</td>
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<td>Multiple locations from Coromandel coast to Kanyakumari (Both Palk Bay and Gulf of Mannar)</td>
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<tr>
<td>Multiple locations in the Palk Bay and Gulf of Mannar region</td>
<td>Estimation of seahorse catches in the Palk Bay and Gulf of Mannar region by non-selective fishing gear, and the impact of the seahorse fishing ban on fisher livelihoods</td>
<td>Vinod et al., 2018</td>
</tr>
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2.3 Data analysis

2.3.1 Where are the species found? Seahorse locations based on fisher reports.

To create maps of seahorse distribution (occurrence), we used fisher reports on the presence or absence of seahorses from our interviews and published literature. We created presence/absence maps by overlaying individual fisher’s maps showing where they caught (presence) or did not catch (absence) seahorses. We then calculated (i) the number of fishers reporting presence/absence of seahorses in a given location and (ii) the proportion of fishers reporting presence/absence of seahorses compared with the total number of fishers who reported fishing in either Palk Bay or the Gulf of Mannar. We used these two metrics to understand the extent of spatial agreement on seahorse presence among fishers. We only kept areas in the maps that included at least two observations by fishers reporting presences or absences (as per Zhang & Vincent, 2017).

We identified seahorse priority habitats by overlaying seahorse presence maps, generated from fisher reports, over our layers of natural/biogenic habitats (from 2.2.2) to estimate the proportion of seahorse
presence in coral and seagrass bed habitats compared to these habitats' overall extent. Our estimates were done for each distinct habitat type, and also for the Palk Bay and Gulf of Mannar region separately.

2.3.2 What pressures do the species face? Pressure on seahorses from fishing.
To estimate the fishing pressures that seahorses faced, we mapped fishing effort for the fishing grounds in the district as measured by the duration that fishing gear was actively employed. We obtained information on the mean number of hauls in a fishing day and each haul’s duration from our interviews. We then overlaid the effort data obtained from the individual fishers to obtain the cumulative number of hours all fishers we interviewed spent fishing in a day. For interviews where information on either the number or duration of hauls was missing, we filled the gap using either published literature (Table 1) or by using information from fishers using similar gear from the same location. However, in the case of the highly variable and diverse gillnet operations, if we could not obtain information from other fisher interviews in the same location, we ignored the data altogether.

2.3.3 What measures are in place to manage the pressures? Existing spatial management.
We considered three existing management measures: (i) The Gulf of Mannar Marine National Park – a 560 km² no-take marine protected area (MPA), forming the core of the Gulf of Mannar Biosphere Reserve (G.O. Ms. No. 962, Forests and Fisheries Department, September 1986; Government of Tamil Nadu, 1986; Melkani et al., 2006); (ii) India’s trawl exclusion zone – a three nautical mile (3 nm) limit from the coastline where bottom trawlers are not allowed to operate, but traditional fishing gears including dragnetters are permitted (Government of Tamil Nadu, 1983); and (iii) a seasonal closure – a 60-day period from April to June, when a majority of the important fish species are believed to spawn, and during which bottom trawlers and dragnetters in the district are not allowed to operate (Government of Tamil Nadu, 2017, 2018; Kumaraguru et al., 2000).

2.3.4 How well are the management measures working? Analysing the implementation of existing management.
To address this dimension of our framework, we analysed spatial management violations in two ways: (1) total area that bottom trawlers reported seahorse catches within the trawl exclusion zone; and (2) total areas that fishers reported catches from the no-take MPA. To do this, we mapped the trawl exclusion zone and the MPA in ArcGIS Pro, and then executed a simple geospatial analysis to calculate the overlap (percent coverage) of these two management measures with our seahorse presence and habitat maps (from 2.3.1). For bottom trawlers, we had to analyze the protection offered by the 3 nm trawl exclusion zone and MPA together because of overlaps in the boundaries (overlap of ~158 km² or 9% of the total area protected).

To understand the effect of the closed season, we compared the overall area covered by traditional fishers (without dragnetters) throughout the year with the overall area that bottom trawlers and dragnetters reported operating in. We acknowledge limitations in our comparisons as we only compared the overall area fished by the different gears over the year and did not compare the effort among the gear types.

3. Results
Our proposed approach to assessing sustainability of exploitation depends on integrating four sets of data, on seahorse presence, seahorse habitats, pressures and management.
Overall, we observed both the greatest number of fishers reporting seahorse presences in their catches, and the greatest fishing effort, in southern Palk Bay, a region rich in seagrass habitats. Bottom trawls and dragnets put pressure on both the seahorses and their habitats, with fishing operations on large tracts (~90%) of critical seahorse habitats in this study. The entire district of Ramanathapuram is protected in principle by a 3 nm trawl exclusion zone, where bottom trawlers are prohibited but dragnetters may still operate, and a closed season for fishing for both bottom trawls and dragnets. The Gulf of Mannar also has one MPA. Throughout the district, bottom trawl and dragnet fishers reported respecting the closed season everywhere but bottom trawl fishers continued to catch seahorses in the trawl exclusion zone outside that closed period. As well, our analysis indicates large violations of the MPA, and continued catches of seahorses from this region. We now provide details on these general findings.

3.1 Where are the species found? Seahorse locations based on fisher reports.

Overall, our analysis showed that seahorses present in 68% of the portion of India’s EEZ considered for this study (7746 of a total 11,357 km$^2$), and at least 88% of areas in which respondents stated they fished within the EEZ (7746 of 8,807 km$^2$).

Our interviews with fishers along the Ramanathapuram coast indicated that more fishers reported the presence of seahorses in the southern Palk Bay region, extending from Devipattinam to Thondi (Figure 3). In the Gulf of Mannar, a greater number of fishers reported the presence of seahorses closer to the shore, near the southern portion of the Rameswaram Peninsula and along the northern section of the Gulf of Mannar (Figure 3). The distribution pattern of seahorse presence was similar whether maps were generated using the number of fishers reporting seahorse presence in their catches in that location (Figure 3) or using fisher presence data scaled by the number of fishers who reported fishing in either Palk Bay or Gulf of Mannar (Annex 1).
Overall, only nine fishers reported locations where they did not report the presence of seahorses, with never more than three fishers per location (Annex 2). These locations occurred across 11 fishing areas compared with the 196 fishing grounds where fishers did report the presence of seahorses. Locations with absences may not be true absences, given that in some of these areas many other fishers reported presences (Figure 3 and Annex 2); the difference could potentially be attributed to the type of fishing gear being operated (e.g., passive gear like gillnets may be less likely to catch seahorses than active bottom trawlers).

When we separated fishers by gear type (bottom trawlers vs. traditional including dragnetters), we found that fishers still reported the greatest percentage of seahorses in the Palk Bay region (Annexes 3 and 4). The greatest percentage of bottom trawl fishers (~43%) and traditional fishers (~26%) reported presences of seahorses along the Devipattinam coast. Distinguishing among gear types, it appears that the absence of dragnetters and the smaller areas fished by other traditional fishers in the Gulf of Mannar region drove the observed patterns.

We found that fishers reported seahorse presence in ~ 90% (483 of 536 km$^2$) of seagrass and coral habitats in the Palk Bay and Gulf of Mannar regions (Figure 4). Fishers reported seahorse presence in 90% of seagrass
bed (316 of 350 km$^2$) and 92% of seagrass beds with sand (155 of 169 km$^2$) in Palk Bay and Gulf of Mannar, respectively (Figure 4). However, fishers reported seahorses in only 70% (14 of 20 km$^2$) of the area covered by coral (alive, dead, or covered with algae). This difference may be because corals were only found only in the Gulf of Mannar region (Figure 4), where fewer people reported fishing (n=49).

**Figure 4.** Map showing seahorse habitats along the Palk Bay and Gulf of Mannar regions of the Ramanathapuram District overlaid with maps of seahorse presence. Seagrass data for the Palk Bay region was extracted from Geeverghese et al. (2017) and for the Gulf of Mannar region from Mathews et al. (2010).

### 3.2 What pressures do the species face? Pressure on seahorses from fishing.

We found that the fishing pressure (measured by the cumulative hours spent actively fishing per day across all fishers) was greatest in the entire Palk Bay region, in shallow waters and near the coastline (Figure 5). Within this region, the greatest effort (197 combined active fishing hours per day) was reported off the coast of Devipattinam, primarily from non-selective bottom trawlers and dragnetters. We found a similar trend in effort when we removed traditional gear (other than dragnetters) from this analysis (Annex 5), probably because we had less information on these gears than active non-selective fishing gears.

In terms of seahorse habitats, altogether fishers reported operating in more than 94% of seagrass and coral reef habitats in Palk Bay and Gulf of Mannar (505 of 539 km$^2$).
Figure 5. Pressures seahorses faced from fishing in the Ramanathapuram District, as measured by the collective duration of time that fishers of all gear types actively deployed their nets (hours per day). Fishing pressure was greatest closest to the shore along the entire extent of the Palk Bay region.

3.3 What measures are in place to manage the pressures? Existing spatial management.
We found that around 1727 km\(^2\) of our study area (15% of the total 11 357 km\(^2\) of ocean within India’s EEZ considered for this study) was covered by either the no-take MPA (404 km\(^2\) or 3.5% of ocean within India’s EEZ considered for this study) or the trawl exclusion zone (1481 km\(^2\) or 13% of study area falling with India’s EEZ), amounting to ~81% of seagrass and coral habitats (435 of 539 km\(^2\); Figure 6). However, only ~13% of these habitats lay within the MPA and were, in theory, completely protected from fishing pressure (72 of 539 km\(^2\)).

3.4 How well is the management working? Analyzing the implementation of existing management.
Overlaying seahorse presence maps with the MPA boundaries and the 3 nm trawl exclusion zone revealed that fishers reported catching seahorse in 85% of the area covered by both the no-take MPA and the trawl exclusion zone (around 1476 of 1727 km\(^2\); Figure 6). We further found that fishers reported catching seahorses in 92% of the area covered by the no-take MPA alone (370 of 404 km\(^2\)).
When we considered fishing pressure from bottom trawls alone, we found that bottom trawl fishers reported fishing in about ~90% of the protected areas (1548 of 1727 km$^2$) and reported seahorse presence in their catch in about 90% of the area they fished (~1388 of 1548 km$^2$) in these supposedly protected areas. When we assessed the violations separately, we discovered that bottom trawlers reported fishing in 98% of the MPA (396 of 404 km$^2$) and reported catching seahorses in 91% of the MPA (366 of 404 km$^2$). They further reported operating in 88% of the trawl exclusion zone (1303 of 1481 km$^2$) and reported catching seahorses in 78% of this area (1149 of 1481 km$^2$). Indeed, we found that fishing pressure from bottom trawls was greatest within the trawl exclusions zone of the Palk Bay region off the coast of Devipattinam (Figure 7). Our findings further indicate that bottom trawl fishers operated on almost all the seagrass and coral habitat that was theoretically protected (91%, 394 of 435 km$^2$).

In contrast, traditional fishers, including dragnetters, reported operating in only about 44%, and seahorse presence in 39%, of the no-take MPA (178 and 158 of 404 km$^2$, respectively); that said, we interviewed fewer traditional fishers (n=19) in the Gulf of Mannar region.

Overall, we found that ~18% of areas with reported seahorse catches within India’s EEZ were violations of existing management measures (1392 of 7746 km$^2$). Seahorse conservation was further undermined by illegal, unreported and unregulated (IUU) fishing outside India’s EEZ. About 16% of the total area where respondents reported fishing lay within Sri Lankan waters in which bottom trawling is prohibited (~1627 of 10 434 km$^2$; Parliament of the Democratic Socialist Republic of Sri Lanka, 2017). Such Sri Lankan waters comprised about 11% of the entire area where fishers reported catching seahorses (~ 946 of 8692 km$^2$).

The only fisheries management measure that may have been effective for seahorse conservation was the 60-day annual fishing ban on the use of bottom trawls and dragnets, both significant pressures, which is highly enforced. During the ban, the remaining fishers use more selective and/or less damaging methods such as passive fishing gear (gillnets), targeted active fishing methods (diving), or non-selective gear more constrained in its extent of operation (shore seines). Such traditional fishers also reported operating in only 19% of the area where bottom trawl and dragnetters fished within India’s waters through the year (1544 of 7936 km$^2$). As such, the temporal closure should effectively eliminate a great deal of the fishing pressure where seahorses live for two months of the year.
Figure 6. Overlay of management measures (3 nm trawl exclusion zone within and MPA boundaries) with seahorse presence maps in the Ramanathapuram District. For temporal closures, during the 60-day ban, both bottom trawlers and dragnetters are prohibited from operating for an extent ranging from the coastline to the international maritime boundary line.
Figure 7. Pressures faced by seahorses from bottom trawlers, as measured by collective duration that fishers employed their nets while fishing (hours per day) in the Ramanathapuram District. Fishing pressure was found to be greatest closest to the shore along the entire extent of the Palk Bay region, and within regions where bottom trawlers should not have been operating.

4. Discussion

Our simple four step process proves helpful in supporting a pragmatic analysis of the status of wild seahorse populations in support of evaluating probable impacts of exploitation and export trade. While it is imprecise in details, the process produces an adequate indication of the well-being of wild populations – as is needed for making CITES NDFs. Overlaying spatial data of animal or plant locations with threats and existing management addresses the core question of sustainable exploitation – and most certainly the core question of an NDF – as to whether management is sufficient to avoid detrimental effects on wild populations (Foster & Vincent, 2016). The important point to remember under CITES is that exports need not be the primary threat; whatever their relative role among pressures on wild populations, exports must be constrained yet further if they are detrimental to those populations. Our intention is for managers and policy makers to use such broad analyses as starting points, and then to refine layers of data, reduce threats and enhance implementation. Such an approach, when married to stakeholder engagement in an explicitly experimental framework, constitutes adaptive management, a paradigm that is increasingly advocated in both conservation and resource exploitation. In conservation, as in so much else, the perfect is the enemy of the good.

The pragmatic approach we suggest here provides a first and useful approximation of where – and indeed how – managers might improve the status of wild populations. In the case of seahorses in the Ramanathapuram District of southern India, we found notable levels of concern. Fishers reported seahorse presence more frequently close to the shore and in shallower waters, commensurate with
where their critical seahorse habitats are found. Given that our observations on seahorse presence were based on fisher catch, fishers are clearly operating extensively in these areas. In addition, we found that seahorse habitats also faced great stress, with destructive fishing occurring on large tracts (~90%) of critical seahorse habitats such as corals (dead and live) and seagrasses. Finally, we calculated that about 18% of the area where fishers reported catching seahorses was ostensibly "protected", but that fishers clearly operated within the no-take marine protected area and used bottom trawls in areas that had banned the gear. We also note insufficient management of dragnet fishing, a key pressure on seahorses in Palk Bay. Though deployed by traditional fishers, dragnets are destructive because their target of juvenile shrimp leads them to operate directly through seagrass beds and thus also to catch seahorses and numerous other non-target species (Sampson Manickam et al., 1987).

**Our conservation assessment identified the opportunity to better implement existing management measures as well as the need for further management action (that would do more than simply banning capture).** Once we consider all four steps of our analysis together, it not surprising that fishers reported seahorse populations in the Ramanathapuram region (and surrounding districts) had declined over the 20 years since the ban was implemented (Vaidyanathan & Vincent, 2021; Vinod et al., 2018). Ideally, the question “how well is the management working” would be answered with data from long term monitoring of wild populations – but India joins most source countries in lacking any such programs for seahorses (CITES, 2022b, 2022c). However, evidence of widespread violations of existing management combined with fisher reported population declines suggest the answer to this critical question is “no”. Authorities in India need to enforce and enhance existing management measures such as preventing the operation of bottom trawls within the trawl exclusion zone, providing official demarcation of the MPA boundary, and actively preventing all fishing within the MPA. They also need to prevent Indian bottom trawlers from actively fishing in Sri Lankan waters. In the case of dragnets, the fishing villages are cohesive enough that community based MPAs may be a possible means of reconciling fisheries with conservation. Such measures would alleviate some of the pressure faced not just by seahorses and numerous other species obtained as bycatch, but also on their habitats and the other species they support (e.g. seagrass and dugong; Anand et al., 2015). Moreover, such management would do rather more for seahorses (and other species) than the current national approach of banning their capture (and subsequent export)... by a wholly nonselective gear. One encouraging step for seahorse and marine conservation in this region lies in the recent formation of an exclusive agency to enforce regulations and prevent illegal fishing (Government of Tamil Nadu, 2020).

**As well as highlighting the need for more management action, our approach to collecting the data had benefits in generating dialogue that is needed to improve such management change.** Deployment of local knowledge has been strongly advocated, especially in the case of co-management (Grafton & Silva-Echenique, 1997; Smith, 1995), with the contribution of data by fishers helping increase the legitimacy of management regimes in the long-run (Neis et al., 1999). Through our interviews, we initiated the conversation with fishers about their thoughts on the ban, what worked, what did not, and ways forward for seahorse conservation (Vaidyanathan et al., 2021). Communities often possess a wealth of knowledge about management structures that may be effective within their belief systems, on practical approaches on improving compliance, and about fishing methods that may work well (effective/conservative) in a local context (Charles, 2001). During our interviews, we found that fishers largely agreed that non-selective fishing gears were particularly damaging and probably caused the decline in seahorse populations. They also noted
that implementation of existing rules such as enforcing the trawl exclusion zone was essential for conservation. Other studies from the region have also reported that fishers advocated the use of gear limitation (reducing bottom trawl numbers), no-take zones and enforcing prohibitions on banned gear were key to seahorse conservation (Vinod et al., 2018). Management authorities will do well to focus on this commonality of views about necessary steps for marine management and conservation, and work with stakeholders to create the conditions for collective action on such measures.

Our “good-enough” approach should be broadly useful for other countries that have decided to end exports to meet their obligations to CITES, rather than creating the NDFs that depend on knowing the species and its status (Foster et al., 2019; Vincent & Foster, 2017). Many key exporting countries decided to end seahorse exports as a means of avoiding the Review of Significant Trade (RST) but are now confronting significant illegal trade in dried specimens, supplied in large part by nonselective fishing gears (Foster et al., 2019; Foster & Vincent, 2021). Such Parties must do more to meet their obligations under the Convention to seahorses. To constrain smuggling, Parties will need to be vigilant and effective in enforcement along supply chains and at national borders. Such enforcement will not be easy. Many factors contribute to the difficulty of enforcement: financial benefits to participants commonly far outweigh the low risks of being caught fishing or trading illegally; dried seahorses can be kept and stockpiled for long periods; dried seahorses can be hidden in shipments, often mixed with other wildlife; and global demand for dried seahorses remains high (CITES, 2022c). On the other hand, supporting Parties to make meaningful NDFs for seahorses would refocus their attention on doing the management that is needed to reduce pressures on wild populations, and that is required by CITES. Such NDFs might be somewhat tentative at first but could be strengthened in an adaptive management approach as information improves through monitoring.

Our pragmatic mapping approach to conservation assessment could be used by a variety of resource managers in assessing and planning for conservation, including when trying to make NDFs for CITES. Our simplified approach would be particularly useful for countries in the developing world, which are often daunted by the process of making NDFs because of the limited understanding of CITES, anxiety about capacity and resources, and lack of baseline data (Abensperg-Traun et al., 2011; De Angelis, 2012). While spatial approaches have historically been neglected in work on NDFs (Rosser, 2008; Rosser & Haywood, 2002; Smith et al., 2011; Thorson & Wold, 2010) their applicability in making NDFs is now being recognised (Aylesworth et al., 2020). Spatial data may be derived from local knowledge (Thornton & Scheer, 2012), can be generated relatively quickly and cheaply (Aylesworth et al., 2017), can be deployed with limited technical training, and is central to many management measures. In proposing this qualitative mapping approach to reconciling conservation and resource management, we follow a practical path that has also been taken, although with some controversy, for establishment of MPAs and terrestrial reserves (e.g., Grantham et al., 2009; Hansen et al., 2011), one where ad hoc or pragmatic action is more imperative than systematic or ideal analyses. Although we used ArcGIS for our analysis, a much simpler approach – such as sketching answers to the four questions on a map – would have largely reached the same conclusions.

Our pragmatic stakeholder-oriented approach has real general value for managing fisheries and other exploitation for long-term sustainability, well beyond its utility in making CITES NDFs. Using spatial data generated from local fisher knowledge and published literature we were able to rapidly evaluate the distribution and key threats, and therefore infer the effectiveness of existing management measures, despite large uncertainties and imperfect data. We find that in data-limited situations, rather than feeling stalled by inadequate information, countries would do well to make decisions
based on existing and imperfect data while building on such knowledge for adaptive management (Aylesworth et al., 2020; Johannes, 1998; Meffe & Viederman, 1995; Smith et al., 2011). In fact, adaptive management is increasingly recommended as the best way forward for reconciling conservation with resource management, in a whole host of scenarios (Smith et al., 2011).

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Supporting Information
Maps using fisher presence data scaled by the number of fishers who reported fishing in either Palk Bay or Gulf of Mannar (Annex 1), places where fishers reported not catching seahorses (Annex 2), percentage of bottom trawl fishers reporting seahorse presence (Annex 3), percentage of traditional fishers (Annex 4) and pressures faced by seahorses from dragnetters and bottom trawlers (Annex 5).

**Annex 1.** Percentage of fishers who reported catching seahorses across the Ramanathapuram District region, represented by the number of fishers reporting seahorse catches as a percentage of the number of fishers that reported fishing in each of Palk Bay (n=86) or the Gulf of Mannar (n=49). Fishers operating from the Rameswaram peninsula tended to fish in both the Gulf of Mannar and Palk Bay.
Annex 2. Locations at which fishers reported an absence of seahorses in their catches across the Ramanathapuram District region. A maximum of three fishers reported not catching seahorses in any given region - on the seaward side of the islands of the Gulf of Mannar and along the eastern part of the Rameswaram Peninsula.
Annex 3. Percentage of all bottom trawl fishers in the Ramanathapuram District from our interviews and published literature reporting presence of seahorses (total n=72 bottom trawl fishers). Most fishers reported seahorses in the Palk Bay region extending from Mandapam to the North of Soliyakudi.
Annex 4. Percentage of traditional fishers from the Ramanathapuram District from our interviews and published literature who reported the presence of seahorses (total n=62 traditional fishers). Most fishers reported seahorses in the Palk Bay region off the coast of Devipattinam, and further north off the coast of Soliyakudi.
Annex 5. Pressures faced by seahorses from bottom trawlers and dragnetters across the Ramanathapuram District, as measured by the collective active time that fishers employed their nets while fishing (hours per day). Fishing pressure was found to be greatest closest to the shore along the entire extent of the Palk Bay region.