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Changes in the trade of bycatch species corresponding to CITES regulations: the case of dried seahorse trade in Thailand

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Abstract

Exploitation for trade is one of the biggest threats to many species, especially for marine fishes. Trade regulations should, therefore, be effective in helping conserve marine fish populations. The Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), one of the few multilateral environmental agreements with enforcement capacity, has embraced a number of marine fishes in recent years. However, the impacts of such measures on wildlife trade have rarely been assessed. We conducted a case study of the dried seahorse (*Hippocampus* spp.) trade in Thailand to understand the trade of these species under CITES regulations. We carried out 203 semi-structured interviews with traders to estimate the economic scale of Thai seahorse trade, and compared perceived changes with official trade datasets. Even though most seahorses were incidentally caught, we estimated that dried seahorses could be worth US$26.5 million per year for Thai fishers. However, the total declared annual export value was only around US$5.5 million, and had decreased to US$1 million in 2013. Considering the economic value of seahorses, the large discrepancy between declared export volumes and catch estimates suggested that trade may be underreported. While official data shows the export volume decreased after the implementation of CITES listing in 2005, our respondents did not report a similar trend. In contrast, the prices of seahorses were reported to be increasing. Our study highlights the economic importance of marine fishes captured as bycatch and the importance of international and domestic management measures for the trade of bycatch species.

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Introduction

Many wildlife populations are in crisis because of human activities, especially for marine species. Biodiversity is being lost at an unprecedented rate, locally and globally, because of anthropogenic effects such as over-exploitation, habitat destructions and climate changes (Aarts and Poos 2009; Abensperg-Traun 2009; Costello et al. 2012). A dominant concern is that exploitation for trade affects millions of animals and plants every year (Smith et al. 2009). International declared wildlife trade, including fisheries and timber, was estimated to be worth about US$332.5 billion in 2005 (Engler 2008), and the high monetary value provides incentives for people to keep extracting animals and plants. Consequently, the extinction risks for traded wildlife species have been accelerating (Lenzen et al. 2012). Among the hundreds of millions of plants and animals that are traded every year, fisheries products comprise one-quarter of the total in terms of value (Engler 2008). Annually, about 79.7 million ton of marine species are extracted from the oceans, and traded for food both domestically and internationally (FAO 2014), contributing more than US$80 billion to the world economy (Willman et al. 2012). Approximately 28–33% of all fish stocks are overexploited because of unsustainable fishing, and declines in abundance continue in many other stocks (Branch et al. 2011). Finding ways to ensure the sustainable use of wildlife, including marine fishes, has become an urgent conservation challenge.

Trade measures have commonly been used to improve the sustainability of wildlife trade, and holds enormous potential to supplement management measures for marine fishes. Trade regulations—such as tariffs, quotas and bans—aim to control the supply of and/or demand for endangered species (Challender et al. 2015a). Even trade treaties that advocate trade liberalization, such as the General Agreement on Tariffs and Trade (GATT), state that Signatories shall be allowed to adopt measures that are 'necessary to protect human, animal, or plant life or health' (Wold 1996). Recent multilateral free trade agreements (e.g., Trans-Pacific Partnership) even require Parties to implement specific multilateral environmental agreements, such as the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Lurié and Kalinina 2015). While international trade regulations have been widely used to protect terrestrial species (e.g., EU's import bans for birds and tariffs for timbers in many countries), conservation measures undertaken for marine fishes have mainly focused on restricting fisheries, with relatively few cases addressing trade (although note examples such as the US import restrictions on shrimps caught by nets without turtle excluder devices) (Vincent et al. 2013).

Recently, a number of economically-valuable marine fishes have been embraced by CITES, the biggest multilateral agreement for international trade with a conservation purpose (Vincent et al. 2013). The species covered by CITES are listed in Appendices to the Convention, according to the degree of protection they require. All species in Appendix I are threatened with extinction because of international trade, and the trade of these species is basically prohibited. Species on Appendix II are or may become threatened by international trade. They can only be exported with permits that national government grants after ensuring the specimens are legally sourced and trade will not endanger wild populations—termed making a Non-Detriment Finding (NDF) (CITES Resolution Conference 16.7 2013). If a Party fails to meet these obligations, the export of this species may be suspended (e.g., exports of *Hippocampus kuda* from Vietnam, CITES 2016). Thus, CITES is the only multilateral environmental agreement with enforcement capacity (Ardron et al. 2014). The outcomes of CITES implementation for the conservation of marine fishes desperately needs to be examined.

CITES implementation can have positive effects by generating monitoring and management for listed species at the national level (OECD 2000). To make the positive NDFs required to permit trade, Parties need to design and implement domestic management measures that can help secure healthy populations (Dickson 2013). Common national implementations of CITES listing including domestic bans on extraction (Hutton 2013), trade quotas (Raymakers and Hoover 2002; Sadovy et al. 2007), and size restrictions (Mejía et al. 2008). Improvement of ranching and captive breeding techniques have also been stimulated by CITES as these can allow traders to obtain permits more easily (Thorbjarnarson 1999; Robinson et al. 2015). For marine species, CITES listings have also stimulated reform in fisheries and trade management. For example, the stock assessment of humphead wrasse (*Cheilinus undulatus*) led to the establishment of a trade quota in Indonesia (Sadovy et al. 2007; Sadovy 2010). In another example, Jamaica introduced its management plan for queen conch (*Strombus gigas*), including restrictions on the number of vessels and closed season, in order to respond to CITES' requests (Aiken et al. 1999; Catarci 2004).

National management strategies in response to CITES measures are usually cognizant of the need for biological sustainability, but rarely consider the socio-economic implications of such strategies, which in turn could change expected outcomes (Challender et al. 2015a; Velázquez Gomar and Stringer 2011; Smith et al. 2011). Management measures that reduce stakeholders' (e.g. fishers' and traders') revenue may lower their willingness to participate in conservation actions and discourage them from following regulations (Roe et al. 2002; Sorice et al. 2013). In addition, while CITES listing has reduced consumer demand for some species by generating conservation awareness (Challender et al. 2015a; Nijman 2015), listing has also provoked undesirable consequences such as growing demand in other endangered, high-value species (Challender et al. 2015a). Diverse responses of the traders and markets to trade interventions are associated with the cultural values of the species, economic status of the stakeholders, and many other social-economic factors (Roe et al. 2002; Challender et al. 2015a). At CITES Conference of the Parties 13 (2003), Parties agreed that the social-economic perspectives of the exporting country (e.g., enforcement and rural population's livelihood) should be considered while implementing CITES (Velázquez Gomar and Stringer 2011). Understanding the types of use, trading systems, and the scale of the industry is a critical step towards achieving effective natural resource management (Smith et al. 2011).

As some of the first marine fishes listed on CITES since its inception, the 41 seahorses species are setting precedents for other marine fishes protected by CITES, yet the effect of CITES on their trade is still unclear. The whole genus of seahorses was listed in CITES Appendix II in 2002 (implemented in 2004) because of large-scale and intensive trade in wild populations. CITES data reported that around 3.3–7.6 million seahorses were traded globally from 2004 to 2011 (Foster et al. 2016). However, data generated by detailed trade surveys estimated that the global catch of seahorses were several times higher than the CITES records, at around 37 million individuals (Lawson et al. 2017). The majority of seahorses are traded dry (Foster et al. 2016) for use in traditional medicines and curios (Foster and Vincent 2005). Most exported seahorses are caught in non-selective fishing gear; in many places the biggest threat for seahorses is their incidental capture during trawling (Lawson et al. 2017). Critical to evaluating the impact of CITES on seahorses is the existence of Customs data for seahorse imports, which started before the CITES listing and provide an invaluable opportunity for us to identify the changes in trade because of the CITES intervention.

Thailand has long been the biggest exporter of wild, dried seahorses, exporting approximately 88% of the total numbers reported in the CITES database (Foster et al. 2016). When CITES scrutinized Thailand's implementation of the Convention, it deemed Thailand's exports of three seahorse species (*Hippocampus kuda*, *H. kelloggi*, and *H. spinosissimus*) to be of Urgent Concern. In 2012, CITES issued Thailand with formal recommendations to address its challenges in making positive NDFs for those seahorse species. CITES Appendix II species are commonly regulated through nationally specific export quotas (Challender et al. 2015a), and so as a precautionary measure, Thailand responded to the CITES recommendations by suggesting a maximum export volume (1500 kg) to exporters. Such a quota, though not mandatory, sought to ensure export levels did not increase while additional support for an NDF was undertaken. This quota was only 10% of previous export volume, and was considered as the maximum sustainable yield of seahorses (Phoonsawat et al. 2015). In 2016, Thailand suspended their seahorse exports. However, no study has been done to understand the restrictions on exports to the fisheries and trade. The last national seahorse trade survey in Thailand was conducted in 1998–1999 (before the CITES listing: Perry et al. 2010), so there is a need for post-CITES data to examine the effect of trade regulations.

The objectives of this study were to generate and share new knowledge about Thailand's trade in dried seahorses since the CITES listing, and explore how the national trade of these valuable marine fishes has changed with trade regulations. To meet these objectives, we gathered data in 2013–2014 after seahorses had been listed in CITES Appendix II. The findings were compared to official statistics for exports, which included pre-CITES period, to assess the impact of CITES implementation. We are interested in two questions: (1) what is the economic scale of the seahorse trade in Thailand; and (2) how might trade have changed with CITES interventions? The three CITES interventions we consider are: CITES listing in 2002, CITES listing implementation in 2004, and the voluntary export volume suggested by the Thai government in 2012 (the export suspension, which starts in 2016, was out of our data scope). We hypothesized that the trade volume would decrease only after the domestic policy was applied, while the price would increase after the CITES listing. The findings of this study will assist the Thai government in developing a management strategy for seahorse trade, while shedding light on the social-economic effects of trade regulations on wildlife.

Methods

To meet the first objective of this research, which was to generate new information of current trade status of dried seahorse trade in Thailand, we conducted a total of 203 semi-structured interviews with people whose work was related to seahorse trade (e.g., fishers, traders, government officers) from 2013 to 2014. For the second objective, to determine whether the trade changed with the three stages of CITES implementation in Thailand, we examined trade volume and prices reported in interviews, and compared our interview results to three external datasets: export and import records from the CITES trade database for 2005–2012 (UNEP-WCMC 2013), and Customs statistics from two of the largest seahorse importers, Hong Kong SAR (1998–2012) and Taiwan (1983–2012).

Fig. 1 Provinces in Thailand surveyed in 2013–2014

Trade surveys—data collection

Our surveys covered 13 Thai provinces (Fig. 1) where trade was known or likely to occur based on two sources: (1) earlier studies of the seahorse trade in Thailand (Perry et al. 2010; Laksanawimol et al. 2013; Phoonsawat et al. 2015) and (2) suggestions from respondents during the surveys. In order to find respondents who were involved in the dried seahorse trade, we undertook snowball sampling in which one respondent indicated other potential respondents (Biernacki and Waldorf 1981). The first and second authors (Taiwanese and Thai citizens respectively) conducted the field surveys. During each interview, questions and answers were translated between Thai and English (n = 172), conducted in Thai (n = 24) or conducted in Mandarin or Hokkien (n = 7). All research was approved by the University of British Columbia's Animal Care Committee (5706-12) and Human Behavioural Research Ethics Board (H12-02731).

During the interviews, we asked questions that included but were not restricted to past and present use of seahorses, trade routes, trade volumes, prices, and seahorse characteristics (colour, spiny/non-spiny, size, etc.). Data were recorded in the units given by respondents but standardized during the analysis for ease of comparison (see below). In order to understand the perceived changes in seahorse trade, traders were asked to either recall the seahorse trade volume or/and price of their first year working in this industry, or of a certain year that was meaningful to them (e.g., the year before export permits were required or the year they started trading seahorses). We used triangulation to cross-validate the information received within interviews by asking the same questions in different ways and comparing the answers within and among interviews, and across trade levels. Each interview took from 5 min to 1.5 h, depending on the engagement of the respondent. We also weighed and measured the height (coronet to tail) of 126 seahorse specimens that were found in trade.

Table 1 Number of respondents interviewed during trade surveys in Thailand, categorized by occupation and location

Occupation	Eastern and central Gulf of Thailand	Southern Gulf of Thailand	Andaman Sea	Total
Fishers (level 1)	47	24	27	98
Primary buyers (level 2)	8	8	6	22
Middle traders (level 3)	3	0	0	3
consolidators (level 3, 4)	5	0	5	10
Internet traders (level 2, 3, 4)	9	1	0	10
Souvenir stores	0	0	10	10
TCM retailers	16	1	6	23
Exporters	9	0	0	9
Others (Gov. officers, NGOs, residents…etc.)	7	7	4	18
Total	104	41	58	203

Fig. 2 Dried seahorse trade structure in Thailand. Arrows indicate the direction of trade flow, from oceans to export
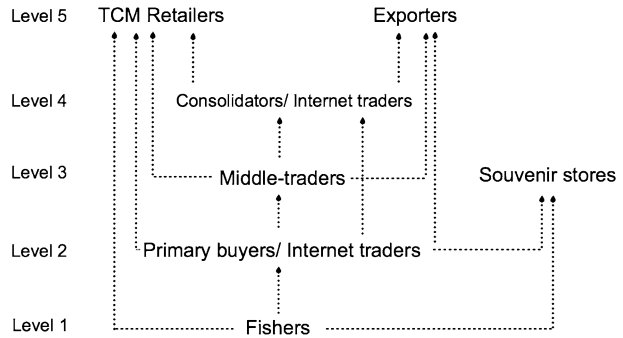
Trade surveys—data analysis

After the interviews, we categorized the respondents according to their role in, or involvement with, the seahorse trade, including fishers, buyers, consolidators (wholesalers), domestic retailers, exporters, government officials, and other experts (Table 1). Fishers and traders were further categorized into different trade levels (Fig. 2). For example, fishers who caught seahorses directly were defined as "level 1", collectors that bought directly from fishers were "level 2", and so on. Note that one respondent could occupy more than one level in the trade chain, and if one did, we defined his/her trade level by the highest position he/she occupied in the trade chain.

We collected information on annual seahorse trade volume and price for each trade level. Reports from individual respondents on trade volumes for discrete time periods (i.e., per week, trip, month, or year) were scaled to annual estimates based on the frequency of trade activity (e.g., number of purchases in a month). Since the price of seahorses varied with size, we standardized the reported prices to Thai Baht (TBH) per gram dried weight. To compare the price across sizes, we divided seahorses into three size-classes: 300–800 seahorses per kilogram (size class Small), 101–300 seahorses per kilogram (size class Medium), and 40–100 seahorses per kilogram (size class Large). To compare the prices reported in a different currency (e.g., exporters might report the price in USD), we used the mean exchange rate of TBH and USD from January 2012 to March 2014 (0.032 USD = 1 TBH) (http://www.usforex.com, accessed April 29th 2014). We carried out all analyses based on seahorse dry weights, converting numbers of individuals to weight using 1 dried seahorse = 3.16 g; this was the mean weight of individual seahorses collected during the surveys (n = 126, SE = 0.16).

Estimate economic scale

To quantify the economic value and effects of CITES on the trade, we used four metrics to determine the economic scale of the dried seahorse industry in Thailand: (1) value generated when the fishes were extracted from the water, termed direct expenditures or gross output; (2) gross value of annual domestic trade; (3) gross value of international trade (i.e. annual exports); and (4) potential number of traders involved in every level of the supply chain. We did not quantify the profits of the seahorse trade because we lacked data about costs. Therefore, we quantified the gross output and export values instead.

Direct expenditure (1) was estimated as the total catch of seahorses in a year [91 ton after conversion from number of individuals; (Aylesworth et al. 2017)] multiplied by the mean ex-vessel price reported by fishers (level 1) and primary buyers (level 2). The gross values of annual domestic trade (2) were calculated by multiplying the mean selling price, the mean trade volume of individual domestic TCM retailers, and the total number of registered TCM retailers in Thailand. To estimate domestic trade volumes, we standardized the reported sold/purchased volume of seahorses into annual quantities for each respondent. The total number of TCM shops in Bangkok (n = 491) was accessed from the Bangkok Medicine Trader Association (http://www.thaicn.net/zyzy.html, accessed April 10th 2013). Then, we multiplied the mean price per gram by the total trade volume for retailers to calculate the gross value of domestic trade and exports. The gross values of annual export trade (3) was calculated as the mean selling prices multiplied by the export volume reported in the CITES trade database.

To understand how many people were involved in the dried seahorse trade (4), we estimated the potential number of traders in each trade level, except for level 1, for which we calculated as the number of trawl vessels instead of number of fishers. The calculation process is detailed in the Supplemental Information. We created two estimates of the number of people involved in the trade: (i) starting at the top of the trade chain (total exports) and working down to number of trawlers, and (ii) starting with an annual catch estimate (Aylesworth et al. 2017) and working up to number of exporters. Since respondents might report purchase volume, sell volume, or both, we applied two methods to calculate the number of traders in each level (using trawlers as level 1), except for level 3 where we lacked data. In Method 1, we considered both trader-reported annual purchasing volumes and selling volumes. In Method 2, we considered either selling volume or purchasing volume, or the larger of the two reported volumes if a trader reported both. These two methods were applied for both top-down and bottom-up calculations. For the top-down calculations, we started with the export volumes reported to CITES in 2011 and 2013; they straddled the arrival of the voluntary export quota in mid 2012. For bottom-up calculation, since the catch estimate was based on known number of fishing vessels (Aylesworth et al. 2017), we skipped level 1 (trawlers) and started our estimate from level 2 (primary buyers).

Estimate income from dried seahorses

We estimated the mean income from dried seahorses for individual fishing vessels and exporters (the bottom and the top of the supply chain). For a fishing vessel, the income from seahorses was calculated by dividing the gross output (value of total catch) by the total number of registered boats [considered all gears that catch seahorses (Aylesworth et al. 2017)]. This calculation assumed all catch goes into trade, although very few may be kept for personal use. We also estimated mean income for vessels based on total declared export and domestic trade volumes, reflecting the possibility that not all caught seahorses enter trade. Mean income per vessel was calculated for commercial and small-scale fisheries separately, by considering the proportion of catch from each type [68% from commercial and 32% from small-scale (Aylesworth et al. 2017)]. The mean income per exporter was calculated as mean reported export volume multiplied by mean reported export price.

Perceived changes in trade volume and prices over time and with CITES Implementation

We collected the historical trade volumes and selling prices to explore changes in seahorse trade over time for each trade level. To account for inflation rate, we corrected historical prices by scaling them with the relative consumer price index (CPI) in Thailand for 2014 (CPI of 2014 = 104, Bank of Thailand 2016). While investigating the trend in the reported trade volume and value, we applied a linear mixed effect model on the reported data with year as the fixed effect and the respondents as random effect.

Examine changes in international trade using external datasets

In addition to interview data, we also used three sets of official trade records to examine changes in the international trade of Thai seahorses. The three data sets were: (1) CITES trade database (https://trade.cites.org, UNEP-WCMC 2013), (2) statistics from the Census and Statistics Department of Hong Kong SAR and (3) Customs Administration records from Taiwan (https://portal.sw.nat.gov.tw/APGA/GA03, accessed at December 7th 2015). CITES trade data were downloaded on September 9th 2015 for all dried trade records involving Thailand from 2004 to 2013. Since the CITES listing for seahorses was implemented in May 2004, data for 2004 may reflect only partial trade volumes for that year (Foster et al. 2016). While the CITES trade database contained both import and export data, we used the "exports reduced from imports" as defined in Foster et al. 2016. Hong Kong SAR's Census and Statistics Department recorded dried seahorse imports (in kg) and prices into Hong Kong from 1998 to 2014, and Taiwan's Customs Administration recorded dried seahorse imports (in kg) to Taiwan from 1983 to 2014, and prices from 2002 to 2014 (although the prices of imports from Thailand were missing in 2013 and 2014).

Results

Trade structure

We found at least five trade levels for the dried seahorse trade in Thailand, with any individual potentially operating in several levels. Fishers (level 1) (n = 98) reported selling dried seahorses to primary buyers (level 2) at ports (Fig. 2). Most level 2 traders we interviewed lived near the ports so they could easily visit whenever trawlers landed their catches (n = 16 of 22); some even maintained grocery shops beside the port as a trading venue for fishers (n = 7 of 22). Some level 2 traders bought seahorses along with other marine products, such as shells, sea cucumbers, and lobsters (n = 4 of 22). A few of the fishers we interviewed at sites near Thailand's borders reported selling to traders in neighbouring countries for a better price (n = 5 of 22; Fig. 3). Exchange of commodities (including seahorses) was also reported by one fisher to happen at sea near the Thailand-Malaysia border.

Primary buyers (level 2 traders) reported that their higher-level buyers (middle-traders, level 3) travelled among coastal cities to gather stock from many primary buyers (n = 22), although some received their commodity by post as well (n = 3 of 22). The level 2 traders we interviewed reported that while they were loyal to their higher-level buyers, an increasing number of new traders were enquiring about seahorses for sale (n = 5 of 22).
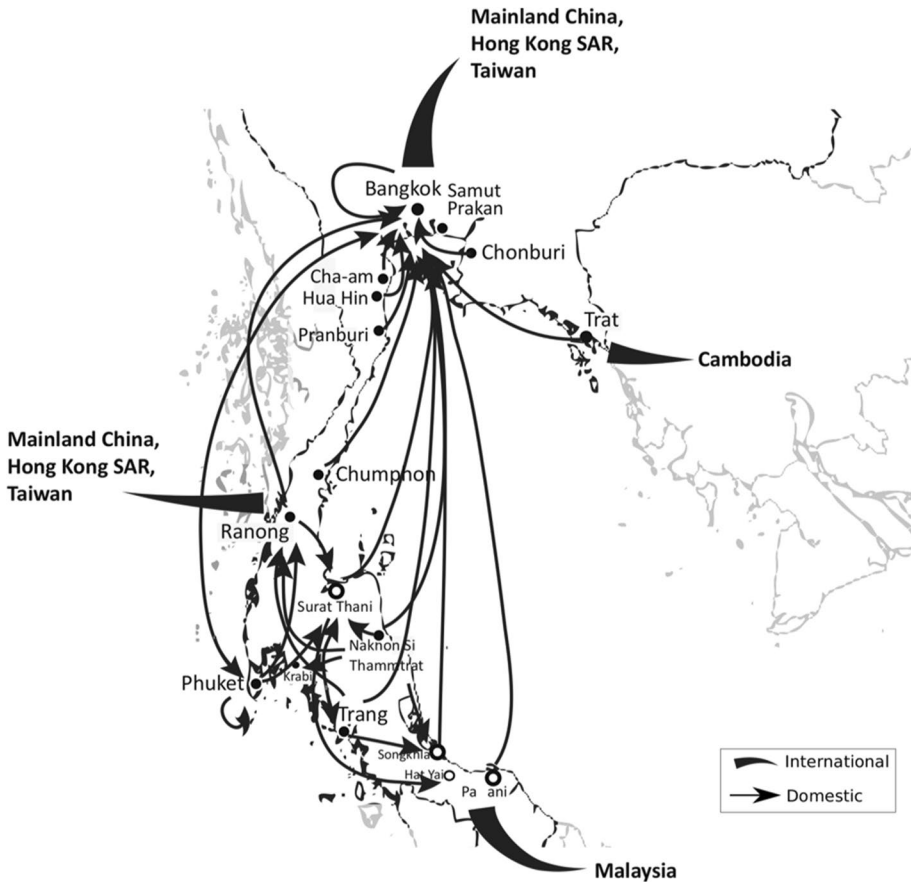
Fig. 3 Potential trade routes for dried seahorses in Thailand as deduced from trade interviews. The arrows show the direction of trade flows. Survey locations are indicated as solid circles, whereas open circles represent places identified by respondents

Level 2 traders reported that they sent the seahorses to where the level 3 traders live (e.g., Ranong, Surat Thani, and Songkhla, as shown in Fig. 3), then level 3 traders dispatched a vast majority of their purchased seahorses to Bangkok to consolidators (level 4). From there seahorses were distributed to retailers (level 5) in other regions of Thailand for sale as TCM (n = 10 of 22) (Fig. 3). Level 2 traders in Phuket also sold seahorses as curios to souvenir stores (level 3; 4 of 9 souvenir stores surveyed in Phuket reported selling seahorses). We could not obtain information about the trade routes from the few level 3 traders (n = 3) we interviewed.

Consolidators (level 4) bought seahorses from level 3 traders and sold them to retailers and exporters (n = 10). In TCM stores (retailers, level 5), the seahorses were sold by weight, with the unit as gram or "tael" (about 3.75 g). Exporters (level 5) obtained most of their seahorses from consolidators (level 4), but sometimes bought them from middle-traders (level 3). Respondents at various trade levels indicated that dried seahorses were exported to China, Hong Kong SAR, and Taiwan as traditional Chinese medicine (n = 24) (Fig. 3).

Table 2 Trade volumes and number of traders of dried seahorses for each trade level in Thailand

	Mean volume per trader ±95% CI[a] (kg trader[-1] year^{-1})			Top-down calculation				Bottom-up calculation	
				CITES 2011		CITES 2013		Catch estimate[b] (2015)	
Volume (kg)				15,256 (UNEP-WCMC 2013)		1430 (UNEP-WCMC 2013)		91,677±77,220[b]	
Annual domestic consumption volume (kg)				265					
	Purchase	Sell	Trade	Estimated number of traders					
				P+S	T	P+S	T	P+S	T
Exporters—2011 (level 5)	1740 (n=1)	1475 (n=2)	1563 (n=3)	10	10	–	–	155	59
Exporters—013 (level 5)	391±364 (n=5)	157±60 (n=7)	309±235 (n=8)	–	–	9	5	692	297
Consolidators (level 4)	242±141 (n=6)	341±323 (n=4)	297±150 (n=10)	53	52	11	6	794	309
Middle-traders (level 3)	30 (n=2)	360 (n=1)	140 (n=3)	–	–	–	–	–	–
Primary buyers (level 2)	23±12 (n=18)	48±60 (n=8)	33±23 (n=21)	267	466	56	51	3967	2776
Total # of traders (level 2, 4, 5) Year: 2011				330	528			4916	3144
Year: 2012						76	62	5453	3382
Trawlers (level 1)			17±17 (n=38)[b]	361	908	78	100	–	
# of otter trawlers registered in Thai Department of Fisheries				2553 (DoF 2015)					

[a]Confidence interval is reported when sample size is larger than 3

[b]Data reported in Aylesworth et al. (2017)

Data obtained from external datasets or literature are in italic. We used reported mean catch from otter trawlers to representative fishers' trade volume (level 1). Number of traders was estimated based on the mean trade volume and by two methods (See Supplemental Information) for sensitive analysis: (1) considering both reported purchase volume and sell volume ($P+S$), and (2) considering only the maximum trade volume (T)

Trade volume in dried seahorses

Level 2–4 traders reported that they sold more seahorses than they bought (Table 2). However, exporters (level 5) reported that they bought more seahorses than they sold annually (Table 2). Traders from level 1 to 4 reported moving a mean of 17 kg per trawler up to 297 kg per consolidator. A few exporters (n = 3) mentioned that their exports changed after implementation of the Thai export quota in 2012, so we separated their reported exports into 2011 (before the Thai quota) and 2012–13 (when we did our surveys); exporters reported that their mean annual export volume dropped from 1563 kg in 2011 to 309 kg in 2012–2013 (Table 2).

Reported domestic consumption of dried seahorses as TCM (from eight TCM retailers) was < 10% of the reported export volume. The estimated mean annual sales volume for a TCM store was 0.54 ± 0.52 kg year^{-1} (n = 8), and the estimated total domestic consumption of dried seahorses at around 265 ± 255 kg year^{-1} (Table 2).

Price of seahorses traded in Thailand

Mean selling price by trade level ranged from US0.29 ± 0.11 g^{-1} (level 1) to US1.29 ± 0.90 g^{-1} (level 4)—a fourfold increase (Table 3). Mean reported buying price increased 1.5-fold between level 2 and 4 traders (Table 3). Retailers (level 5) and exporters (level 5) reported buying and selling prices were lower than those reported by level 4 traders (Table 3).

The price of seahorses was based on size across all levels of the trade (n = 72). Fishers sold seahorses individually, and reported that selling price increased with seahorse size (n = 53 of 58 fishers). Higher-level traders (levels 3–5) paid more per kg for a bag of large seahorses than small ones (n = 16 of 45); level 4 and 5 traders (n = 13) reported the average selling price of the largest seahorses (40–100 seahorse/kg) to be at least four times higher than the average price of the smallest seahorses (300–800 seahorses/kg) (Table 3).

Economic scale of dried seahorse trade in Thailand

(1) *Direct expenditures* Based on the most recent annual seahorse catch estimate [91 \pm 39 ton; (Aylesworth et al. 2017)] and mean ex-vessel price (US$0.29 per gram, n = 36, Table 3), the direct expenditure (gross output) of dried seahorses in Thailand was around US$26.5 million (95% CI: US$0.1–67.1 million). Within the US$26.5 million, US$18.1 million were generated by commercial fisheries and US$8.4 million came from small-scale fisheries.

(2) *Annual domestic consumptive value* The domestic consumptive value was only US$0.2 million (CI: US$0–0.6 million) because of the relatively low trade volume (265 ± 255 kg per year), even though the retail prices in Thailand were high compared to the ex-vessel price (mean = US0.81 ± 0.25 per gram, n = 14, Table 3).

(3) *Annual gross export values* Annual gross export values were calculated for 2011 and 2013 in order to distinguish the effect of the quota starting in 2012. The annual gross export value for 2011 was US$5.9 million (export = 15,256 kg, and mean export price US$0.39 per gram, n = 3), and dropped to US1.0 ± 0.4 millions in 2013 (export = 1430 kg, and mean export price US0.72 ± 0.26 per gram, n = 7).

Table 3 Mean purchasing and selling price of dried seahorses in each trade level (USD per gram) across three seahorse size categories [small (S), medium (M), large (L)]

	Purchasing price in USD per gram	Mean price by size (n)			Selling price in USD per gram	Mean price by size (n)		
	Mean ± 95% CI (n)	S	M	L	Mean ± 95% CI (n)	S	M	L
Exporter—2012, 2013 (level 5)	0.71 ± 0.26 (6)	0.25 (2)	0.56 (4)	0.97 (4)	0.72 ± 0.26 (7)	0.13 (3)	0.46 (4)	1.15 (5)
Exporter—2011 (level 5)					0.39 (3)			
Retailer (level 5)	0.33 ± 0.2 (4)				0.81 ± 0.25 (14)			
Consolidators (level 4)	0.81 ± 0.27 (7)	0.39 (4)	0.93 (3)	1.70 (2)	1.29 ± 0.90 (9)	0.31 (8)	0.73 (7)	1.11 (6)
Middle-traders (level 3)	0.30 (3)	0.32 (1)	0.49 (1)		0.44 (2)	0.48 (1)	0.58 (2)	
Primary buyers (level 2)	0.53 ± 0.48 (9)				0.68 ± 0.41 (21)		0.35 (3)	0.37 (1)
Fishers (level 1)	–	–	–	–	0.29 ± 0.11 (36)		0.42 (2)	

Sample sizes (number of respondents) are shown next to the prices in brackets

(4) *Number of traders* According to our top-down calculation, the estimated number of traders based on buying and selling volumes (Method 1, 'B + S' in Table 2) suggested that the CITES-reported export volume from Thailand in 2011 may involve at least 330 people in the supply chain (not account for level 3 traders or fishers). In contrast, the CITES-reported export volume from Thailand in 2013 suggested only 23% as many people (again, not account for level 3 traders or fishers) (Table 2). If the calculation were based on trade volume (Method 2, 'T' in Table 2), estimates of the number of traders would decline from around 530 people in 2011 to about 60 people in 2013 (Table 2). For both methods and time periods, the estimates for the number of trawlers catching seahorses derived from the export volumes represented 3–33% of the number of trawlers registered in Thai Department of Fisheries (Table 2). Using our bottom-up approach, by Method 1, we estimated that an annual catch of about 91 ton may involve more than 5400 people in the supply chain in levels 2, 4, and 5 in 2011 (so excluding number of level 3 traders and fishers; Table 2), but only 4900 people in 2013 (Table 2). Method 2 suggested that fewer people were involved in the trade, with 3400 people in 2011 and 3100 people in 2013 (Table 2).

Income from trading dried seahorses

Based on the gross output, we estimated that a commercial vessel could potentially earn US$2784 from dried seahorses while a small-scale fishing boat could only earn US$227 in a year. If the income from seahorses was evenly divided by the crew as reported to us in some provinces (e.g., Phuket), each crew member could potentially earn US$116–232 p.a. from seahorses [crew size 12–24 per trawler (DoF 2015)]. However, if based on the total trade volume in 2011, 15,552 kg (export = 15,256 and domestic trade = 265 kg), we estimated that the income from seahorses was US$434 for a commercial fishing boat and US$39 for a small-scale vessel. The decline in export volume in 2013 could potentially reduce the annual per vessel income from seahorse to US$108 for a commercial vessel and just US$8 for a small-scale vessel. Exporters reported their individual mean annual income from seahorses to be US$609,570 in 2011 (1,563,000 g × US$0.39) and US$222,480 in 2013 (309,000 g × US$0.72).

Perceived changes in trade volume and price

Most respondents who described the trend in seahorse trade volume reported a decline trend [8 of 9 primary buyers (level 2), 7 of 7 consolidators (level 4), and 8 of 8 exporters (level 5)]. Only one level 2 trader described the trend of dried seahorse volume as stable. Level 3 traders and retailers (level 5) did not report historic trade volumes. Both primary buyers and the consolidators' reported trade volume shows a decline overtime (level 2, logarithm slope = −0.13, p = 0.02; level 4, logarithm slope = −0.18, p = 0.01, Fig. 4a). In contrast, the decline in reported volumes for exporters was not significant (level 5, logarithm slope = −0.21, p = 0.11; Fig. 4a).

The reported selling price of dried seahorses significantly increased at all levels of trade (Fig. 4b). The rate of increase in historic selling price was the highest for exporters (level 5, logarithm slope = 0.22, p < 0.01), and lower with each subsequent descending trade level (slope = 0.16 for consolidators, 0.10 for primary buyers, and 0.06 for fishers, all p-value < 0.01).
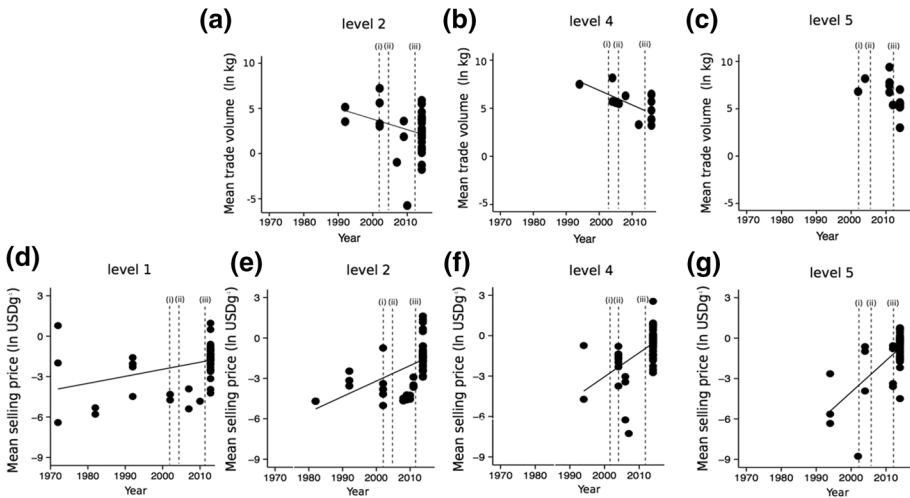
Fig. 4 Changes in (**a**–**c**) mean trade volume and (**d**–**g**) per-gram selling price of dried seahorse reported by traders in each trade level in Thailand. Data were log transformed. The changes in trade volume and prices are presented by linear regression lines (if significant). The three interventions are marked by dashed lines: (i) CITES listing, (ii) CITES implementation, (iii) Thailand voluntary export quota implemented

It appears that the trend in trade volume did not show a large change after each of the CITES interventions, though exporters have reported that they reduced the exports after Thai government's suggested quota (Fig. 4a). Similarly, although respondents at every trade level reported increases in prices, only fishers reported a large increase in selling price corresponding to the Thai quota at 2012.

Comparisons of Thai seahorse exports among different data sources

(1) Trade volumes

The CITES database reported the dried seahorse export volume from Thailand to range from 9598 to 20,980 kg per year from 2004 to 2011, with the annual mean estimated at 15,690 kg (SD = 3094). In 2013, the year after Thai government implemented the voluntary annual export quota, CITES data reported a total of just 1430 kg seahorses exported from Thailand. According to CITES trade records, Hong Kong SAR was the biggest importer of Thai dried seahorses, with an average of 9896 kg per year from 2005 to 2013 (SD = 4963), which accounted for 50–90% of the total reported Thai dried seahorse exports (Fig. 5). Taiwan was reported as the second largest importer overall, but from 2005 to 2013 reported Taiwanese import volumes decreased steadily from 4791 to 318 kg (Fig. 5). CITES data also reported Thai seahorses being exported to mainland China, Singapore, Australia, New Zealand, USA, Cyprus, and Malaysia from 2004 to 2013.

Hong Kong SAR's data showed that the mean annual import from Thailand (including seahorses re-exported from Hong Kong SAR) between 1998 to 2011 was 9678 kg. The year of the CITES listing, 2002, corresponds to the importing peak of seahorses from Thailand to Hong Kong. Since 2004, Hong Kong's imports of seahorses from Thailand have gradually declined. In 2013, Hong Kong reported only imported 839 kg
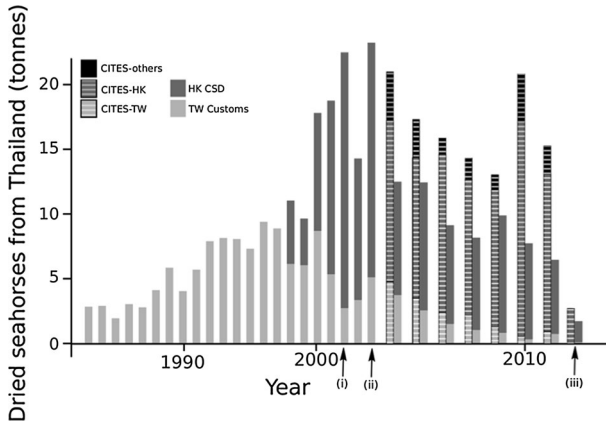
Fig. 5 A comparison of international trade volume from Thailand using three official datasets (CITES, Hong Kong CSD, and Taiwan Customs). Records from importers were stacked into one bar for each year; Hong Kong Census and Statistics data were in dark grey and Taiwan customs data were in light grey. For the CITES data, trade volume from Thailand to Hong Kong (HK) and Taiwan (TW) were shown in the same colour code as the Customs data but with stripes (HK: dark grey; TW: light grey), and to other destinations were in black. The three interventions were marked by arrows: (i) CITES listing, (ii) CITES implementation, (iii) Thailand voluntary export quota implemented

of dried seahorses from Thailand, which was the lowest point on record, and lower than reported trade volumes from Thailand to Hong Kong in the CITES database (Fig. 5).

Imports from Thailand reported by Taiwan showed a mean annual import of 5473 kg between 1983 and 2004, and the quantity started decreasing to a mean annual import of 1226 from 2005 to 2012 (Fig. 5a). The imports to Taiwan in 2002 decreased to one of the lowest levels since the records started, but gradually increased until 2004. Then, Taiwan reported that its imports of seahorses from Thailand steadily decreased since

Fig. 6 Comparing prices that Hong Kong (HK) and Taiwan (TW) imported seahorses from Thailand. The three interventions are marked by arrows: (i) CITES listing, (ii) CITES implementation, (iii) Thailand voluntary export quota implemented
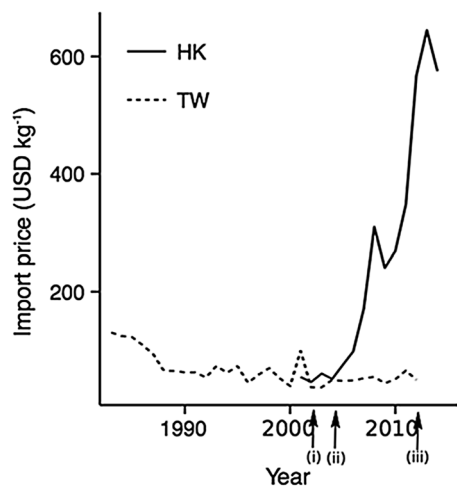
2005, and dropped to only 100 kg in 2012 and 219 in 2013 (Fig. 5a).

(2) Prices

Import prices in Hong Kong have been increasing since 2004, and jumped higher in 2012 (Fig. 6). These two increases are corresponding to the global implementation of CITES listing (2004) and the voluntary export quota in Thailand (2012). In contrast, import price in Taiwan has fluctuated with no apparent trend (Fig. 6).

Discussion

Our study found that the seahorse trade was worth surprising amounts of money and there was a significant discrepancy between reported catch and export volume, suggesting the possibility of under-reporting. Our quantification of the potential direct expenditures generated by dried seahorses suggested that these bycatch fishes have significant economic importance. However, the declared export value was only 20% of calculated direct expenditures. The discrepancy between fisher-reported catch and CITES export volumes suggested that more seahorses might be in the trade than CITES data depicted. Traders perceived a decline in trade volumes over time but did not consider it a result of the trade management interventions. In contrast, Thai traders perceived that price increased significantly, and Hong Kong's import data especially showed an increase, after CITES implementation.

The notable economic value of dried seahorses helps maintain the trade and could be a strong incentive for fishers to continue fishing even if their target species are overexploited. The potential gross output of seahorses found in our study, which we estimated to be US$26.5 millions direct expenditures in a year, was about 1/3 of the declared cash value of total fish for reduction (often dismissed as "trash fish") in Thailand (US$ 79 million in 2012, OECD 2015). The income from seahorses could be about 20% of the fisheries income of small-scale fisheries (Bennett et al. 2014), and up to 10% of a crew's earning on commercial vessels [6500 TBH/month (International Labour Organization and Asian Research Centre for Migration 2013)]. In addition to fishers, exporters could benefit much more by selling seahorses. The mean income from seahorses for an exporter was 37–100 times higher than the mean per capita income in Thailand [US$5977 for 2011–2016 (The World Bank 2016)]. Such estimate of exporters' income might even be underestimated, since the export prices reported by exporters were lower than the selling prices reported by consolidators. Given the apparent cash value of seahorses, there may need to be other incentives to support conservation actions for seahorses (Roe et al. 2002) particularly given that the seahorses are bycatch (Yasué et al. 2015). The economic revenue from bycatch can help subside the fishers to continue fishing even when the abundance of their target species are largely decreasing (Branch et al. 2013).

The huge mismatch between the Thai seahorse catch estimate and CITES declared export volume suggests that a large part of the trade might not be reported to Thai CITES Authorities, creating a concern for effective management (Srikosamatara et al. 1992; Shepherd and Nijman 2007). In our top-down calculations for estimating the number of traders, both methods agreed that the number of trawlers deduced from declared export volume was far lower than the actual number of registered vessels (DoF 2015). This discrepancy could arise if most seahorse catch is being retained rather than traded. Given the high economic values of seahorses, however it is more likely that a significant number of seahorses in trade went unreported to Thai CITES Authorities and thus in the CITES records (Blundell and Mascia 2005). We could not validate the CITES database independently since the exporters we interviewed had all registered for CITES permits, and scaling up from lower

levels of trade requires full knowledge of how many traders are operating at these levels. The large gap between trade records and catch made the declared export volumes an inaccurate indicator of extraction levels, and might create a delay in noticing and addressing over-exploitation (Blundell and Mascia 2005; Cooney and Jepson 2006; Foster et al. 2016).

Our findings show that the catch of seahorses continued untrammeled even when there are hints of changing exports after CITES interventions. We found that reported catch and lower-level trade volumes of seahorses were declining, but not strongly affected by CITES interventions. In contrast, Hong Kong and Taiwan's data showed that Thai exports of seahorses had declined after both global implementation of CITES and the domestic restrictions on exports (Kuo and Vincent 2018). Such inconsistent, or delayed responses in the changes in trade volume among trade levels have also been found in other wildlife trade when export quotas were applied (Beissinger and Bucher. 1992; Lee and Smith 2010). In our case, it may indicate that reducing exports has limited effects on bycatch extraction of fishes or, therefore, on lower levels of trade (Casale 2010). Moreover, the changes in declared exports might not be the true export volume, as a certain proportion of trade might be unreported (Blundell and Mascia, 2005; Foster et al. 2016). While other studies have found that illegal trade of seahorses continue even when export bans have been implemented (O'Donnell et al. 2012; Foster and Apale 2016; Foster et al. 2017), enhancing the enforcement of current trade and fisheries measures is critical for the sustainability of seahorses.

The increases in price of trade-regulated seahorses, as seen in every trade level in our study, might result from the rising international demand, coupled with declining supply because of overfishing or/and trade restrictions (Challender et al. 2015a, b). The majority of trawl fishers in Thailand reported perceived declines in seahorse catch (Aylesworth et al. 2017) even while exporters and wholesalers we surveyed indicated that the demand from Mainland China and Hong Kong had been increasing. In addition, after CITES implemented its listing of seahorses, many large source countries, such as Philippines, banned export of seahorses (Yasué et al. 2015). Facing the significant reduction in seahorse supply, the international market might depend more on the few exporting countries, including Thailand. That was not surprising that the import price of seahorses to Hong Kong would increase almost 7 times from 2004 to 2011. However, the import prices of Taiwan have fluctuated and did not show this apparent trend, which might suggest a different market response to Hong Kong. The reasons behind such differences in the import prices need further investigation. Although nearly all seahorses are obtained as bycatch in Thailand, the rise in the price still needs to be carefully considered as a driving force for further exploitation. Taking the example of sharks, while only a few pelagic shark species (e.g., *Isurus oxyrinchus* and *Lamna nasus*) were targeted in the past for the meat (Dulvy et al. 2008), the increasing value of shark fin has led to more shark species (e.g., *Prionace glauca*) being targeted (Dulvy et al. 2008).

This study highlights one of the challenges that arises in implementing CITES Appendix II listing of species that are obtained in by-take or by-catch. Even if countries seek to manage exports in conformity with their CITES obligations by imposing an export quota or some other restriction, this may only result in reduced exports at best and not in reduced catches or impacts on the wild populations. Indeed, a recent survey in one of the largest seahorse import market, Hong Kong, still found a huge amount of seahorses sourced from countries that impose export bans (including Thailand) (Foster et al. unpublished data). It may generally be much more effective in conservation terms for Parties to eschew the allure of a simple fix through export measures, and instead to manage extraction in a way that allows for exports. One of CITES' recommendations

for Thailand in the 2012 was that Thailand increases its enforcement of fisheries restrictions (e.g., the three nautical miles wide trawl exclusion zone along the coast of the entire country) (CITES AC26 2012). The current concerted effort from Thailand to address Illegal, Unregulated and Unreported (IUU) fishing—goaded by European Union concerns (Leroy et al. 2016)—will advance national capacity to improve all fisheries sectors. The goal of CITES Appendix II listings is, after all, to ensure persistence of carefully managed trade, not to close it down.

CITES is a promising tool for ensuring the sustainable trade of marine species, but it is not a stand-alone solution. CITES has urged governments to improve their management for the protected species, and successful stories have been found in terrestrial species (Aiken et al. 1999; Sadovy et al. 2007; Recharte Uscamaita and Bodmer 2010). However, reforming international/national management and enhancing enforcement is still the key to controlling exploitation. The "trash fishes" comprise 30–40% of the total catch from Thai waters (Ahmed et al. 2007), though the proportion may have declined in recent years, with the Thai DoF reporting 17% across all gear types in 2017 (Poonsawat pers. comm.). Managing seahorse extraction and ensuring the sustainability of its trade has implications for the management of other "trash fishes". Bycatch species can be highly valuable—as our case shows—and ensuring the sustainability of their trade would be not only beneficial to the species, but also to the people depending on them.

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