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Seahorse exploitation and trade in Viet Nam

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Director's Foreword

UBC's Institute for the Oceans and Fisheries takes pride in contributing original research to help address policy questions of importance to regions, nations and the world. Our vision is a world in which the ocean is healthy and its resources are used sustainably and equitably. In its origins as the UBC Fisheries Centre and in its current form, the IOF has generated notable and effective input into policy questions that include fisheries management, trade regulation, habitat recovery, protected area designation, and climate change amelioration.

One of IOF's valuable contributions to policy change came when Project Seahorse supported the Convention on International Trade in Endangered Species of Wild Fauna and Flora (www.cites.org) to begin regulating export of marine fishes of conservation concern. In 2002, for the first time since the inception of the Convention in 1975, CITES agreed to place marine fishes on Appendix II. Exports of such species are only permitted when they do not damage wild populations, when they are legally sourced and, for live animals, when they are humanely transported. CITES had seen considerable vigorous debate on adopting such provisions for marine fishes so it was remarkable when Project Seahorse's pioneering work on seahorses led to them being added to Appendix II, along with whale sharks and basking sharks.

Project Seahorse is a partnership between UBC and the Zoological Society of London, UK. Its vision is a world in which marine ecosystems are healthy and well-managed. At UBC, Project Seahorse work is led by its co-founder and director, Professor Amanda Vincent. Her team of students and staff are engaged in marine research and management around the world, using seahorses as a way to focus efforts in finding marine conservation solutions in a context of sustainable use. They are committed to interdisciplinary collaboration with stakeholders and partners at scales ranging from community initiatives to international accords.

Although a new policy instrument was born with the adoption of CITES for marine fishes – and many more species have since been added – the challenge lies in implementation. Here, too, Project Seahorse has assisted CITES to apply its provisions for marine fishes, setting precedent for other species. It has been particularly active in supporting the process of Review of Significant Trade, in which nations are asked to justify their levels of reported export trade as sustainable. As part of this process, Viet Nam was the first CITES member country to experience a trade ban for marine fishes, when CITES suspended exports from Viet Nam for a seahorse species, *Hippocampus kuda*.

The IOF is proud of finding solutions to management, environmental, and conservation challenges. It is thus in keeping with our approach that Project Seahorse has been active in supporting Viet Nam to address the CITES-imposed trade suspension. This report covers field research executed by Project Seahorse to help fill gaps in Viet Nam's knowledge and capacity of its seahorse biology, fisheries, aquaculture, and trade. Its intention is to help Viet Nam move towards full implementation of the Convention and the lifting of the CITES export suspension, by developing conditions where seahorse exports are indeed sustainable, legal and ethical.

I congratulate the authors on this important work, and hope that it will support sound ocean management.

Prof. Evgeny Pakhomov
Director, Institute for the Oceans and Fisheries
University of British Columbia

Abstract

The Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) decided to implement export controls for all seahorses in 2002, the first such controls for any marine fishes. Viet Nam had difficulties implementing CITES regulations and was eventually subject to an export trade suspension in 2013. To help address gaps in knowledge and capacity, we gathered information on the biology, fisheries, aquaculture, and trade of seahorses in Viet Nam, conducting 146 interviews in eight provinces.

Fishers reported catching seahorses from seven different types of fishing gear with two-thirds of the respondents reporting use of single trawls. Some divers and single trawls reported targeting seahorses directly, but most catch was incidental. Mean catch varied among gear types from fewer than one seahorse per day per seine net, to as high as 15 seahorses per day per pair trawler. The southernmost province, Kien Giang, obtained 85% of the total national catch estimate of about ~16.7 million individual seahorses per annum. The large number of vessels means that pair trawls land approximately 12.5 million seahorses per annum (75% of Viet Nam's total catch), four times more than single trawls (around 20%).

Landed seahorses enter a complex trade, with large domestic consumption of seahorses in Viet Nam for seahorse wine and tonics and considerable export; we could not discern the ratios that enter each. The reported purchase volume of dry seahorses was more than three times that of wet seahorses, with buyers in Kien Giang purchasing the largest number of seahorses per annum. Five different seahorse species were identified in trade with *Hippocampus trimaculatus* comprising nearly two-thirds of specimens surveyed from seahorse buyers.

Seahorses born in captivity to wild parents – and traded live – made up 90% of reported wild exports in the CITES database for 2008-2014. Aquaculture facilities, all focused on *H. kuda*, reportedly struggled to close the life cycle on breeding – thus retaining dependence on wild broodstock, obtained from fishers – and extracted food for their seahorses from the wild. According to CITES data, two-thirds of live trade from 2005-2014 apparently went to the USA and 11% to France.

Ninety-five per cent of fishers from all provinces reported a decline in seahorse CPUE over a ten-year period with a mean 59% decline. Most fishers also reported inferred decline in body height (down 44%) and an increase in price of seahorses over the same time period (up 42%). A minority of buyers and two culturists also reported declines in supply.

Given that seahorses are pioneers in implementation of CITES for marine fishes, our work is of broad importance. We indicate that Viet Nam is not fully implementing CITES regulations: none of the seahorse catch was being monitored or regulated to any extent to assess sustainability; large exports of dried seahorses were either exported illegally without CITES permits or exported with permits that Viet Nam did not report to CITES; and the purported switch in exports of cultured seahorses from *H. comes* to *H. kuda* after CITES banned exports of the latter in 2013 needs probing.

Introduction

The value in conservation agreements comes from the action that follows the decisions, not from the words on the page. This is true for all taxa and at all geographic and political scales. It is particularly the case for Multilateral Environmental Agreements where there can be many a slip between the accord and the implementation. Good intentions can be derailed by, among other things, political obstructions or inertia, gaps in capacity and resources, confusions about process and responsibilities, or a dearth of technical knowledge and guidance (Shihata 1997; Mitchell 2003). Often, of course, myriad challenges combine to determine that little happens of benefit to the species, spaces or systems of concern.

Implementation of conservation accords can be highly problematic for marine species. The history of management for marine fishes and invertebrates, in particular, has revolved around maximizing production for consumption and economic return. The first IUCN Red List assessments of conservation status relating to marine fishes, which only unfurled twenty years ago (Vincent and Hall 1996), played a significant role in directing attention to marine life as intrinsically important. Ever since, debate has raged over the balance between exploitation and conservation of marine fishes, in particular (Ludwig *et al.* 1993; Cochrane 2000; Vincent *et al.* 2014). Over these decades, multilateral agreements and agencies, including the UN Food and

Agriculture Organization and Regional Fisheries Management Organizations, have sought increasingly to address concerns about long-term biodiversity and food security with previous priorities for production (FAO 2012). The Convention on Biological Diversity gave new impetus to this challenge in 2010 with Aichi Target 6, which requires 196 countries to ensure that, by 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems, and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits (Target 6; CBD 2016).

The Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES; www.cites.org) resisted regulating exports of marine fishes after its inception in 1975, before finally agreeing export controls for all seahorses and two species of sharks in 2002 (Vincent *et al.* 2014). Many Parties argued that the FAO and RFMOs were the better international forums for conservation action for marine fishes despite clear evidence that marine taxa were threatened – or likely to become threatened – by export trade, in which CITES holds primacy (Vincent *et al.* 2014). CITES finally placed the first few marine fish taxa on its Appendix II in 2002, requiring the (now 183) national members to ensure that trade does not damage wild populations of regulated marine fishes - known as making Non-Detriment Findings - and includes only legally sourced specimens (Vincent *et al.* 2014; Foster and Vincent 2016; IUCN 2016a;). Parties to CITES then had to address the challenge of implementing trade controls in a context where most such regulation, previously almost solely for terrestrial taxa, had been effected by national environmental or forestry agencies (Vincent *et al.* 2014). This requirement posed challenges given national ocean and fisheries agencies' unfamiliarity with CITES and in many cases their discomfort with a conservation agenda (IUCN 2016b). Moreover, these agencies struggled to obtain the knowledge and technical capacity to implement the CITES listings in the absence of historic monitoring and engagement with these taxa (Cochrane 2015; IUCN 2016b).

Seahorses – 43 species in one genus, *Hippocampus* (Lourie *et al.* 2016; Zhang *et al.* 2016; Hamilton *et al.* 2017; Han *et al.* 2017) – were the first marine fishes to receive more than the required support (two-thirds of the Parties) for listing on CITES Appendix II, in 2002 (Vincent *et al.* 2014; Vincent and Foster 2017). Implementation followed in 2004, along with advice to Parties to begin by establishing a minimum size limit for seahorses in export (Foster and Vincent 2005). This stopgap measure was always intended to be replaced with more suitable and precise national regulations on fisheries and exports as the Parties grew into their responsibility for seahorses. From 2004, CITES asked Parties to justify the levels of their exports for what eventually became eight species of notable concern in trade (Foster 2016; IUCN 2016c). Four Parties found this difficult enough that they became subject to a CITES Review of Significant Trade in which their export levels were scrutinized. Failures to respond to ensuing recommendations led CITES to recommend trade suspensions (effectively bans) for three countries, *Hippocampus kuda* from Viet Nam in 2013 (CITES 2014a) and *H. algiricus* from Guinea and Senegal in 2016 (CITES 2016a). These were the first global export bans ever imposed on any country for any marine fish species under any agreement. In addition, Thailand acknowledged enough difficulties in meeting CITES recommendations that it also suspended exports, for all *Hippocampus* species (CITES 2016b; Vincent and Foster 2017). The importance of these four Parties in seahorse trade is such that 96% of previous trade in seahorses should now have ceased, at least in legal channels (Vincent and Foster 2017). The challenge of reconciling fisheries and conservation is, however, best met by sustainable exploitation, not by trade bans that may well just drive extraction and export underground (Mason *et al.* 2012; Lawson *et al.* 2017).

Viet Nam, which has long played a notable role in seahorse export (Vincent 1996) expressed keen interest in establishing export levels that do not threaten wild populations, in a bid to lift the trade suspension imposed by CITES. It faced a number of challenges, however, most notably in capacity and knowledge. Interviews with buyers and exporters in Viet Nam in the late 1990s estimated annual catches at over two million seahorses a year (Meeuwig *et al.* 2006), with exports at a similar scale (Giles *et al.* 2006). Most seahorses were thought to be exported, generally through unofficial and unregulated channels across the northern border into Guangxi province of China (Giles *et al.* 2006). Even CITES official data – which are full of inconsistencies – reported Viet Nam as exporting a minimum of hundreds of thousands of seahorses per annum (Foster *et al.* 2014). Yet Viet Nam knew little about seahorse biology, fisheries, or trade beyond what we had provided in papers and reports dating from the late 1990s, and much appeared to have changed. Analyses of catches in Phu Quoc Island, Kien Giang province conducted in 2014 estimated numbers a full order of magnitude larger than that reported in previous studies, not least because some trawlers had begun explicitly targeting seahorses (Stocks *et al.* 2017). At the same time, there were hints of much increased domestic consumption and of notable aquaculture operations for seahorses.

We here report on the biology, fisheries, and trades of seahorses in Viet Nam. Viet Nam can only hope to implement CITES export regulations for seahorses, and thus resume international trade in *H. kuda* without threatening wild populations, by improving and updating its understanding of seahorse exploitation and its likely consequences. We set out to produce (a) a qualitative description of the seahorse fishery, aquaculture, and trade, (b) quantitative estimates of trade volumes and prices, and (c) a description of the perceived temporal trend in seahorse landings. Such work will allow national authorities to (i) evaluate change since the late 1990s, (ii) set a new baseline for ongoing monitoring, and (iii) develop a targeted management response to unsustainable exports. Our ultimate aim is for Viet Nam to make the changes needed to achieve sustainable exports of seahorses. Such changes would help lift the CITES trade suspension for Viet Nam while restoring seahorse populations and sustaining legal trade and livelihoods. Such an outcome would help ensure that CITES gains credibility as an international instrument that can move beyond agreements on paper into action for the ocean.

Methods

Study overview

We obtained information for this study by (a) interviewing a wide array of people associated with seahorse exploitation in Viet Nam, (b) measuring seahorses in trade, and (c) accessing existing but overlooked data sets. To spot shifts and trends, we compared the new field results with our earlier Vietnamese trade surveys, official data from other Parties, and CITES data held by UNEP-WCMC.

Data sources

Interviews

We conducted research to capture information on seahorse biology, fisheries, aquaculture, and trade in Viet Nam through interviews with fishers, buyers, wholesalers, retailers, exporters, and seahorse culturists. The interviews were carried out in Vietnamese by one of the authors, Dr. Hoang Do Duu, a Vietnamese national. Dr. Hoang had also conducted the first seahorse trade surveys in Viet Nam in the late 1990s, thus providing consistency, and has more than 20 years experience in seahorse culture and species identification. Dr. Hoang conducted 146 interviews across eight provinces in Viet Nam from November 2016 to January 2017 (Figure 1; Table 1). We had ethics clearance for our interviews from the University of British Columbia (permit H12-02731), based on Canada's national standards.

For fishers and traders, we focused our efforts on (i) ports where landed seahorses are introduced into commercial trade and (ii) larger communities and cities where they are bred, bought, sorted, and sold for domestic consumption and international export. These locations were chosen as a result of previous surveys (Giles *et al.* 2006; Meeuwig *et al.* 2006; Stocks *et al.* 2017), information from a national CITES workshop on seahorse trade and conservation held in May 2013 (Project Seahorse 2015), anecdotal reports, and narrative accounts obtained during interviews in the course of this study. We were successful in interviewing fishers in seven provinces, buyers, and other traders in eight provinces, and seahorse culturists in two provinces, in central and southern Viet Nam (Table 1).

Fishers and traders were located through a combination of haphazard sampling (e.g. of fishers at landing sites) and snowball sampling (where first leads guided us to other sources of information; Gubrium and Holstein 2002) for respondents who were more difficult to locate, such as seahorse retailers and exporters. Interviews were semi-structured and we used triangulation to cross-validate the information received by (i) asking the same questions in three different ways within an interview and (ii) comparing the answers within and among interviews, at the same trade level and across trade levels.

Participants in the seahorse trade were categorized according to their roles (e.g. fisher, primary buyer, secondary buyer), although an individual could be active in more than one role. We also noted where traders acted as domestic retailers and exporters as this could occur at any level of trade. Primary buyers bought exclusively from fishers. Secondary buyers bought from other buyers but typically within their own province. Upper level buyers bought from both primary and secondary buyers, and typically mentioned purchasing seahorses from other provinces. Seahorses followed trade routes beginning with lower-level traders (e.g. fishers and primary buyers),

through intermediate-level traders (e.g. secondary buyers), to upper-level traders, although the actual number of levels within individual trade routes varied.

In addition to fishers and traders, we interviewed known seahorse culturists in Viet Nam – individuals that bred seahorses for commercial trade. We were aware of five commercial breeding operations that had actively bred seahorses for trade in Viet Nam (four in Khanh Hoa, one in Kien Giang). We interviewed representatives from the four farms in Khanh Hoa province (Table 1): two farms in Nha Trang and two in Cam Ranh. We also interviewed someone who use to culture seahorses in Kien Giang (Table 1), but had not done so since 2011. Beyond the commercial farms, the Viet Nam Institute of Oceanology (IO, located in Nha Trang) has been breeding seahorses since 2008 – for research purposes (to advance breeding techniques for different species), but also to sell for export. We also interviewed the principle seahorse culturist at IO (Table 1).

Table 1. The number of respondents interviewed during surveys in Viet Nam including fishers, traders, and culturists involved in seahorse exploitation and trade across eight provinces in Viet Nam from November 2016 – January 2017.

Province	Fishers	Traders	Culturists	Total
Thua Thien-Hue	3	1	0	4
Da Nang	6	2	0	8
Phu Yen	21	6	0	27
Khanh Hoa	22	11	5	38
Binh Thuan	14	8	0	22
Ba Ria-Vung Tau	3	1	0	4
Ho Chi Minh	0	4	0	4
Kien Giang	24	14	1	39

Measuring seahorses

We obtained information on seahorse species and sizes in fisheries through interviews with fishers and by examining specimens held by buyers. Fishers were asked to describe the type and size of the seahorses they caught. Fishers were also questioned specifically about depths where they obtained seahorses. Fishers did not report species by their known Latin or common names, but by type – which were reported according to colour and texture – black, yellow, spiny, smooth, etc. Eleven buyers allowed us to photograph seahorses in their stock.

Our measurements and life history information come from a total of 31 photographs that we took in Thua Thien-Hue, Phu Yen, Khanh Hoa, Binh Thuan, Ba Ria-Vung Tau, and Kien Giang provinces, covering 823 individual seahorses. The photographs were processed to determine species, size, sex, and male reproductive status. Seahorse species were identified with reference to Lourie *et al.* (2004). Seahorse size was measured as height – from the tip of the tail to the top of the coronet (Lourie *et al.* 1999), using ImageJ software (Schneider *et al.* 2012). Sex was determined by the presence of the brood pouch on male seahorses, and reproductive state of males (i.e. whether pregnant or not) was determined by the presence of a swollen brood pouch (Lourie *et al.* 2004).

Datasets

Our fisher interview data were supplemented by official fisheries data provided by five provincial governments in Viet Nam, and also by the Research Institute of Marine Fisheries (RIMF) within the national Ministry of Agriculture and Rural Development.

Other key sources of information came from Customs Data from foreign jurisdictions, and CITES trade statistics derived from the CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK (UNEP-WCWC 2017). Records from the Taiwanese Directorate General of Customs began in 1983, while records from the Census and Statistics Department in Hong Kong SAR date from 1998.

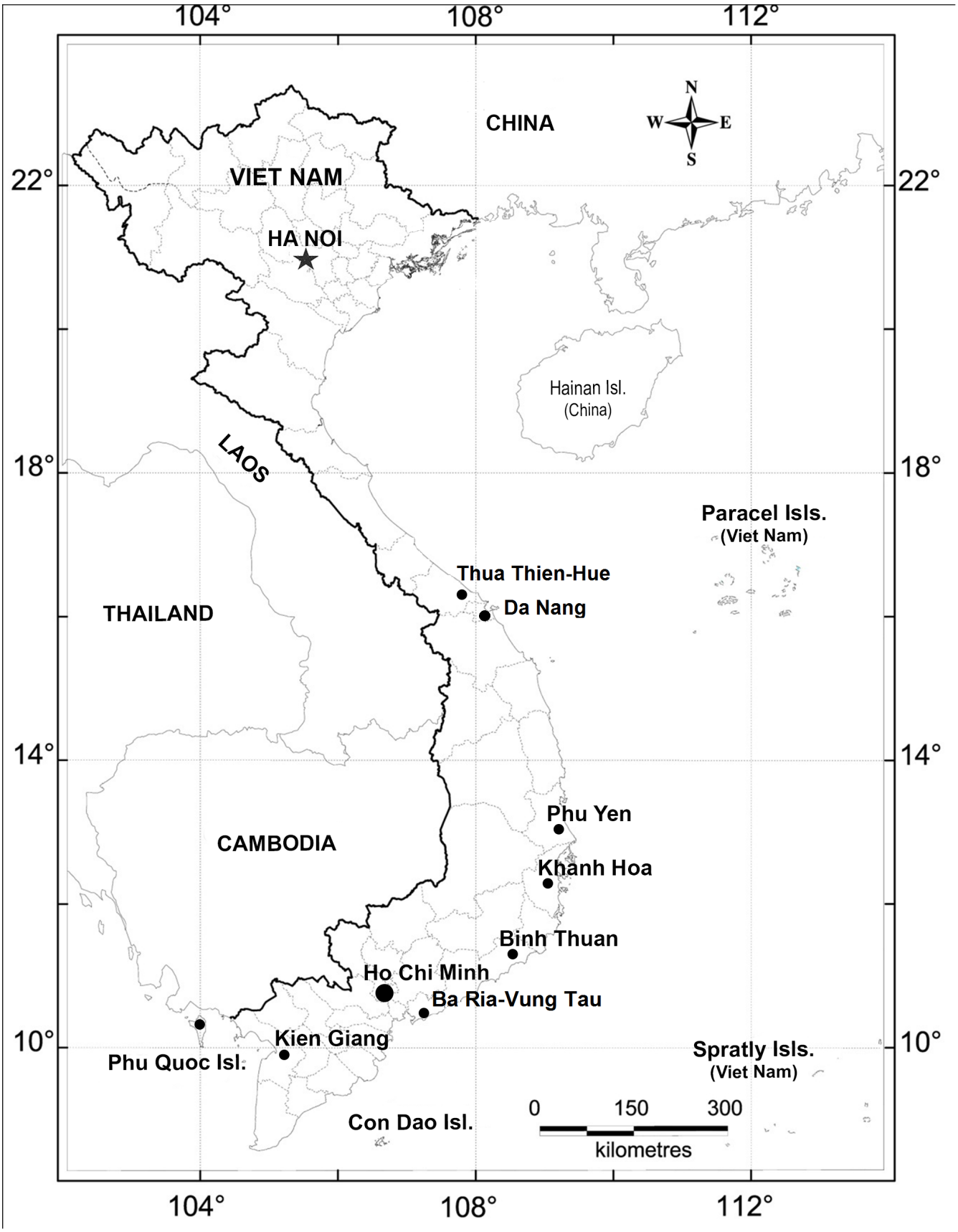

Figure 1. Locations within Vietnamese provinces where interviews with seahorse fishers, traders, and culturists were carried out from November 2016 – January 2017.

Information and analyses

Catch

Fishers were asked to describe their fishing activities and seahorse catches. For fishing activities, they were asked about gears, depths fished, and typical fishing duration per day, trip, month, and year. Although there are multiple types of single trawls (e.g. otter, beam), we did not ask respondents to specify the type of single trawl used during interviews. For seahorse catches, they were asked to identify the gears they used that captured seahorses, numbers, and frequency of catch, whether seahorses were target or incidental catch, how they kept seahorses on the boat, and how they sold seahorses. We offered fishers the opportunity to report seahorse catch by day, fishing trip, week, month, or year. Fishers themselves chose whether to report catches in number of individuals or kilograms; sometimes fishers reported both. We also inquired about seasonality of catch.

We sought information from individual respondents on landings for discrete time periods (i.e. per day, fishing trip, week, month, or year). These were then standardized to a catch per unit effort (CPUE) of number of seahorses vessel^{-1} day^{-1}. Where catch was reported in kilograms, we converted kilograms to number of seahorses using fisher reported values of number of seahorses per kilogram by province. To calculate CPUE for each gear type, we used a mean that accounted for seasonality of catches [e.g. mean CPUE = (proportion of the year for high season * CPUE high season) + (proportion of the year for low season * CPUE low season)].

We generally calculated the mean CPUE for each gear type at the national level but had enough data to examine variation in CPUE by province for single trawls. For single trawls, we further examined whether engine power (HP), mean trip length (in days), and mean fishing depth (in meters) were correlated with reported seahorse CPUE. To do this, we ran Kruskal-Wallis tests on these variables and, when significant differences were found, we ran a Dunns-test for multiple comparisons to determine where the significant difference lay.

We scaled up mean seahorse CPUE by gear type to annual catch per vessel (seahorses vessel^{-1} year^{-1}) by multiplying the daily CPUE by fishing effort metrics (i.e. number of days fished per month, months fished per annum). We scaled up mean seahorse CPUE using fishing effort metrics reported by fishers (after accounting for reported seasonal variation in fishing activities and seahorse catches), and those reported in national governmental fisheries statistics. Then, where data were available, we multiplied the annual catch rate for each gear by the number of fishing vessel in each province, to obtain a rough estimate of total annual seahorse landings by gear type and province. We scaled up gear-specific catch rates using fleet estimates from both official provincial and national governmental fisheries statistics.

We only scaled up CPUE in provinces for which our study had generated a CPUE estimate; we did not assume gears caught seahorses in provinces for which we had no evidence. For example, although we know pair trawls operate from several provinces in Viet Nam, we only estimated catch by this gear type in the one province where we interviewed pair trawlers and thus had an estimate of CPUE. Finally, we summed catch estimates by gear type and province to generate a minimum total seahorse catch estimate for Viet Nam.

Trade

We estimated volumes in seahorse trade – including domestic sale and export – from respondents' reported trade volumes at all levels of trade. We asked all traders interviewed about how many seahorses they bought per day or per month, and whether those seahorses were obtained dry, wet, or live. Buyers were free to report their collection metrics in either number of individuals or kilograms. All estimates were converted into number of individuals, using trader reported conversions. Traders were also asked to share similar information – volumes, frequency, and state of specimens - for seahorses they sell and whether those seahorses were traded dry, wet, or live. Information obtained was summarized by province, trade level, and overall. We were careful to obtain information on throughputs – akin to trade rates – rather than standing stock.

We scaled the daily purchase and sell volumes reported by buyers to annual estimates per buyer, both by province and trade level. Since information to scale daily volumes to annual rates was unavailable, we assumed a five-day workweek per month, and that traders worked 12 months per annum. By scaling daily volumes to annual rates this would enable us to compare current volumes with previous research.

We define the different levels of seahorse trade in Viet Nam as follows:

- Level 2 only – traders that only buy from fishers, and only operate at this trade level. Purchase volumes at this trade level can be compared to fisher reported catch volumes.
- Middle & upper level buyers – traders operating at levels higher than level 2. We would expect purchase volumes at these levels to be higher than those of level 2 traders.
- Multiple levels – traders operating at various levels of trade.
- Domestic only – traders that only reported selling seahorses domestically (~retailers).
- Export only – traders that only reported exporting seahorses out of Viet Nam.
- Retailers and exporters – combined group of traders that reported selling seahorses domestically and/or exporting seahorses.

Pricing

Both fishers and traders reported price information on seahorses. Fishers reported prices received for selling seahorses. Traders did not share information on what they paid but did report their selling prices for dry, wet, and live seahorses. All prices were converted from Vietnamese dong (VND) into United States dollars (USD) using average rates of exchange from the time of surveys based on mid-point values from Oanda.com (https://www.oanda.com/fx-for-business/historical-rates). Prices were reported by weight and by number. We have summarized this information by province and overall.

Culturists

We asked culturists about their facilities, methods, the species they cultured, production volumes, and questions around the reliance of their activities on wild broodstock. Culturist interviews were carried out at the facilities, and so we were able to gather further information by site inspection.

Seasonality

We asked fishers, traders and culturists about seasonality of catch, trade, and production. Fishers reported the months when annual periods of high catch volumes began and ended. Most buyers reported the months when annual periods of supply (from fishers) were high. Responses were summed by month to look at the variation in reported high seasons by province (for fishers and traders) and by gear type (for fishers). We then derived the average reported high season by determining when at least 50% of respondents (either by province or gear type) had reported that high season began (or ended). Culturists reported peaks in breeding activity based on a peak in the number of pregnant males.

Changes over time

During fisher interviews, fishers were given the opportunity to comment on changes over time of the number and size of seahorses in catch and any changes in the price of seahorses. We then summarized these changes by province and by gear type.

Since interviews were semi-structured, some buyers and culturists freely reported their observations about seahorse supply over time. For traders (only) we were able to summarize responses by province and determined the range of changes over time.

Other trade datasets

Information from the Taiwanese Directorate General of Customs contained 13 records of seahorse imports from Viet Nam from 1989 to 2004, while data from Hong Kong SAR's Census and Statistics Department contained just one such record in 2003. The CITES trade data (UNEP-WCWC 2017), when downloaded on 06 January 2017, contained a total of 324 records of seahorse trade reportedly originating in Viet Nam, 73 records of re-export reportedly originating in Viet Nam, and no records of seahorse imports into Viet Nam across 2004-2014. We did not include re-exports in our analyses, to avoid any double counting.

Comparison with previous research

Where possible, we attempted to compare our current study to previous research for both fisheries and trade: four studies had information on fisheries (Giles *et al.* 2006; Meeuwig *et al.* 2006; Ut and Tam 2012; Stocks *et al.*

2017) and one had information on trade (Giles *et al.* 2006). To compare fisheries data, we reviewed mean CPUE (seahorses vessel^{-1} day^{-1}), annual catch estimates, fleet sizes and provinces surveyed across comparable gear types. For trade data, we compared the selling volumes for domestic retailers and exporters, sale and purchase prices (in VND), and provinces surveyed.

Results

Seahorse fisheries

Gears

Fishers reported catching seahorses from seven different types of fishing gear (Tables 2 and 3), but more than 68% of the respondents interviewed reported using single trawls. Divers and fishers using crab nets, seine nets, and all trawl boats (single and pair) reported using boats with engines. Two types of fishing gears did not report using engines – basket divers and electric shock fishers. Basket divers manually paddled their boats to fishing locations whereas electric shock fishers set nets from shore to catch fish.

Provinces varied by the gears documented as catching seahorses, although our surveys may not have been comprehensive (Table 2). We encountered the greatest diversity of gear types catching seahorses in Phu Yen. We interviewed single trawlers in all provinces except the most northern we visited, Thua Thein-Hue. As it happened, we only interviewed divers in the central provinces, and pair trawls in the southernmost province of Kien Giang.

Some divers and single trawls reported targeting seahorses directly, while others reported catch as incidental (Table 3). The fisher we interviewed who reported using an electric shock net said he targeted seahorses. Four gears – basket divers, crab nets, seine nets, and pair trawls – reported seahorse catch as incidental (Table 3).

Fishers using seine nets and single trawls reported selling seahorses in three forms: dry, wet (commonly referred to as “freshly dead”, kept on ice and sold dead but wet to buyers), and live (Table 3). Pair trawls also reported selling seahorses dry. Basket divers and divers reported selling seahorses live, whereas crab fishers only reported selling seahorses “freshly dead.” Fishers in all provinces, except for Ba Ria-Vung Tau, reported selling seahorses both live and dry – Ba Ria-Vung Tau fishers only reported selling dry seahorses.

Species

Fishers did not reference seahorse types by scientific names, but single trawl fishers, basket divers, and divers described the most types of seahorses (Table 3). Pair trawl fishers did not report the type of seahorses caught, whereas seine nets and fishing by electric shock did not describe many types.

Both spiny and smooth seahorses were reported in all but one province (Table 2). The northern most province we surveyed – Thua Thien-Hue – reported only one type of seahorse – the ‘black’ seahorse (Table 2). Phu Yen province reported the most types of seahorses – spiny, smooth and black, yellow, long, and Indonesian seahorses were described.

Fishers reported capturing seahorses ranging in mean size from ~8 cm (crab nets) to ~13 cm (basket divers) (Table 3). The reported mean size was significantly different between crab nets and basket divers, but not among the other gears (Kruskal-Wallis chi-squared value = 13.19, df = 6, $p = 0.04$; Dunn’s test – crab and basket divers $p = 0.01$; all other $p > 0.05$).

Reported mean depth at which fishers caught seahorses varied by gear type, but seahorses were captured in both shallow (< 2 m) and deeper waters (25 m) (Table 3). Divers, electric shock, and seine nets caught seahorses at significantly shallower depths than pair trawls (Kruskal-Wallis chi-squared value = 19.27, df = 6, $p < 0.01$; Dunn’s test – pair trawls and divers ($p < 0.05$), electric shock ($p < 0.05$), and seine nets ($p < 0.05$), all other comparisons $p > 0.05$).

Table 2. Information on seahorses obtained during interviews with fishers and buyers in seven provinces of Viet Nam. Buyer information came from photographs of their seahorses for sale. No fishers were interviewed and no buyer photographs were obtained in Ho Chi Minh; it is therefore not included in the table.

Province	# fishers inter-viewed	Gears reported to catch seahorses	Types of seahorses reported caught	# buyers interviewed	Total # of seahorses photo-graphed	Species observed in photographs (n)
Thua Thien-Hue	3	Diving; Seine net	Black	1	40	*H. kuda* (40)
Da Nang	6	Trawl (single)	Spiny Smooth	0	0	Not applicable
Phu Yen	21	Basket divers; Diving; Electric shock; Trawl (single)	Spiny Smooth Black Yellow Long Indo	2	111	*H. kelloggi* (10) *H. kuda* (15) *H. spinosissimus* (3) *H. trimaculatus* (82) Unknown (1)
Khanh Hoa	22	Diving; Trawl (single)	Spiny Smooth Black Indo	2	431	*H. histrix* (2) *H. kelloggi* (11) *H. kuda* (9) *H. spinosissimus* (89) *H. trimaculatus* (320)
Binh Thuan	14	Crab net; Trawl (single)	Spiny Smooth Indo	2	84	*H. kelloggi* (1) *H. kuda* (4) *H. spinosissimus* (7) *H. trimaculatus* (72)
Ba Ria-Vung Tau	3	Trawl (single)	Spiny Smooth Indo	1	16	*H. kelloggi* (1) *H. spinosissimus* (14) Unknown (1)
Kien Giang	24	Crab net; Trawl (single); Trawl (pair)	Spiny Smooth Black Short-snout	4	141	*H. kelloggi* (3) *H. kuda* (54) *H. spinosissimus* (38) *H. trimaculatus* (42) Unknown (4)
Total	**93**	**Diving; Basket divers; Electric shock; Seine net; Crab net; Trawl (single); Trawl (pair)**	**Spiny Smooth Black Yellow Long Indo Short-snout**	**12**	**823**	***H. histrix* (2) *H. kelloggi* (26) *H. kuda* (122) *H. spinosissimus* (151) *H. trimaculatus* (516) Unknown (6)**

Table 3. Information from fishers interviewed across seven Vietnamese provinces on types of seahorses caught, whether fisheries targeted seahorses, method of sale, mean size of captured seahorses, and depth at which they were caught. If fisheries did not target seahorses directly, they were caught incidentally.

Gear type	**# fishers inter-viewed**	**Types of seahorse caught (n)**	**Target seahorses? (n)**			**Type of seahorse acquired**			**Mean seahorse size (cm) [SE] (n)**	**Mean seahorse depth found (m) [SE] (n)**
			Yes	No	No response	Dry	Wet	Live		
Basket diving	6	Spiny (2) Smooth (2) Black (3) Yellow (2) Indo (1)	---	5	1	---	---	5	12.6 [1.1] (5)	5.0 [0.5] (4)
Crab net	4	Spiny (4) Smooth (4)	---	4	---	---	4	---	7.7* [0.6] (4)	10.0 [0] (2)
Diving	11	Spiny (4) Smooth (4) Black (7) Yellow (3)	2	9	---	---	---	11	9.6 [0.3] (8)	3.6** [0.4] (4)
Electric shock	1	Black (1) Yellow (1)	1	---	---	Not reported			10.0 [0] (1)	1.3** [0] (1)
Seine net	2	Black (2)	---	2	---	2	1	1	10.0 [0] (1)	3.5** [0] (1)
Trawl (single)	64	Spiny (49) Smooth (49) Black (8) Yellow (4) Long (3) Short-snout (1) Indo (7)	4	60	---	8	48	16	10.1 [0.3] (34)	23.5 [2.8] (37)
Trawl (pair)	5	Not reported	---	5	---	4	1	---	8.8 [0.3] (3)	25.0 [0] (2)
Total	**93**	**Spiny (59)** **Smooth (49)** **Black (21)** **Yellow (10)** **Long (3)** **Short-snout (1)** **Indo (8)**	**7**	**85**	**1**	**14**	**54**	**33**	**10.0 [0.3] (56)**	**19.2 [2.3] (51)**

* = Significantly different from basket diving only. ** = Significantly different from trawl (pair) only.

Fishing effort

Among gears

Fishers for five gear types – all except single and pair trawls – reported fishing trips of approximately one day (Table 4) and explained their catch as number of individuals (Table 4). Fishers using single trawls reported fishing trips of ~10 days and their catch in kilograms and number of individuals caught, whereas pair trawlers reported the longest fishing trips (several months long) and explained their catch in kilograms.

Table 4. Characteristics of the fishing gears that catch seahorses in Viet Nam, as reported by fishers interviewed across seven provinces. Note fishers could report catch for multiple time periods and by both number of individuals and kilograms.

Gear type	# fishers interviewed	Mean trip length (days) [SE]	Reporting time period (n)		Reported catch in individuals or kg (n)		Mean CPUE (seahorses vessel^{-1} day^{-1}) [SE] (n)
			Day	Trip	Individuals	kg	
Basket diving	6	0.9 [0.1]	4	3	4	---	13.7 [3.9] (4)
Crab net	4	1.0 [0]	4	4	4	---	1.4 [0.4] (4)
Diving	11	1.0 [0]	10	---	10	---	5.8 [1.2] (10)
Electric shock	1	1.0 [0]	1	---	1	---	7.5 [2.5] (1)
Seine net	2	1.0 [0]	1	1	2	---	0.5 [0] (2)
Trawl (single)	64	10.3 [2.2]	26	46	51	16	7.9 [1.6] (61)
Trawl (pair)	5	96.0 [3.6]	---	5	---	5	15.1 [2.2] (5)
Total	**93**		**46**	**59**	**72**	**21**	

Within single trawls

When we explored reported single trawl characteristics at the provincial level, we observed that fishers reported using bigger boats (as measured by horse power, HP), and fishing at deeper depths in the two southernmost provinces of Kien Giang and Ba Ria-Vung Tau (Table 5). Indeed, HP and trip length of single trawls were significantly different among provinces (Kruskal-Wallis = 13.63, df = 5, p = 0.02; Kruskal-Wallis = 24.60, df = 5, p = <0.01), and this difference lay in comparisons of all provinces with Ba Ria-Vung Tau and Kien Giang. The mean body size of captured seahorses reported by single trawlers did not vary significantly among provinces (Kruskal-Wallis = 9.26 df = 5, p = 0.09). However, mean reported seahorse depth differed significantly (Kruskal-Wallis = 13.72, df = 5, p = 0.01) because of contrasts among Ba Ria-Vung Tau (where fishers reported catching seahorses at the deepest depths), Phu Yen and Khanh Hoa (where fishers reported catching seahorses at the shallowest depths).

Table 5. Fisher reported characteristics of single trawl fishing gears, including engine size, mean trip length, mean depth fished, mean reported seahorse size, and reported mean depth at which seahorses were caught. Sample sizes indicate total number of trawl fishers interviewed for each province.

Province	# fishers inter-viewed	Mean engine HP [SE] (n)	Mean trip length (days) [SE] (n)	Mean depth fished (m) [SE] (n)	Mean reported seahorse size (cm) [SE] (n)	Mean seahorse depth (m) [SE] (n)
Da Nang	6	35.0 [7.6] (3)	1.0 [0.0] (5)	19.5 [0.5] (5)	8.9 [0.3] (5)	18.7 [1.2] (2)
Phu Yen	11	64.5 [4.5] (11)	1.9 [0.4] (6)	20.4 [3.1] (9)	10.9 [1.3] (9)	16.6 [2.5] (10)
Khanh Hoa	15	50.3 [4.8] (13)	2.8 [0.2] (7)	21.9 [2.3] (12)	10.0 [0.8] (3)	16.2 [0.8] (6)
Binh Thuan	12	78.3 [7.9] (12)	3.5 [1.3] (8)	33.2 [5.1] (11)	10.0 [0.6] (8)	22.5 [1.6] (9)
Ba Ria-Vung Tau	3	305.0 [147.8] (3)	46.2 [1.2] (3)	46.7 [15.8] (3)	12.2 [0.2] (3)	68.3 [3.3] (3)
Kien Giang	17	98.5 [19.9] (15)	25.3 [6.0] (5)	31.6 [5.7] (16)	9.1 [0.2] (7)	22.9 [5.1] (7)

Catch Rate

Among gears

Mean CPUE varied among gear types from fewer than one seahorse per day per seine net, to as high as 15 seahorses per day per pair trawler (Figure 2; Table 4). Single trawls, for which we had the most data, fell in the middle of the range – reportedly catching about eight seahorses per day. The differences in CPUE among gear types were significant (Kruskal-Wallis chi-squared = 19.00, df = 6, p = <0.01); basket divers had significantly higher CPUEs than seine and crab nets (Dunn's test p = 0.02); crab nets had significantly lower catch rates than divers and pair trawls (Dunn's test p = 0.04; Dunn's test p = 0.02); seine nets had significantly lower catch rates than single trawls and pair trawls (Dunn's test p = 0.04; Dunn's test p = 0.02); and finally, pair trawls had significantly higher CPUE's than single trawls (Dunn's test p = 0.02).

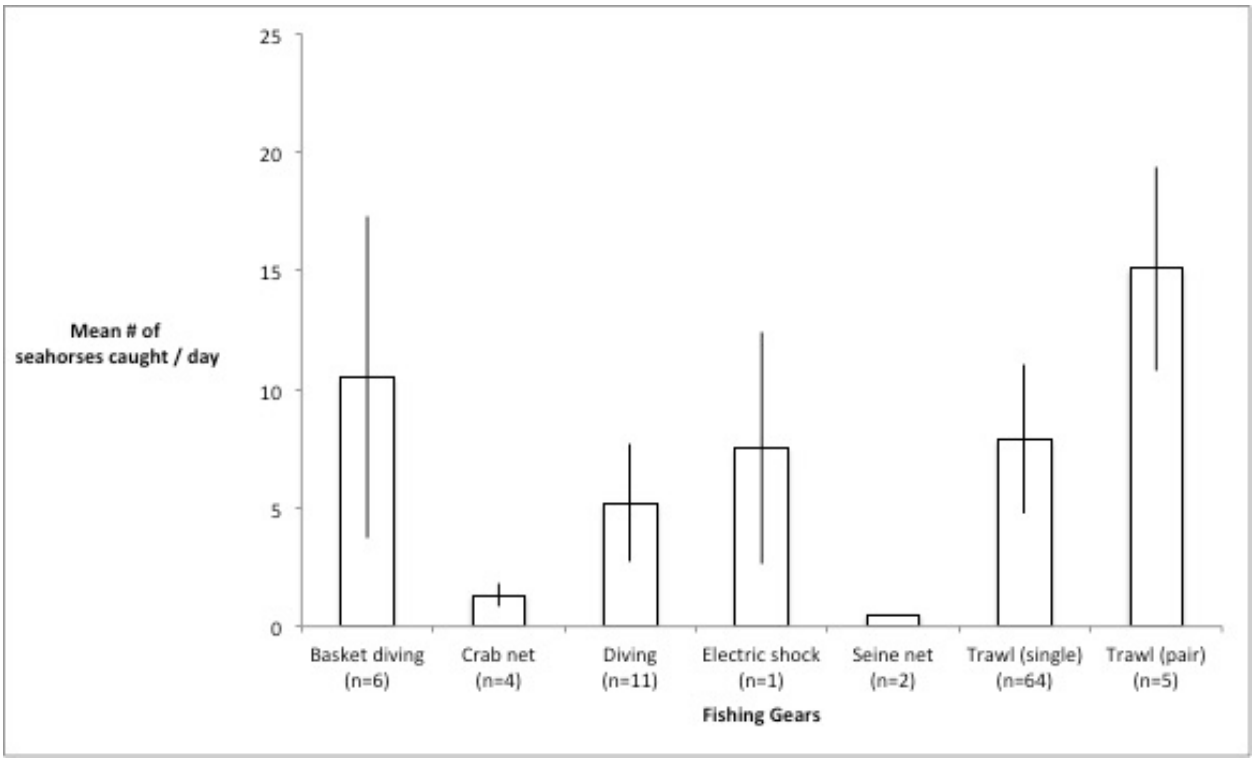

Figure 2. Fisher reported mean number of seahorses day^{-1} (+/- 95% CI) by gear type from interviews conducted with fishers in seven provinces in Viet Nam from November 2016 – January 2017.

Within single trawls

When we calculate CPUE for single trawlers by site, we observe high variation in catch rates within each province (Table 6), and higher CPUEs from Khanh Hoa, to the southern provinces of Binh Thuan, Ba Ria-Vung Tau and Kien Giang (Figure 3; Table 7). Mean and maximum CPUE were not statistically different among provinces (for mean CPUE: Kruskal-Wallis chi-squared = 7.53, df = 5, p = 0.18; for max CPUE: Kruskal-Wallis chi-squared = 10.43, df = 5, p = 0.06) although minimum CPUE did differ (Kruskal-Wallis chi-squared = 14.56, df = 5, p = 0.01). We therefore calculated a mean CPUE of about eight seahorses per day for individual single trawls among all provinces to allow comparison with other fishing gears (reported in Table 4).

Table 6. Variations in fisher reported metrics used to calculate fisher reported mean catch per unit effort by location in each of six Vietnamese provinces where single trawls fishers were interviewed. n = the number of fishers reporting information.

Province	Location (n)	Reported catch in # of individuals or kg (n)		Mean reported # seahorses kg $^{-1}$ (n) [range]	Mean trip length (days) [SE] (n)	Mean CPUE (seahorses vessel^{-1} day^{-1}) [SE] (n)
		Individuals	kg			
Da Nang	Son Tra (6)	6	---	Not reported	1.0 [0.0] (5)	1.5 [0.2] (6)
Phu Yen	Xuan Canh (3)	3	3	Not reported	2.5 [0.0] (3)	7.6 [1.0] (3)
	Xuan Hai (2)	2	1	Not reported	1.5 [0.5] (2)	3.7 [1.3] (2)
	Xuan Than (6)	5	---	Not reported	1.6 [0.7] (6)	2.3 [0.6] (5)
Khanh Hoa	Cua Be (12)	11	---	Not reported	3.1 [0.1] (12)	3.3 [0.7] (11)
	Van Hung (3)	2	---	Not reported	1.0 [0.0] (2)	2.1 [0.9] (2)
Binh Thuan	Ham Tan (4)	4	---	Not reported	1.0 [0.0] (4)	2.9 [0.4] (4)
	Mui Ne (2)	2	---	Not reported	1.5 [0.5] (2)	2.2 [0.3] (2)
	Phan Thiet (6)	3	3	120.0 (1) [90-150]	5.9 [2.2] (6)	30.9 [13.5] (6)
Ba Ria-Vung Tau	Cat Lo (3)	3	3	325.0 (3) [250-400]	46.2 [1.3] (2)	6.2 [0.2] (3)
Kien Giang	An Thoi (3)	---	3	112.5 (2) [80-150]	28.0 [0.0] (3)	9.5 [1.3] (3)
	Bai Sao (3)	3	---	Not reported	4.5 [1.0] (3)	2.8 [0.5] (3)
	Ha Tien (4)	4	---	Not reported	30.0 [0.0] (4)	0.5 [0.1] (4)
	Ham Ninh (2)	2	---	Not reported	1.0 [0.0] (2)	22.5 [2.5] (2)
	Hon Thom (2)	2	---	Not reported	1.0 [0.0] (2)	42.5 [7.5] (2)
	Rach Gia (3)	---	3	100.0 (3) [90-120]	70.0 [5.0] (3)	18.6 [1.7] (3)

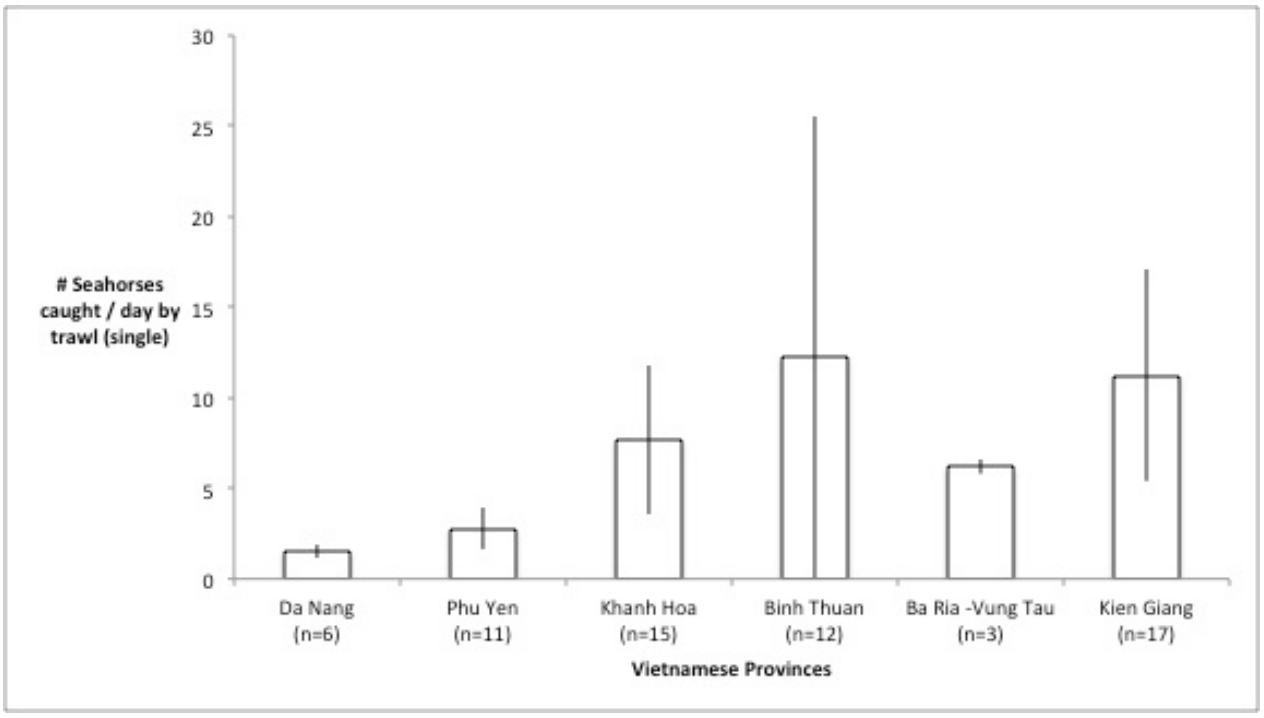

Figure 3. Fisher reported mean number of seahorses day^{-1} by single trawls (+/- 95% CI) from interviews conducted with fishers in six provinces in Viet Nam from November 2016 – January 2017.

Table 7. Fisher-reported values used to derive single trawl catch per unit effort in six Vietnamese provinces from November 2016 – January 2017.

Province	Catch reported in # of individuals or kg (n)		Mean # seahorses kg $^{-1}$ (n)	Mean trip length (days) [SE] (n)	Mean CPUE (seahorses vessel^{-1} day^{-1}) [SE] (n)
	Individuals	kg			
Da Nang	6	---	Not reported	1.0 [0.0] (5)	1.5 [0.2] (6)
Phu Yen	9	4	120*	1.9 [0.4] (6)	2.8 [0.6] (10)
Khanh Hoa	13	---	Not reported	2.8 [0.2] (7)	7.7 [2.1] (13)
Binh Thuan	9	3	120 (1)	3.5 [1.3] (8)	12.2 [6.8] (12)
Ba Ria-Vung Tau	3	3	325 (3)	46.2 [1.2] (3)	6.9 [0.2] (3)
Kien Giang	11	6	105 (5)	25.3 [6.0] (5)	11.2 [2.9] (17)

*Not reported but values used in analysis taken from next closest province (Binh Thuan) to allow for conversion of data reported in kg to number of individual seahorses.

Catch volumes

Annual volumes by vessel

When we scaled up gear specific CPUEs to estimate annual catch per vessel, we found that pair trawlers had the highest reported per vessel catch volumes in Viet Nam (~4,500 per boat per annum; Table 8). This was double the number of seahorses compared to the gear with the next highest annual per vessel volume (basket divers), and 2.6 times more than single trawls. Seine nets and crab nets were reported to catch the fewest seahorses per vessel, at less than 300 individuals per annum.

Table 8. Annual seahorse catch rate estimates (seahorses vessel^{-1} year^{-1}) as reported by fishers for various Vietnamese fishing gears across seven central and southern provinces. We estimated 10 fishing months year^{-1} when no responses were given, which is the mean reported months fished year^{-1} across all other gear types.

Gear type	CPUE (seahorses vessel^{-1} day^{-1}) [95% CI] (n)	Days month^{-1} [SE] (n)	Months year^{-1} [SE] (n)	Annual catch rate (seahorses vessel^{-1} year^{-1}) [95% CI]
Basket diving	10.5 [3.7-17.3] (4)	22.5 [4.7] (2)	9.2 [1.2] (5)	2,173 [766-3,581]
Crab net	1.3 [0.8-1.8] (4)	21.3 [1.3] (2)	10.0 [0.2] (4)	276 [70-383]
Diving	5.2 [2.7-7.7] (10)	24.3 [1.5] (7)	10.0 [0.3] (9)	1,263 [656-1,871]
Electric shock	7.5 [2.6-12.4] (1)	27.0 [0] (1)	Not reported*	2,025 [702-3,348]
Seine set	0.5 [0.5-0.5] (2)	25.0 [0] (1)	Not reported*	125 [125-125]
Trawl (single)	7.9 [4.8-11.0] (61)	21.6 [0.6] (32)	10.0 [0.1] (57)	1,706 [1,037-2,376]
Trawl (pair)	15.1 [10.8-19.4] (5)	30.0 [0] (5)	9.9 [0.2] (5)	4,485 [3,207-5,762]

*estimated 10

Annual volumes by gear

We were able to scale up from CPUE to per annual catch volumes per vessel for four gear types per province combinations, those for which we obtained estimates of total fleet size (Table 8; Table 9). We obtained fleet size information for single and pair trawls in all provinces in which we documented these gears to catch seahorses, but for very few provinces for the other gear types (Table 9). The largest number of pair trawlers and crab nets

was reported in Kien Giang province. A large number of seine nets was also reported in Phu Yen and Binh Thuan provinces, especially compared to other gears.

Scaling up per vessel catches to annual volumes by gear type revealed that pair trawls were reported to catch the most seahorses in Viet Nam, at approximately 12.5 million individuals per annum (Table 10). Indeed, this gear type reportedly caught about four times more seahorses than single trawls, the gear with the next highest catch volume. Seine nets had the lowest reported annual catch volumes, together catching fewer than 90,000 individuals per annum. Crab nets reportedly caught about three-quarter of a million individuals per annum. We could not estimate annual catch for three gears (basket diving, diving, electric shock) because we lacked the fleet sizes to scale up (see Table 9).

Table 9. Estimates of fleet size by Vietnamese province and gear type. Data are from Vietnamese provincial governments from 2016.

Gear type	Thua Thien-Hue	Phu Yen	Binh Thuan	Ba Ria-Vung Tau	Kien Giang
Basket diving	No fleet data	No fleet data	No fleet data	No fleet data	No fleet data
Crab net	No fleet data	No fleet data	No fleet data	2	2,880
Diving	No fleet data	No fleet data	261	No fleet data	No fleet data
Electric shock	No fleet data	No fleet data	No fleet data	No fleet data	No fleet data
Seine net	713	2,487	2,152	140	223
Trawl (single)	103	378	885	101	572
Trawl (pair)	No fleet data	No fleet data	339	327	2,800

Table 10. Volume estimates [95% CI] of individual seahorses by gear type from Vietnamese fisheries in five provinces. We indicate "no fleet data" for provinces for which we do not have a fleet size estimate for a particular gear type, and "no catch data" for provinces where our interviews did not generate catch estimates for a particular gear type.

Gear Type	Thua Thien-Hue	Phu Yen	Binh Thuan	Ba Ria-Vung Tau	Kien Giang	Total
Basket diving	No fleet data	No fleet data	No fleet data	No fleet data	No fleet data	No fleet data
Crab net	No fleet data	No fleet data	No fleet data	No catch data	794,880 [489,600 – 1,103,040]	**794,880** [489,600 – 1,103,040]
Diving	No fleet data	No fleet data.	No catch data	No fleet data	No fleet data	**No catch or fleet data**
Electric shock	No fleet data	No fleet data	No fleet data	No fleet data	No fleet data	**No fleet data**
Seine net	89,125	No catch data	No catch data	No catch data	No catch data	**89,125**
Trawl (single)	No catch data	644,868 [391,986 - 898,128]	1,509,810 [917,745 – 2,102,760]	172,306 [104,737 – 239,976]	975,832 [593,164- 1,359,072]	**3,302,816** [2,007,632- 4,599,936]
Trawl (pair)	No fleet data	No fleet data	No catch data	No catch data	12,558,000 [8,979,600 – 16,133,600]	**12,558,000** [8,979,600 – 16,133,600]
Total	**89, 125**	**644,868** [391,986 - 898,128]	**1,509,810** [917,745 – 2,102,760]	**172,306** [104,737 – 239,976]	**14,328,712** [10,062,364- 18,595,712]	**16,744,821** [11,565,957- 21,925,701]

Total volume for Viet Nam

We estimated total seahorse catch in Viet Nam to be ~16.7 million individual seahorses per annum (Table 10). The majority of seahorse catches were reported in southern Viet Nam (Table 10); the most southern province, Kien Giang, had the highest catch estimate of all provinces, reportedly obtaining 85% of the total national catch estimate. By gear type, pair trawls accounted for 75% of our estimated seahorse catch volume and single trawls accounted for ~20% (Table 10).

Volume estimates with RIMF data

Our estimate of 16.7 million individual seahorses per annum (reported in Table 10) was generated using fisher reported variations in fishing effort (from Tables 5 and 6) and fleet size data reported by provinces (from Table 9). We wanted to see how the estimates might change if we used national (RIMF) reported variations in fishing effort and national fleet size tallies – data that were available for single and pair trawls only.

National estimates of fishing effort are given as Boat Activity Coefficients (BAC), which represent the proportion of days fished per month (Table 11). National data reported fewer days fished per month than was reported by fishers in our study. National fleet size estimates for single trawls were higher than those reported by provinces for five of the seven provinces for which data were available. In the one province for which pair trawl data were available at both the provincial and national levels, the number of days fished per month as well as the estimated size of the fishing fleet were lower nationally (RIMF data) than with provincial estimates (Table 11).

Table 11. Comparison of annual seahorse catch estimate using fisher reported effort with Vietnamese provincial fleet sizes and Vietnamese national level (RIMF) data for effort and fleet size for single and pair trawls.

	Effort (days month^{-1}) [SE]		**Fleet size (# vessels)**		**Annual catch rate (seahorses vessel^{-1} year^{-1}) [95% CI]**		**National catch estimate (seahorses year^{-1}) [95% CI]**	
	Fisher reported	**RIMF**	**Provincial**	**RIMF**	**Fisher / provincial**	**RIMF**	**Fisher / provincial**	**RIMF**
Thua Thien-Hue	No data	No data	103	563	---	---	No catch data	No catch data
Da Nang	21.5 [0.6]	17.0 [0.4]	No fleet data	49	---	---	No catch data	No catch data
Phu Yen	22.3 [3.0]	17.0 [0.4]	378	618	---	---	644,868 [391,986 - 898,128]	878,796 [533,952 - 1,223,640]
Binh Thuan	22.5 [0.5]	17.0 [0.4]	885	598	---	---	1,509,810 [917,745 – 2,102,760]	850,356 [516,672 - 1,184,040]
Ba Ria-Vung Tau	> 1 month duration	18.8 [0.6]	101	0	---	---	172,306 [104,737 – 239,976]	No fleet data
Kien Giang	18.7 [0.6]	20.9 [0.3]	572	652	---	---	975,832 [593,164-1,359,072]	927,144 [563,328 - 1,290,960]
Trawl (single)	**21.6**	**18.0**	---	---	**1,706** [1,037-2,376]	**1,422** [864 - 1,980]	**3,302,816** [2,007,632-4,599,936]	**2,656,296** [1,613,952 - 3,698,640]
Trawl (pair)	**30.0**	**21.7**	2,800	2,509	**4,485** [3,207-5,762]	**3,243** [2,320-4,168]	**12,558,000** [8,979,600 – 16,133,600]	**8,136,687** [5,820,880 - 10,456,764]
National estimate (both gears)							**16,744,821** [11,565,957-21,925,701]	**14,333,464** [8,318,837 - 15,039,409

Scaling up fisher generated CPUE (from Table 4) using RIMF effort and fleet size data yielded a lower annual catch rate per vessel, and a lower national estimate of seahorse catch for Viet Nam than that generated using fisher reported effort and provincial fleet data (Table 11). Only the annual seahorse catch estimate for Phu Yen was higher with the RIMF data because national fleet statistics were higher than provincial data for this province (Table 11). The total seahorse catch estimate for Viet Nam obtained using RIMF data was slightly lower than (14%) the estimate we obtained using fisher reported effort and provincial fleet sizes (14.3 million seahorses versus 16.7 million seahorses, respectively). This is because for both single and pair trawls the RIMF effort and vessel estimates were lower than those provided to us by the provinces.

Trade

Species

A total of five different seahorse species were identified in photographs of seahorses found at buyers' premises (Table 12). *Hippocampus trimaculatus* was the most commonly observed species representing 63% of individuals overall. In contrast, *H. histrix* was the least common species at less than 1% of individuals, and was only observed in photographs from Khanh Hoa (Table 2). *Hippocampus kuda* was the only species photographed in the central province Thua Thien-Hue (Table 2) whereas photographs from all other provinces contained multiple species. Photographs from Khanh Hoa had the highest diversity of species – with five species photographed – and showed the highest number of individuals – with ~215 individuals per buyer (Table 2). *Hippocampus kelloggi*, *H. spinosissimus* and *H. trimaculatus* were documented in all provinces for which we had data, from Phu Yen south to Kien Giang (Table 2). *Hippocampus kuda* was also commonly observed in all provinces for which we had data from Phu Yen south, except for Ba Ria-Vung Tau province.

Table 12. Results of Vietnamese buyers' seahorse photos by species including number of individuals photographed, number of participating buyers and seahorse species observed. Buyers in six of the eight Vietnamese provinces surveyed from November 2016 – January 2017 allowed photographs of their seahorses.

Seahorse species (*Hippocampus* spp.)	**# individuals photographed**	**Sex ratio (males, n: females, n)**	**# of pregnant males (% pregnant males)**	**Mean size (cm) [SE]**
H. histrix	2	0:2	0	14.5 [2.3]
H. kelloggi	26	6:19 Unknown 1	0	20.3 [0.7]
H. kuda	122	57:63 Unknown 2	23 (40.3)	14.4 [0.3]
H. spinosissimus	151	62:89	15 (24.2)	16.8 [0.2]
H. trimaculatus	516	133:381 Unknown 2	10 (7.5)	11.9 [0.1]
Unknown	6	1:1 Unknown 4	0	10.9 [1.0]
Total	**823**	**259:555 Unknown 9**	**48 (18.5)**	**13.5 [0.1]**

We observed more female seahorses in trade than males, and the difference was significant for all species (Table 12). We photographed pregnant male *H. kuda*, *H. spinosissimus* and *H. trimaculatus* (Table 12); *H. kuda* had the highest percentage of specimens that were pregnant (~40%). The mean size of observed seahorses varied by species: *H. trimaculatus* were smallest and *H. kelloggi* were, on average, the largest (Figure 4; Table 12). The mean size of observed individuals was greater than the documented height at reproductive activity for *H. histrix*,

H. kelloggi, and *H. spinosissimus*, and slightly above or equal to documented height at reproductive activity for *H. kuda* and *H. trimaculatus,* respectively (Figure 4).

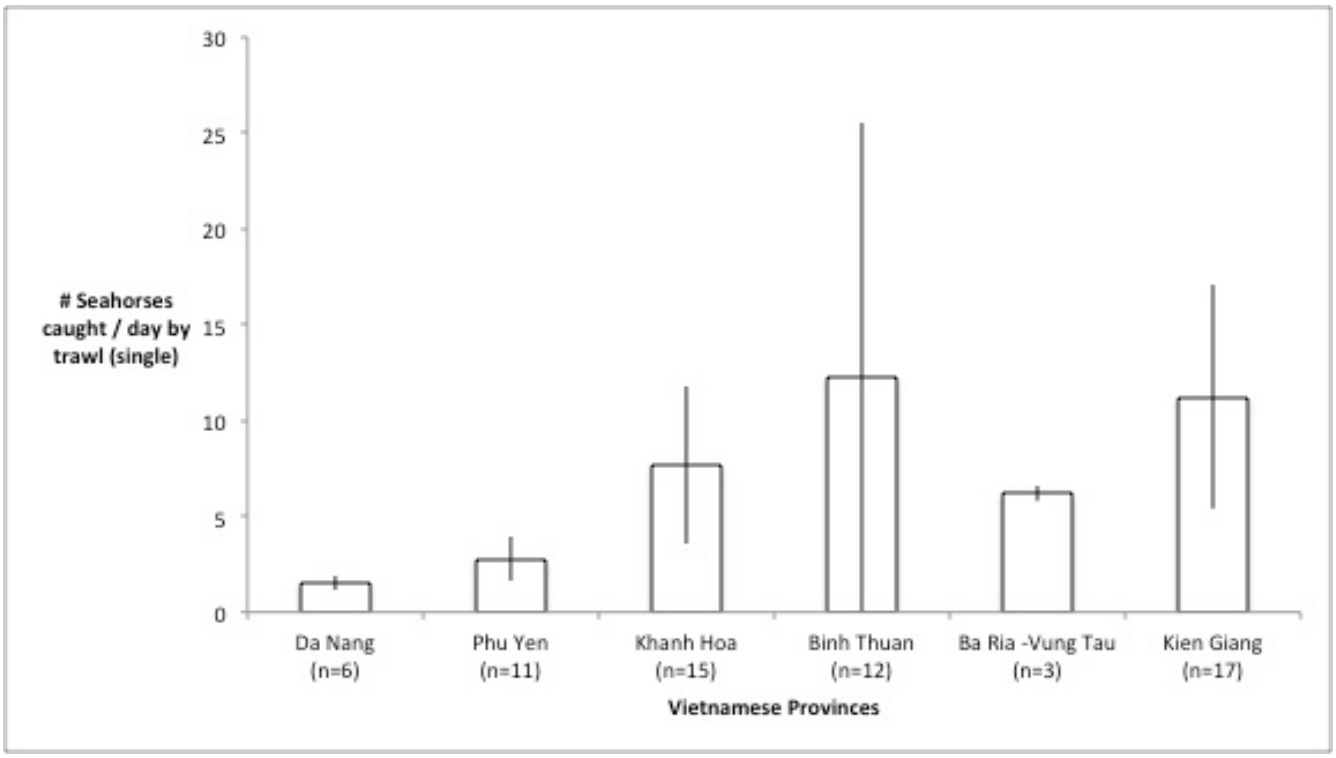

Figure 4. Mean seahorse size by species observed in buyer photos in Viet Nam. Horizontal lines are heights at reproductive activity (as summarized in Meyers (1991); Randall (1995); Kuiter (2000); Lawson *et al.* (2015)). Error bars represent 95% confidence intervals. (n = number of individuals.)

Uses

Seahorses were reportedly sold both domestically and internationally. Domestic uses for live seahorses included being put in alcohol for tonics, and being sold as broodstock to seahorse culturists. Freshly dead seahorses were also used in Viet Nam to make tonics, and as Traditional Chinese Medicine (TCM). Dry seahorses were sold domestically for use in tonics and medicines, but were also ground into seahorse wine. Dry seahorses were furthermore reportedly exported to China for use as TCM. Indeed, the fate of dry and live seahorses landed by fishers seems to be the same as there was no obvious live trade for aquaria display – instead seahorses that were landed live were eventually put, while alive, into alcohol for tonics.

Trade levels

We interviewed a total of 47 buyers from eight provinces that represented multiple levels of trade (Table 13). Over 72% of buyers were primary buyers, who sourced their seahorses directly from fishers (Table 13). Approximately 21% of buyers reported occupying an upper level of trade (Table 13). Many buyers reported occupying more than one trade level (Table 13). Domestic retailers and exporters were found to operate across all levels of trade (Table 13). Some individuals further identified themselves as both domestic retailers and exporters. The number of buyers reporting their role as a domestic retailer was almost three times the number of reported exporters (Table 13). We found the greatest number of domestic retailers in Khanh Hoa and the most exporters in Kien Giang province.

Table 13. Number of respondents interviewed during trade surveys in Viet Nam carried out from November 2016 to January 2017, categorized by occupation (trade level) and location. Traders may represent more than one trade level; therefore some individuals are double counted.

	Thua Thien -Hue	Da Nang	Phu Yen	Khanh Hoa	Binh Thuan	Ba Ria-Vung Tau	Ho Chi Minh	Kien Giang	Total
Fishers (Level 1)	3	6	21	22	14	3	0	24	93
Culturists (Levels 1, 2 and 3)	0	0	0	5	0	0	0	1	6
Primary buyers (Level 2)	1	2	6	5	8	Unknown	Unknown	12	34
Secondary buyer (Level 3)	0	0	3	11	2	Unknown	Unknown	9	25
Upper level buyer (Level 4)	0	0	0	10	0	Unknown	Unknown	0	10
Domestic retailer (Levels 2-4)	1	0	3	11	1	1	4	5	26
Exporter (Levels 2-4)	0	0	1	2*	2	0	0	4	9
Total	**4**	**8**	**27**	**38**	**22**	**4**	**4**	**39**	**146**

*One respondent occupied this trade level in the past, but not at the time of interviews.

Trade routes

Limited information suggested that buyers generally sourced their seahorses from fishers in the same province in which they operate (Table 14). The main exceptions were buyers in Khanh Hoa province that reported sourcing seahorses from Kien Giang, Binh Thuan, and Ninh Thuan provinces. Buyers in Ba Ria-Vung Tau province reported that seahorses could be sourced from boats fishing in Indonesian waters.

We obtained more information on reported destinations (Table 14). The most commonly cited destinations for seahorses in trade were local (within same province), but buyers and exporters also reported sending seahorses to non-specified provinces (Table 14). Ho Chi Minh City was the most commonly cited domestic destination, and China was the most commonly reported export destination (Table 14). One exporter who claimed to be retired in Khanh Hoa reported previously exporting seahorses to the USA and Japan. One quarter of buyers reported sending seahorses by bus, but more than 60% of buyers reported that they sold to people who came in person to purchase seahorses.

Trade volumes

Buyers bought seahorses in three forms (Table 15): (i) dry (5 of 8 provinces), (ii) wet or freshly dead (6 of 8 provinces), and/or (iii) live (3 out of 8 provinces; Phu Yen, Khanh Hoa and Kien Giang).

Our interviews with 47 buyers from four provinces produced only limited quantitative information on purchase volumes of dry and wet (freshly dead) seahorses in trade, and none for live seahorses (Table 15). Volumes of dry seahorses acquired per day per buyer ranged from 37.5 individuals in Thua Thien-Hue province to 254 individuals in Kien Giang province. In comparison, volumes of wet seahorses acquired per day ranged from 2.8 individuals in Da Nang to 68.6 individuals per day in Kien Giang. When we scaled reported volumes to yearly estimates, the reported purchase volume of dry seahorses was more than three times that of wet seahorses (Table 15). Buyers in Kien Giang purchased the largest number of seahorses per annum for both dry and wet categories (Table 15). We could not obtain information on the number of buyers (or shops) per province, and so were unable to scale up per buyer purchase volumes to a national estimate.

Table 14. Seahorse trade routes in Viet Nam reported from (a) buyers (not including exporters) and (b) exporters located in the provinces surveyed from November 2016 – January 2017. Exporters were only encountered in four of eight provinces surveyed. Buyers in Ho Chi Minh provided no information about seahorse trade routes and therefore is not included in the table.

Province	Source							Destinations							
	Indonesia*	**Da Nang**	**Kien Giang**	**Binh Thuan**	**Ninh Thuan**	**Local (same province)**	**Other province (not specific)**	**USA**	**Japan**	**China**	**Ho Chi Minh**	**Mon Cai**	**Phu Yen**	**Local (same province)**	**Other province (not specific)**
(a) Buyers															
Thua Thien-Hue		X									X			X	
Da Nang						X								X	X
Phu Yen						X	X							X	X
Khanh Hoa			X	X	X	X								X	X
Bin Thuan						X							X	X	X
Ba Ria-Vung Tau	X		X											X	
Kien Giang						X					X			X	X
(b) Exporters															
Phu Yen						X	X			X		X		X	X
Khanh Hoa				X	X	X		X^	X^	X	X			X	X
Bin Thuan						X				X	X			X	X
Kien Giang						X				X	X	X		X	X

* Caught in Indonesia but entered the market in Viet Nam. ^Buyer exported to USA and China in the past, prior to 2011.

Table 15. Values used to determine annual number of individual seahorses collected year $^{-1}$ buyer $^{-1}$, by province.

Province	**Type of seahorses acquired**			**Sample size of respondents reporting # of seahorses in a kg**			**Mean # seahorses kg $^{-1}$ [SE]**			**Mean # of seahorses acquired day $^{-1}$ [SE]**			**# of days acquiring seahorses month $^{-1}$**	**# of months acquiring year $^{-1}$**	**Annual mean # of seahorses acquired year^{-1} buyer $^{-1}$ [95% CI]**		
	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live			Dry	Wet	Live
Thua Thien-Hue	X	X	---	1	---	---	375 [0]	---	---	37.5	---	---	20	12	9,000	---	---
Da Nang	---	X	---	2	---	---	338 [37.5]	101 [1.3]*	---	---	2.8 [0.4]	---	20	12	---	680 [490-871]	---
Phu Yen	X	X	X	1	4	---	325 [0]	101 [1.3]	---	---	---	---	20	12	---	---	---
Khanh Hoa	X	X	X	4	---	---	366 [25.3]	101 [1.3]*	---	39.25 [13.7]	43.2 [21.1]	---	20	12	9,420 [3,000-15,840]	10,368 [456-20,280]	---
Binh Thuan	---	X	---	2	6	---	363 [12.5]	100 [7.3]	---	---	23.6 [5.8]	---	20	12	---	5,667 [1,132-10,200]	---
Ba Ria-Vung Tau	X	---	---	---	---	---	---	---	---	---	---	---	20	12	---	---	---
Ho Chi Minh	---	---	---	---	---	---	---	---	---	---	---	---	20	12	---	---	---
Kien Giang	X	X	X	4	3	---	325 [17.7]	212 [94.3]	---	254.2 [124.5]	68.6 [16.8]	---	20	12	60,996 [2,432-119,560]	16,464 [8,568-24,360]	---
Total	**X**	**X**	**X**	**14**	**13**	---	**348 [10.5]**	**126 [23.2]**	**---**	**128.6 [58.4]**	**38.7 [8.6]**	---	**20**	**12**	**26,472 [0-60,306]**	**8,294 [1,698-14,891]**	**---**

* Indicates that we know seahorses are acquired but no volumes were given, therefore values were taken from closest province of Phu Yen. We assumed buyers worked a 5-day work week throughout the year.

Buyers reported buying seahorses in dry and wet forms at all trade levels (Table 16). Level 2 buyers apparently acquired the most dry seahorses per day (77,592 individuals), whereas middle buyers and those operating on multiple levels estimated volumes at less than 20% of the level 2 buyer amounts. Exporters reported acquiring approximately three times more dry seahorses per day than domestic retailers (Table 16). In contrast, numbers were more consistent for wet seahorses: an average level 2 buyer reported acquiring half the number (5,856) reported by an average middle buyer (13,896 individuals) or a buyer operating at multiple levels (11,664 individuals). More than half the buyers we interviewed (27/48) reporting selling seahorses either domestically (4), internationally (2) or both (21).

Table 16. Values used to determine annual number of seahorses acquired per year per buyer (# of individual seahorses acquired year $^{-1}$ buyer $^{-1}$), for domestic exporters and retailers based on interviews with buyers in eight provinces of Viet Nam.

Trade Level (n)	**# of buyers reporting type of seahorses acquired**			**Mean # of seahorses acquired day^{-1} [SE]**			**Assumed # of days acquiring seahorses month $^{-1}$**	**Assumed # of months acquiring year $^{-1}$**	**Annual mean # of seahorses acquired year $^{-1}$ buyer at a given trade level $^{-1}$ [95% CI]**		
	Dry	Wet	Live	Dry	Wet	Live			Dry	Wet	Live
Domestic retailer only (7)	4	4	---	48.6 [19.3]	57.7 [20.6]	---	20	12	11,664 [2,585-20,742]	13,848 [4,158-23,538]	---
Exporter only (1)	2	---	---	149.5 [110.5]	---	---	20	12	35,880 [0-87,859]	---	---
All domestic retailers & exporters (14)	11	6	---	75.3 [26.2]	60.3 [13.7]	---	20	12	18,072 [5,747-30,396]	14,472 [8,027-20,916]	---

Just over one-third of buyers we interviewed reported information on seahorse selling volumes (Table 17). Dead seahorses were sold in more provinces than live seahorses. Mean selling volumes across all provinces surveyed were 274 dry individuals per day, and 414 live seahorses per day. Buyers in Khanh Hoa reported selling the most dead seahorses per day and Binh Thuan the fewest. Only Kien Giang reported selling live seahorses. When we scaled daily estimates to annual volumes, buyers we interviewed reported selling an average of 65,760 dry seahorses and 99,360 live seahorses per annum. We did not obtain information on the number of buyers (or shops) per province, and so were unable to scale up per buyer selling volumes to a national estimate.

Based on our limited sample sizes, exporters sold higher volumes of dead seahorses per day and per annum than domestic retailers (Table 18). Only domestic retailers reported selling live seahorses, and these estimates were higher than those for dry seahorses both per day and per annum (Table 18). We did not obtain information on the number of retailers or exporters per province, and so were unable to scale up these volumes to a national estimate.

The only domestic consumption data we have is for the production of seahorse wine in Khanh Hoa province. One producer reported that they collected ~ 1.3 tonnes of dry wild seahorses each year – which is roughly equivalent to ~420,000 individuals (based on conversation of 325 dry seahorses per kilogram reported by fishers from our interviews). Because they grind the seahorses to make wine, they do not care what species or size they collect. The producer reported buying seahorses from a trader in Cam Ranh – who in turn collects seahorses from Kien Giang and Ba Ria-Vung Tau.

Table 17. Buyer reported volumes of seahorses sold in Viet Nam by province.

Province (n)	Method of sale		Selling volume of seahorses in # of individuals day $^{-1}$ [SE]		Assumed # of days selling seahorses month $^{-1}$	Assumed # of months acquiring year $^{-1}$	Estimated annual mean # of seahorses sold year $^{-1}$ buyer $^{-1}$ [95% CI]	
	Dead	Live	Dead	Live			Dead	Live
Thua Thien-Hue (0)	---	---	---	---	---	---	---	---
Da Nang (0)	---	---	---	---	---	---	---	---
Phu Yen (1)	X *	---	98	---	20	12	23,520	---
Khanh Hoa (9)	X	---	389 [206]	---	20	12	93,360 [0-190,320]	---
Binh Thuan (1)	X	---	23	---	20	12	5,520	---
Ba Ria-Vung Tau (0)	---	---	---	---	---	---	---	---
Ho Chi Minh (0)	---	---	---	---	---	---	---	---
Kian Giang (7)	X	X	151 [59]	414 [73]	20	12	36,240 [8,400-63,994]	99,360 [65,021-133,699]
Overall mean (18)	**X**	**X**	**274 [119]**	**414 [73]**	**20**	**12**	**65,760 [9,840-121,681]**	**99,360 [65,021-133,699]**

* Response not given, assumed dry.

Table 18. Buyer reported volumes of seahorses sold in Viet Nam from domestic retailers and exporters. We assumed a five-day work week and year-round sale to scale daily volumes to annual volumes.

Trade level (n)	# of buyers reporting selling volumes		Selling volume of seahorses in mean # of individuals day $^{-1}$ [SE]		Assumed # of days selling seahorses month $^{-1}$	Assumed # of months acquiring year $^{-1}$	Estimated annual mean # of seahorses sold year $^{-1}$ buyer $^{-1}$ [95% CI]	
	Dead	Live	Dead	Live			Dead	Live
Domestic retailer only (7)	7	1	298 [119]	341 [0]	20	12	71,520 [15,542-127,497]	81,840 [0]
Exporter only (1)	1	---	487 [0]	---	20	12	116,880	---
All domestic retailers & exporters (14)	12	2	333 [156]	414 [73]	20	12	79,920 [6,538-153,302]	99,360 [65,021-133,699]

Values

Fishers

Fishers sold live seahorses to buyers for more than twice the value (per individual) of wet or dry seahorses (Table 19 in VND; Table 20 in USD). Fishers in Ba Ria-Vung Tau reported receiving the highest amount of money for their dry seahorses both per individual and per kilogram. Those in Phu Yen reported the highest price for live seahorses per individual and for wet seahorses per kilogram, and fishers in Da Nang reported the highest price for wet seahorses per individual (Table 19).

Table 19. Prices for dry, wet and live seahorses by province from fishers and buyers in Vietnamese Dong (VND, values are thousands of VND). No buyers reported purchase price of seahorses.

Province	**Fisher reported price received individual^{-1} [SE] (n)**			**Fisher reported price received kg $^{-1}$ [SE] (n)**			**Buyer selling price individual $^{-1}$ [SE] (n)**			**Buyer selling price kg $^{-1}$ [SE] (n)**		
	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live
Thua Thien-Hue	36 [9] (2)	---	43 [0] (1)	---	---	---	---	---	---	17,750 [0] (1)	---	---
Da Nang	---	32 [2] (6)	---	---	---	---	---	---	---	10,750 [1,125] (2)	---	---
Phu Yen	---	26 [5] (4)	94 [18] (7)	---	3,733 [125] (5)	---	---	---	1,314 [208] (6)	21,600[245] (5)	4,875 [106] (6)	---
Khanh Hoa	---	26[8] (9)	41 [4] (11)	---	---	---	340 [92] (7)	788 [0] (1)	122 [57] (3)	18,266 [1372] (3)	7,000 [500] (2)	5,000 [0] (1)
Binh Thuan	---	24 [3] (13)	---	---	3,000 [250] (3)	---	70 [0] (1)	1,936 [1,218] (5)	---	17,750 [1,109] (4)	---	---
Ba Ria-Vung Tau	43 [6] (3)	---	---	1,350 [1,528] (3)	---	---	---	---	---	2,250 [0] (1)	---	---
Ho Chi Minh	No fishers interviewed			---	---	---	---	---	---	---	---	---
Kien Giang	15 [2] (8)	31 [4] (12)	43 [3] (2)	3,500 [102] (4)	3,357 [203] (7)	4,000 [0] (1)	60 [0] (2)	---	90 [0] (1)	13,369[1606] (13)	---	8,500 [167]
Overall mean	**25 [4] (13)**	**28 [2] (44)**	**59 [8] (21)**	**7,786 [2,102] (7)**	**3,411 [128] (15)**	**4,000 [0] (1)**	**237 [54] (14)**	**1,745 [1,012] (6)**	**834 [230] (10)**	**15,477[1,079] (29)**	**5,406 [369] (8)**	**7,875 [966] (4)**

Table 20. Prices for dry, wet, and live seahorses by Vietnamese province from fishers and buyers in USD. No buyers reported purchase price of seahorses. Values converted from VND (Table 19) using 1 USD = 22,655 VND (From Oanda.com; Nov 2016 – Jan 2017).

Province	Fisher reported price received individual^{-1} ($USD) [SE] (n)			Fisher reported price received kg^{-1} ($USD) [SE] (n)			Buyer selling price ($USD) individual^{-1} [SE] (n)			Buyer selling price ($USD) kg^{-1} [SE] (n)		
	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live	Dry	Wet	Live
Thua Thien-Hue	1.60 [0.39] (2)	---	1.87 (0) [1]	---	---	---	---	---	---	772.45 [0] (1)	---	---
Da Nang	---	1.40 [0.08] (6)	---	---	---	---	---	---	---	474.51 [49.65] (2)	---	---
Phu Yen	---	1.13 [0.22] (4)	6.04 [0.81] (7)	---	164.77 [5.53] (5)	---	---	---	58.00 [9.18] (6)	953.43 [10.81] (5)	215.18 [4.69] (6)	---
Khanh Hoa	---	1.15 [0.35] (9)	1.83 [0.16] (11)	---	---	---	15.00 [4.05] (7)	34.78 [0] (1)	5.38 [2.52] (3)	806.27 [60.56] (3)	308.98 [22.07](2)	220.70 [0] (1)
Binh Thuan	---	1.05 [0.14] (13)	---	---	132.42 [11.04] [3]	---	3.09 [0] (1)	85.45 [53.76] (5)	---	783.49 [48.95] (4)	---	---
Ba Ria-Vung Tau	1.91 [0.29] (3)	---	---	595.89 [67.43] (3)	---	---	---	---	---	99.32 [0] (1)	---	---
Ho Chi Minh	No fishers interviewed			---	---	---	8.27 [0] (4)	---	---	---	---	---
Kien Giang	0.66 [0.11] (8)	1.38 [0.17] (12)	1.87 [0.11] (2)	154.49 [4.50] (4)	148.19 [8.96] (7)	176.56 [0](1)	2.65 [0] (2)	---	3.97 [0] (1)	590.11 [70.89] (13)	---	389.90 [7.37] (3)
Overall mean	**1.09 [.18] (13)**	**1.21 [0.10] (44)**	**2.61 [0.36] (21)**	**343.67 [92.78] (7)**	**150.56 [5.67] (15)**	**176.56 [0] (1)**	**10.46 [2.38] (14)**	**77.02 [44.67] (6)**	**36.81 [10.15] (10)**	**683.16 [47.63] (29)**	**238.62 [16.29] (8)**	**347.60 [42.64] (4)**

Traders

No buyers reported purchase price information, but we do have sale price information from all four provinces where buyers were interviewed (Table 19 in VND; Table 20 in USD). The most common buyer reported price was for dry seahorses, and these selling prices were higher than those reported by fishers (about 9.5 times higher per individual and 2 times higher per kilogram) (Table 19). Where reported, wet seahorses were sold at lower prices per kilogram than dry seahorses (Table 19, but we note that a kilogram of wet seahorses contains many fewer individuals than a kilogram of dry seahorses). Individual live seahorses were the most expensive; buyers in Phu Yen reported selling one live seahorse for approximately 1.3 million VND ($58 USD; Table 20), about 14 times what fishers reported receiving for an individual live seahorse.

The one wine producer we talked to reported paying ~200 USD per kilogram of dry seahorses – which after accounting for an annual reported purchase volume of 1.3 tonnes, scales up to a total purchase value of 260,000 USD each year.

Culture

The commercial facilities we visited were open air, with concrete tanks. They extracted food for their seahorses from the wild – for example one culturist reported feeding his seahorses with wild copepods and mysids collected in the shrimp ponds nearby – or fed them frozen *Acetes*. The number of observed tanks ranged from 10-24, and ranged in size from 4 to 7 m^3. The facilities have reportedly struggled to close the life cycle on breeding – producing mostly F1 generation (young born in captivity to wild-caught males that were already pregnant on arrival).

The four commercial facilities we visited had each been in operation more than 10 years (starting production in 2004-2007) (Table 21). Three facilities reportedly stopped breeding for trade in 2013 or 2014, when exporters supposedly lost their CITES permits (Table 21); however, one of these still had seahorses on site, reportedly being bred for fun (we counted 10 adult *H. kuda* and 400-500 *H. kuda* juveniles on site at the time of our visit). Only one facility we visited was supposedly still producing seahorses for trade; the culturist reported producing *H. kuda* (7,000) and *H. comes* (5,000) as recently as 2016 – and we estimated about 500 *H. kuda* of commercial size (8-10 cm), 1000 declared *H. kuda* broodstock, and 50,000 *H. kuda* juveniles (2 days – 3 weeks in age) on site at the time of our visit. One facility that had stopped production declared plans to produce 10,000 seahorses for a research project/contract with the Vietnamese army in 2017.

In addition to the commercial facilities, the Viet Nam Institute of Oceanology (IO) has been breeding seahorses since 2008 – for research purposes (to advance breeding techniques for different species), but has also sold seahorses for export. We interviewed the principal seahorse culturist at IO. The culturists reported that although exporters did not have permission to export at the time of our interview, she was maintaining broodstock of some species while waiting for permission to be granted.

Species

All five commercial culture operations reported breeding only or mostly *H. kuda* (by volume: 90% n = 1; 95% n = 1; 100% n = 3). The other species, reported by just two culturists, was *H. comes*, though in much smaller volumes (5 and 10%). One culturist reported that *H. comes* is a challenge to produce as it is hard to find broodstock, and the species does not change colour like *H. kuda* (and is thus less desired by consumers). As mentioned above, we observed seahorses at two facilities, and in both cases we only observed *H. kuda*.

IO has bred six seahorse species in the past. It successfully closed the life cycle of *H. comes*, *H. histrix*, and *H. kuda*. It has further produced F1 juveniles of *H. kelloggi*, *H. spinosissimus,* and *H. trimaculatus* – but has not closed the life cycle for these species.

Broodstock

Only one commercial facility had declared broodstock on site. We estimated about 1000 *H. kuda* in a tank that the culturist declared as F1 broodstock – though the seahorses were small (8-10 cm). The culturist reported that he moves pregnant males from the broodstock tank to another tank to give birth, and then returns the adults to the broodstock tank.

Four culturists reportedly sourced broodstock from the wild through seahorse buyers who in turn collected seahorses from fishers (Nha Trang, Van Ninh, and Xuan Tu Village were reported as buyer locations). The culturists purchased wild, pregnant seahorses from the buyers. After the males gave birth, three respondents either (i) sold the males back to the buyer, or (ii) put them in a sea cage with other seahorses to get pregnant again. One respondent reported he selected the good, big, and healthy wild males with high fecundity to breed again. We do not know what proportion of broodstock is used once versus used multiple times. We furthermore do not know how many pregnancies a single male might have while being kept in a sea cage. A fourth culturist reported releasing wild seahorse broodstock back to the sea after they gave birth. The seahorse broodstock used at IO were also sourced from up to three buyers, who in turn reportedly sourced them from divers or trawl fishers in Khanh Hoa.

The culturist from IO shared some life history information for the species she cultured. Males across all species were reportedly observed pregnant at around 12-15 cm height, but *H. comes* could be pregnant as small as 10 cm height. She reported that *H. comes* sourced from the wild had an average broodsize of about 350 young. This was higher than she observed for F1 broodstock, which were reported to have a broodsize of 200-300 young when >1 year in age. *Hippocampus comes* was reported to have about two pregnancies a month, each lasting 12-14 days; males would mate as soon as they were returned to the broodstock tank after giving birth. She reported mate switching among *H. comes* individuals held in tanks.

There was consensus among the culturists that wild broodstock are better than F1. Two culturists reported that wild broodstock produce more, bigger, and healthier babies – that have higher survival rates. Two others commented that the fecundity of F1 broodstock is low (for example just 80-200 babies seahorses – versus >300 for wild broodstock), and the babies are weak and grow slowly. However, one culturist did comment that F1 broodstock are better adapted to tank life (i.e. not as susceptible to disease, maintain pair bonds).

The information we received from culturists did not provide much insight into the reliance of breeding operations on wild broodstock (only two respondents commented on this questions), but suggests facilities may use just a couple hundred wild broodstock each year. Annual reported production ranged from 3,000-40,000 individuals (Table 21). One respondent suggested 100 pregnant males, if bred several times, could produce 20,000 young; another reported that it took 100-150 wild males (again bred several times) to produce 30,000 – 40,000 seahorses. These reports are plausible – if *H. kuda* produce around 200 young per pregnancy, then 200 pregnancies would produce 40,000 young such that on average each male would only have to be pregnant twice. We can infer, therefore, that facilities may need at most a couple hundred wild broodstock at peak annual production (40,000 individuals; Table 21). The respondent from IO reported that even if the life cycle is closed, you still need about 5-10 wild males to replace broodstock each year to maintain the genetic diversity of the stock. Two culturists reported that wild broodstock live from 2-3 years, with a maximum life expectancy of four years.

Destination

Three of the commercial culture operations reported selling their seahorses to export companies in Ho Chi Minh. One also reported selling directly to a Hong Kong company. Another reported that the seahorses went from Ho Chi Minh to China and Europe. Finally, one culturist reported supplying domestic trade only – selling them live to local people or companies, or putting them in alcohol to sell through his shop. IO sold its seahorses for export through a middleman. The culturist reported market demand to be unpredictable – producers generally never knew what the demand would be from buyers in advance, so they bred more seahorses than were eventually demanded by exporters. From this we infer that culturist reported production values (Table 21) are likely higher than what were actually sold into the supply chain. One culturists reported releasing any “extra” seahorses to the wild (those not sold for export), another reported drying “extra” seahorses for domestic sale.

Table 21. Seahorse culture production in Viet Nam based on interviews with six culturists carried out from November 2016 to January 2017.

Type of operation	Location	Year started production	Years for reported production volumes	Reported annual production (seahorses year^{-1})	Size/age at which seahorses are ready to sell	Notes
Commercial	Cam Ranh	2007	2007-2016	14,000-15,000	8-10 cm / 1.5-2 months	In 2016 7,000 *H. kuda* and 5,000 *H. comes*
Commercial	Cam Ranh	2004	Prior to 2014	7,800-26,000*	6-8 cm / 1.5-2.5 months	Can sell larger seahorses for higher price; ~70% survival rate to 9-10 cm
Commercial	Nha Trang	2004	2004	30,000-40,000	---	---
			2005-2014	20,000	---	---
			Early 2016	3,000	---	---
Commercial	Nha Trang	2005	2013	30,000-40,000	6 cm / 1.5 months	---
Commercial	Kien Giang	2010	2010-2011	5,000		---
Institute of Oceanography	Nha Trang	2008	2008-2013	20,000-30,000	---	Mostly *H. comes and H. histrix*; production depends on market demand

*export company was demanding 300-500 seahorses every 1-2 weeks before 2014; 300-500 every 1-2 weeks → 7,800 – 26,000 year^{-1}.

Seasonality

Fishers

The majority of fishers who responded to our question about seasonality reported that seahorse catches varied with season (82 of 84 fishers); only one fisher in Da Nang and another in Binh Thuan reported no seasonality to seahorse catches. The high season was reported to start as early as January (in Kien Giang), and run as late as December (in Kien Giang) (Table 22). The reported high season for seahorse catches was longest in Kien Giang (7 months) and the shortest in Ba Ria-Vung Tau and Binh Thuan (2 months; Table 22).

Traders

All buyers we interviewed reported a seasonality to supply for seahorses, however only 30 buyers reported the specific months of seasonality. Overall, the season of high supply reported by buyers was March – July (Table 22), which roughly matches the inferred reported high season by fishers (April – July; Table 22). According to buyers, the high season of supply began as early as February in Khanh Hoa and Kien Giang provinces and ran as late as August in three provinces (Khanh Hoa, Binh Thuan, Kien Giang). Additionally, some buyers reported that prices for seahorses changed based on seasonality of demand (selling volumes), although no buyers reported quantitative information about such changes.

Culturists

The commercial operators reported that while seahorses breed year round, there were peaks in breeding activity (recognized by a peak in number of pregnant males). Two culturists reported the peak to last from October or December through February. A third respondent reported a peak in number of pregnant males from August to December, with fewer pregnant males in January and February. These reported peaks in breeding activity coincide with our observation that 40% of *H. kuda* held by buyers from Nov-January were pregnant (Table 12). In contrast, the culturist at IO reported peak pregnancies to occur from April to September, but she mostly bred *H. comes* and *H. histrix* – whereas the commercial culturists mostly bred *H. kuda* – so this discrepancy could reflect differences among species. Past research on seahorse fisheries in Viet Nam reported peaks in catch of

pregnant males in April, May, September, and December – though the findings were not species specific (Meeuwig *et al.* 2006).

Table 22. Fisher and buyers responses by province about beginning and end of seahorse high season in Viet Nam. n = number of respondents.

	Fishers (high season of seahorse catch)			**Buyers (high season of seahorse availability)**		
Province	**High season starts (n)**	**High season ends (n)**	**Inferred high season (> 50% responses are within these months)**	**High season starts (n)**	**High season ends (n)**	**Inferred high season (> 50% responses are within these months)**
Thua Thien-Hue	May (3) April (1) May (5)	July (2) August (1) June (1)	May - July	No response	No response	No response
Da Nang	June (1) February (2) March (4) April (5) May (2)	August (3) May (3) June (1) July (4) Aug (6)	May - August	April (2)	July (2)	April - July
Phu Yen	June (2) Feb (2) March (9) April (3) May (5)	Sept (1) May (4) June (8) July (4)	April - July	April (2) Feb (1) March (1) May (1)	July (2) May (1)	April - July
Khanh Hoa	June (1) April (3) May (9)	Aug (4) May (1) June (8)	March - June	June (4) March (3) April (2)	August (6) June (2) July (2)	June - August
Binh Thuan	June (1)	July (4)	May - June	May (1)	Aug (2)	April - July
Ba Ria-Vung Tau	April (1) May (2) January (1) Feb (15) March (5) April (1)	June (3) May (1) June (5) July (3) Aug (6) Sept (5) Oct (2)	May - June	No response Feb (4) March (8) April (1)	No response March (1) June (3) July (5)	No response
Kien Giang	June (2)	Dec (1)	Feb-August		Aug (4)	March - July
Overall	**January (1) February (19) March (18) April (14) May (26) June (7)**	**May (9) June (26) July (17) Aug (20) Sept (6) Oct (2) Dec (1)**	**April - July**	**Feb (5) March (12) April (7) May (2) June (4)**	**March (1) May (1) June (5) July (11) Aug (12)**	**March -July**

Changes over time

Fishers

Ninety-five per cent of fishers from all provinces reported a decline in seahorse CPUE over a ten-year period with a mean 59% decline (Table 23). The steepest declines over this period were reported by fishers in Thua Thien-Hue province, where fishers reported declines of over 90% (Table 23). Moreover, 60% of respondents, from six of seven provinces surveyed, reported an inferred decline in the body height of seahorses over a ten-year period, (mean decline 44%; Table 23). Finally, all fishers from six of seven provinces surveyed reported that the price of seahorses had increased over ten years (Table 23). Those that commented on per cent price increase reported a mean increase of 42% over ten years (n = 16 fishers).

Table 23. Fisher reported changes over time, by province, in seahorse catch in terms of numbers, size and selling price in Vietnam. n = number of respondents.

Province (n)	Reported trend in seahorse numbers over 10 years (n) [% of those reporting decline]	Fisher reported declines (%) in seahorse catch per unit effort over 10 years [95% CI] (n)	Reported trend in seahorse size (n) [% of those reporting decline]	Fisher reported change (% reduction) in seahorse size [SE] (n)	Reported trend in seahorse price (n)[% of those reporting increase]
Thua Thien-Hue (3)	Decline (3) [100]	93.3 [92-95] (3)	No change (1)	---	Increase (1) [100]
Da Nang (6)	Decline (6) [100]	53.3 [49-58] (6)	Decline (1) [100]	---	Increase (5) [100]
Phu Yen (21)	Decline (19) [90]	54.8 [42-66] (18)	Decline (17) [100]	---	Increase (13) [100]
Khanh Hoa (22)	Decline (18) [90] No change (2)	48.5 [39-58] (13)	Decline (2) [12.5] No change (12) Not sure (2)	---	Increase (11) [100]
Binh Thuan (14)	Decline (10) [83] Not Sure (2)	48.9 [46-52] (9)	Decline (4) [40] Not sure (6)	35.0 [0] (1)	Increase (10) [100]
Ba Ria-Vung Tau (3)	Decline (3) [100]	66.7 [63-70] (3)	Decline (2) [100]	---	Increase (2) [100]
Kien Giang (24)	Decline (22) [100]	66.7 [60-73] (22)	Decline (13) [76] No change (1) Not sure (3)	46.3 [5.5] (4)	Increase (14)]93] Not sure (1)
Total (93)	**Decline (81) [95] No change (2) Not sure (2)**	**58.5 [54-63] (74)**	**Decline (39) [61] No change (14) Not sure (11)**	**44.0 [4.8] (5)**	**Increase (56) [98] Not sure (1)**

When we look at fishers reported changes over time by gear type, six of the seven gear types had 100% of interviewed fishers reporting declines in catch over a ten-year period (Table 24). All pair trawl fishers and basket divers we interviewed, the two gears with the highest daily catch rates (Figure 2), also reported a decline in seahorse size (Table 24). However, some divers, seine net fishers, and single trawl fishers reported no change in seahorse size over time (Table 24). All basket divers, divers, seine net fishers, and single trawl fishers reported an increase in seahorse price over time, while two-thirds of crab net fishers did the same (Table 24).

Traders

Only 17% of buyers reported a decline in supply over a ten-year period. These observations represent potential declines in five of eight provinces where interviews were conducted. Only buyers in Binh Thuan and Kien Giang were able to provide estimates of how much supply had declined over ten years, with estimates ranging from 50-60%.

Table 24. Fisher reported changes over time in seahorse catch per unit effort (CPUE) and body size, by gear type in Viet Nam. n = number of respondents.

Gear type (n)	Fisher reported declines (%) in seahorse CPUE over 10 years [95% CI] (n)	Reported trend in seahorse size (n) [% of those reporting decline]	Fisher reported change (% reduction) in seahorse size [SE] (n)
Basket diving (6)	45.6 [22-69] (4)	Decline (4) [100]	---
Crab net (4)	51.7 [38-65] (3)	Decline (2) [50] Not sure (2)	52.5 [2.5] (2)
Diving (11)	73.2 [62-85] (9)	Decline (5) [71] No change (2)	---
Electric shock (1)	83.0 (1)	---	---
Seine net (2)	92.5 (2)	No change (1)	---
Trawl (single) (64)	53.9 [49-59] (50)	Decline (26) [56] No change (11) Not sure (9)	38.3 [6.0] (3)
Trawl (pair) (5)	73.5 [72-75] (5)	Decline (2) [100]	---
Total	**58.5 [54-63] (74)**	**Decline (39) [61] No change (14) Not sure (11)**	**44 [4.8] (5)**

Culturists

Two culturists commented on declines in the availability of wild broodstock. One reported that the number of wild seahorses was 80% lower than 10 years ago; he attributed this decline to other forms of trade, and not pressure from culture. The other culturist reported the number of wild broodstock to have declined 80-90% in 10 years, along with a reduction in the size of wild seahorses.

Other trade data sources

CITES data

Live trade

Almost all trade in the CITES database from 2004-2014 reported as exported from Viet Nam was of live seahorses (95% of reported exports by volume; Figure 5). Of this, three-quarters were reported as born in captivity to wild parents (source code F, 75% of reported exports by total volume) (Figure 6). The remaining live trade was reportedly sourced from the wild (source code W, 18% by total volume), or bred in captivity (source code C, 6% by total volume). All live exports were reported as for commercial purposes (purpose code T). Viet Nam reported a great deal of the live trade reported to CITES as sourced in Viet Nam (91% by total volume; 77% by total number of records – 195/253; 103 of these 195 records were also reported by the importing Party).

Live exports, which averaged 68,400 individuals from 2005 through 2014 (range 30,100 – 102,800), supposedly declined over time – with the peak reported volume in 2006 about 3 times higher than that reported in 2014 (102,800 vs 38,900) (Figure 6). This was due in part to a notable decline in the proportion of reported live wild exports over time – from 100% of reported wild exports in 2005 to 40% in 2006, and then to just 1 or 2% in each of 2010-2014. Notable exports of truly captive bred seahorses were restricted to 2006. Seahorses born in captivity to wild parents made up most of reported wild exports in all years except 2005 and 2006 – accounting for more than 90% of trade from 2008-2014.

Live exports were reported as one of eight species. One species – *H. kuda* – made up more than three-quarters of reported live exports (80% by total volume across 2004-2014). *Hippocampus comes* accounted for 12% of reported live exports, while *H. kelloggi*, *H. spinosissimus,* and *H. trimaculatus* together made up another 2%. Three reported species (*H. erectus, H. fuscus,* and *H. reidi*), each reportedly wild sourced, do not occur in Viet Nam's waters and so must have been misidentified or miscoded. Together these three species accounted for just

1% of total reported live exports. A further 1% of total reported live exports were not identified to the species level. Only *H. comes* and *H. kuda* were reported as F or C, with the remaining species all reported as only sourced from the wild (Figure 6).

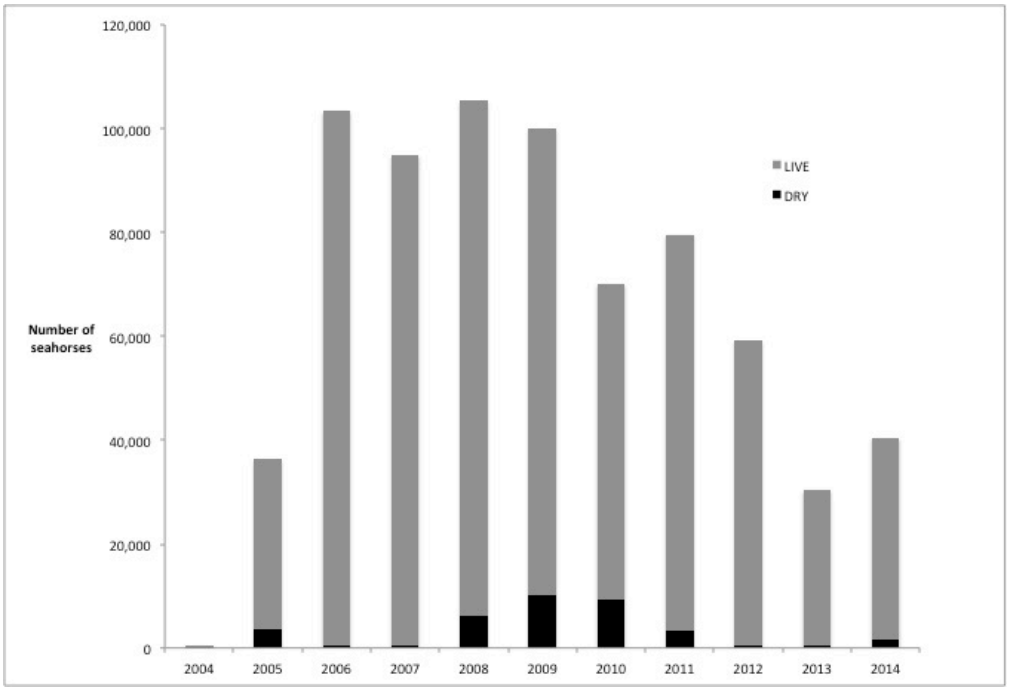

Figure 5. Volumes of live and dry seahorses supposedly exported from Viet Nam reported in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

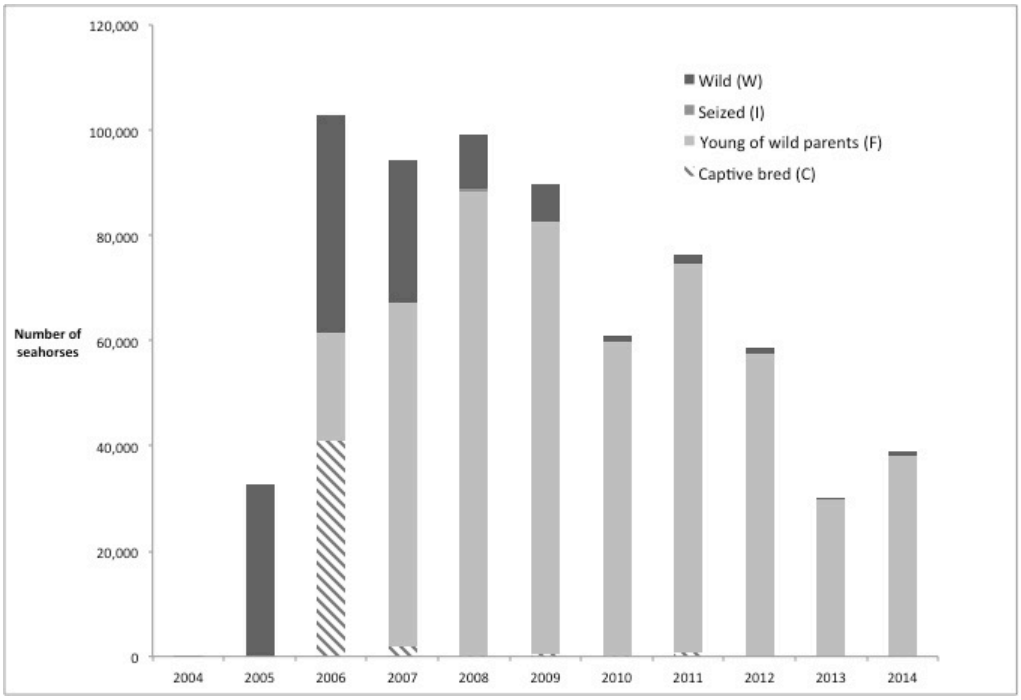

Figure 6. Volumes of live seahorses by source code supposedly exported from Viet Nam reported in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

The United States was the top reported destination for Viet Nam's live seahorse exports in the CITES database (68% of total trade from 2005-2014) – and this was true across time (Figure 7). France was the reported destination of 11% of live seahorses from Viet Nam overall, but its importance as a destination declined over time. The UK and Canada were each reported to receive 4% of live seahorses from Viet Nam, although the UK reportedly imported more seahorses than Canada in more recent years. The Netherlands ranked fifth overall as a reported destination for reported live exports from Viet Nam, accounting for 2% of overall volumes. A further 30 countries were reported as destinations for Viet Nam's live seahorses, together accounting for 10% of reported trade for 2005-2014.

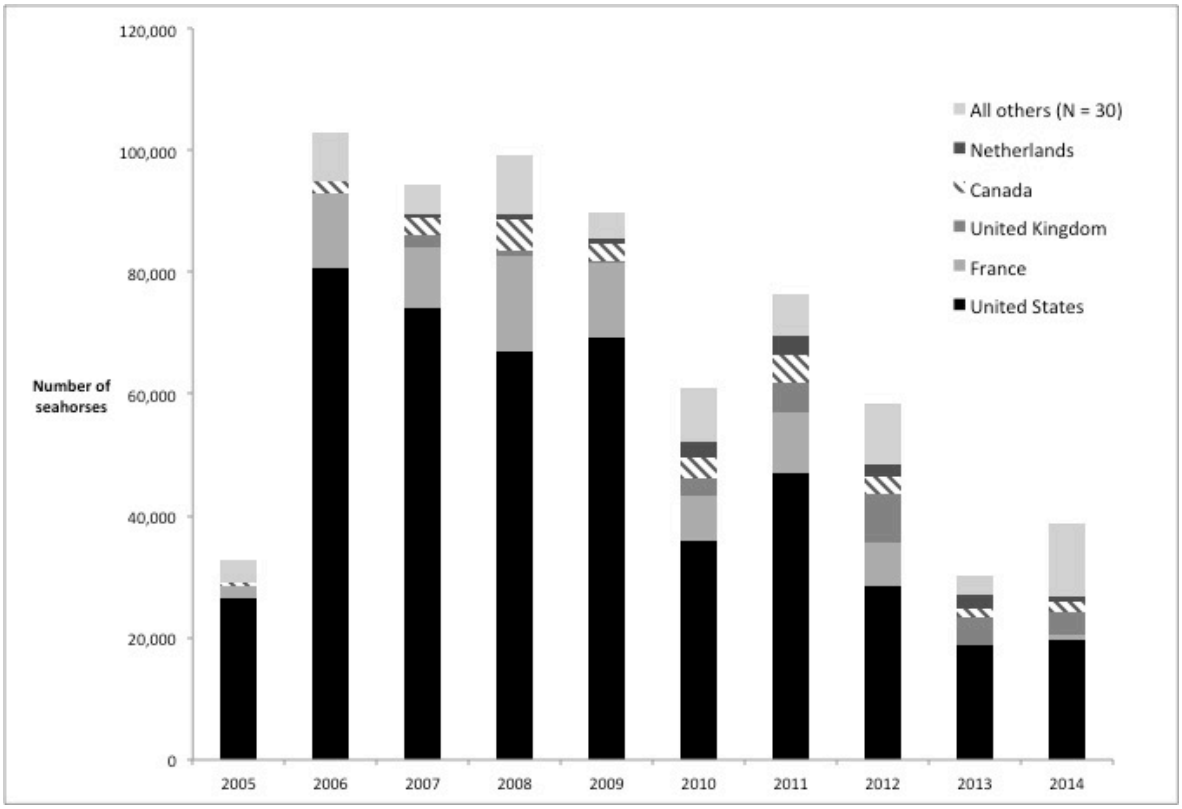

Figure 7. Reported destinations of live seahorse exports supposedly originating from Viet Nam, based on data in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

As the majority of supposed Vietnamese exports were reportedly live individuals born in captivity to wild parents (84% overall), we focus in on these now. These exports were primarily reported as *H. kuda* (84% of total volumes), with smaller volumes reported as *H. comes* (16% of total). However, reported exports of *H. comes* increased over time, whereas reported exports of *H. kuda* decreased (Figure 8). In 2014, reported export of *H. kuda* was just 200 individuals – compared to a peak reported export of 85,700 in 2008, whereas reported exports of *H. comes* had climbed from an average of 5,200 individuals across 2006-2012, to 38,100 individuals in 2014 – a volume approaching the annual average exports of *H. kuda* from 2005-2014 (48,000 individuals, range 270 – 85,700). The reported destinations of live, F exports supposedly from Viet Nam were the same as those reported for live exports overall: the US (64%), followed by France (12%), UK (5%), Canada (5%), and the Netherlands (2%).

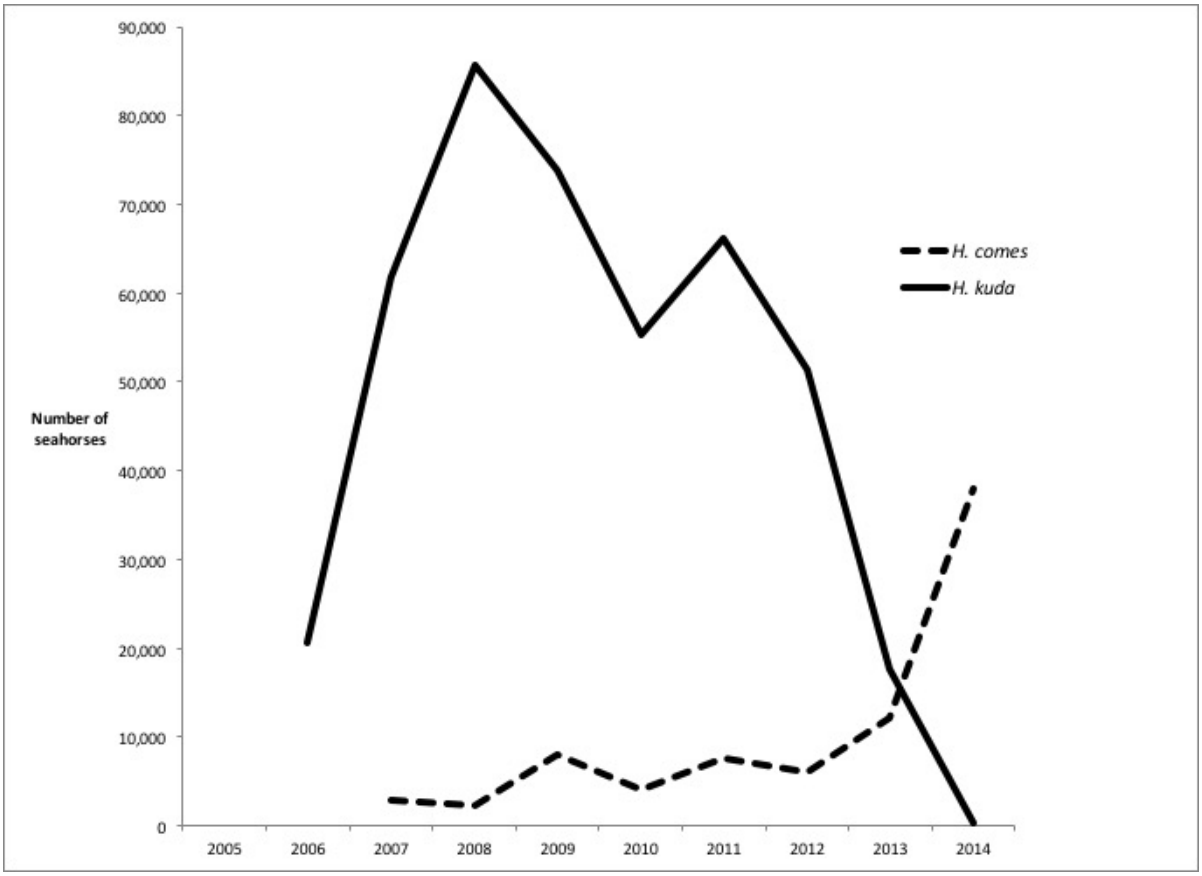

Figure 8. Reported species composition of live seahorse exports supposedly originating from Viet Nam, based on data in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

Dry trade

Dry seahorses made up just 5% of total reported exports from Viet Nam in the CITES database (Figure 5), with reported volumes averaging 3,300 individuals from 2004-2014 (range 360 – 10,100). Reported dry exports peaked in 2009 and 2010, and declined thereafter (Figure 9). More than two-thirds of the total dry trade reportedly exported from Viet Nam was reported as having been seized by the declared importing country (source code I, 66%) while the remainder was reported as wild-sourced (source code W, Figure 9). Dry exports reported as originating in Viet Nam were apparently destined for either commercial trade (57% of total volume) or personal use (purpose code P, 41% of total). Importing countries reported nearly all dry trade reported to CITES as sourced in Viet Nam only (95% by total volume; 99% by total number of records – 75/76).

The majority of dry exports reportedly sourced in Viet Nam were not identified to the species level; 69% of total reported dry exports were labelled as *Hippocampus* spp. The remaining dry exports were reported as one of six species. *Hippocampus kuda* made up one-quarter of reported dry exports (24% of total volume), followed in volume by *H. kelloggi* (5% of total). *Hippocampus spinosissimus* and *H. trimaculatus* together accounted for another 1% of total reported dry exports. Two reported species (*H. erectus*, *H. hippocampus*), both reported as seized, do not occur in Viet Nam's waters; together these species accounted for less than 1% of reported dry exports overall.

The majority of dry trade reportedly sourced from Viet Nam was reported to CITES by the US (93%). This was constant across time (Figure 10). Eight other countries were reported in CITES data as the destinations of dry seahorses supposedly sourced from Viet Nam – but each in only small volumes, ranging from a total of 1 – 1,860 seahorses. However, the US was the only reported destination from 2011-2014. About two-thirds of the dry seahorses were reported by the US as seized (69%), and the rest as wild-sourced (31%) – but only seized seahorses were reported after 2010.

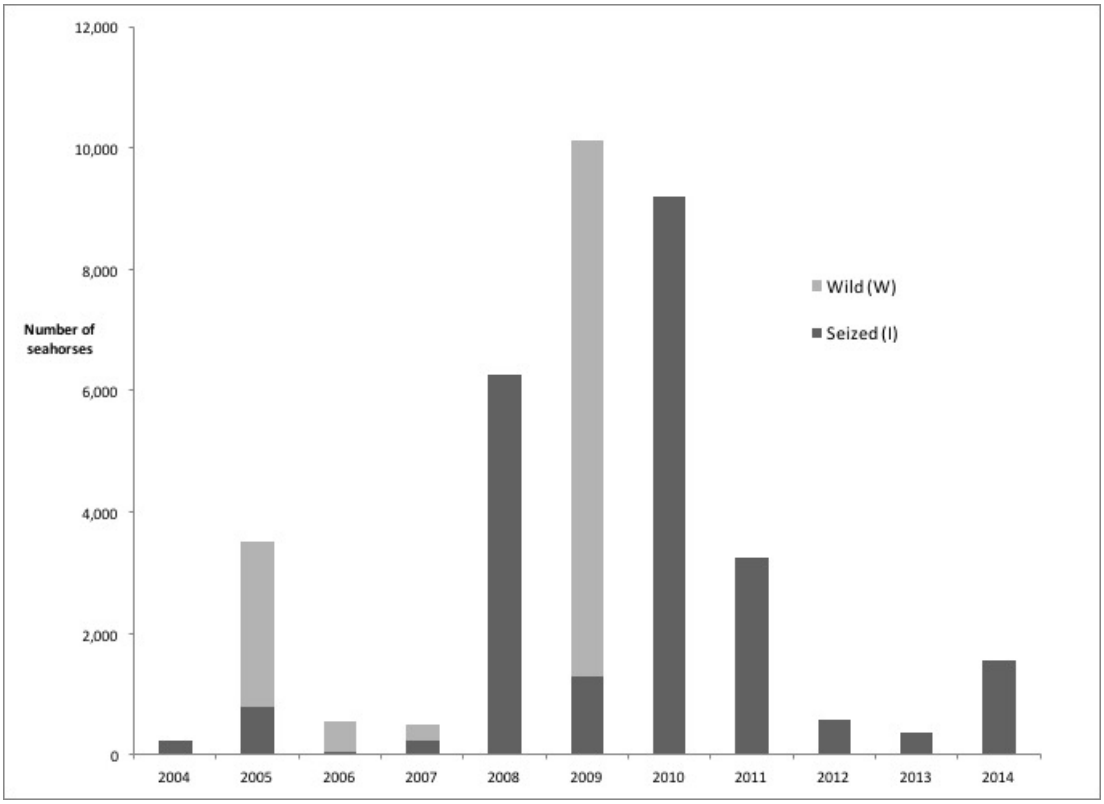

Figure 9. Volumes of dry seahorses by source code supposedly exported from Viet Nam reported in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

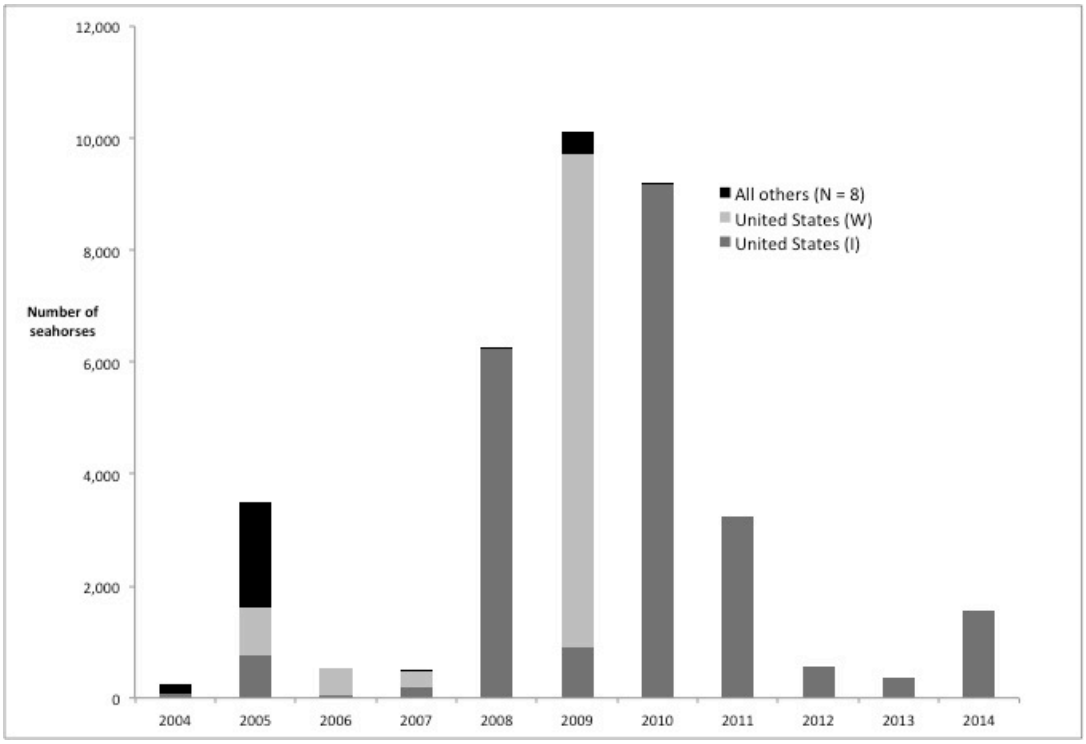

Figure 10. Reported destinations of dry seahorse exports supposedly originating from Viet Nam, based on data in the CITES Trade Database from 2004-2014. As the CITES listing of seahorse species took effect in May 2004, all 2004 data represents only a partial year.

Customs data- dry only

Hong Kong's CSD data from 1998 through 2014, which are reported only as *Hippocampus* spp., contained just one record of trade reportedly from Viet Nam, for 28,700 individuals in 2013, worth 75,000 HKD (9,600 USD based on 2003 average exchange rate of 0.128; (https://www.oanda.com/fx-for-business/historical-rates). CITES data contained no records of dry trade into Hong Kong from Viet Nam. All trade from Viet Nam into Hong Kong reported in CITES data was of live seahorses.

Taiwan's data from 1989 through 2004, which are also reported only as *Hippocampus* spp., contained 13 records of imports reportedly sourced in Viet Nam – with a mean reported import of 36,300 individuals across all years (range 3,500 – 134,300). The value of one 2002 record of ~53,000 individuals was reported as 3,000 USD. Values were not reported for the other records. CITES data contained just one record of dry trade reportedly sourced in Viet Nam and sent to Taiwan – 1,860 wild-sourced individuals, reported to CITES by Viet Nam and not Taiwan. The remaining five records reporting trade between Viet Nam and Taiwan in the database were reported by Viet Nam, and involved exports of wild (1 record) or cultured (F or C, 3 and 1 records, respectively) live seahorses from Viet Nam to Taiwan.

Comparing to past studies

Species

This latest survey of trade documented at least five seahorse species being exploited in Viet Nam's waters, and all five have been documented in past research, with the addition of *H. mohnikei* – the catch of which appears to be highly seasonal (Meeuwig *et al.* 2006). *Hippocampus trimaculatus* was the most common species documented in our study, in agreement with Meeuwig *et al.* (2006) which documented seahorse landings to be dominated by *H. trimaculatus*, comprising 62% of their samples. *Hippocampus spinosissimus* made up less than a fifth of our documented individuals, roughly equal to *H. kuda* – whereas past studies documented *H. spinosissimus* as more dominant, with many fewer *H. kuda* (Giles *et al.* 2006; Meeuwig *et al.* 2006). Indeed, *H. spinosissimus* was the main species documented in Phu Quoc (Ut and Tam 2012; Stocks *et al.* 2017) – about 2.5 times the number of landed of *H. kuda* and 12.5 times the number of landed *H. trimaculatus* (Stocks *et al.* 2017).

Fisheries

We were only able to compare our findings to those of past research for two gears, single trawl and diving gears (Table 25); the results for single trawls were variable across studies whereas the results for divers aligned well. Our CPUE estimate for single trawls was roughly 3-30 times higher than those reported in Giles *et al.* (2006) and Meeuwig *et al.* (2006), although our studies surveyed different provinces. Our CPUE estimates for single trawls fell within the range reported by Stocks *et al.* (2017). Stocks *et al.* (2017) research, focused only on Phu Quoc Island (Kien Giang province), produced a wide range of CPUE estimates for single trawls because it separated out trawls that targeted seahorses from those that caught them indiscriminately – the former had much higher CPUEs than the latter. Our CPUE estimate for single trawls was lower than that found by Ut and Tam (2012), also focused on Phu Quoc Island; their CPUE estimate for single trawls was similar to that found by Stocks *et al.* (2017) for trawls that targeted seahorses. Our CPUE estimate for divers also fell within the range reported by Stocks *et al.* (2017), which as with single trawls, reported a wide range of CPUE estimates for divers depending on whether they targeted or indiscriminately caught seahorses.

We could only compare our annual estimates of seahorse catch for single trawls with that of Giles *et al.* (2006), as that study was on a similar scale to ours (Table 25). Our estimate is ~1 million more or ~30% higher than Giles *et al.* (2006). The difference may lie in the fact that the studies covered different provinces.

Comparing the findings of the current study to those carried out in the past was challenging for four reasons. First, not all gear types were included in each study (Table 25). Second, even when gears were comparable (e.g. single trawls, divers), the geographic locations of surveys varied. Third, not all studies (e.g. Ut and Tam 2012) provided annual catch estimates. Fourth, fleet sizes for single trawls across years and by location varied making it challenging to interpret annual catch estimates.

Table 25. A comparison of research results from this study to previously published research from Viet Nam about seahorse fisheries' catch per unit effort, annual catch estimates, and fleet sizes.

Gear	Study	Years of data collection	Mean CPUE (seahorses vessel^{-1} day^{-1}) [95% CI] (n)	Estimated # of individual seahorses year^{-1}	Fleet size across provinces	Provinces surveyed
Trawl (single)	Our study (using provincial fleet sizes) ***	Nov 2016–Jan 2017	7.9 [1.8-16.9] (61)	3,302,816	1936	Phu Yen, Binh Thuan, Ba Ria-Vung Tau, Kien Giang
	Giles *et al.* 2005*	1995-1999	0.25-2.5 [0-3] across years and provinces (308^)	2,275,000	200-9,076^{+}	Binh Thuan, Ca Mau, Bac Lieu, Kien Giang
	Meeuwig *et al.* 2006**	1996-2000	0.9-1.6 [0.7-2.0] (16)	36,000–62,000	150-170^{+}	Khanh Hoa (Cua Be only)
	Ut and Tam 2012***	Dec 2010-Nov 2011	27.8-27.9 (30)	Not provided	Trawl (single)	Kien Giang (Phu Quoc only)
	Stocks *et al.* 2017 **	April–July 2014	2.5 (indiscriminate, 123) – 23.3 (target, 42)	161,840	124	Kien Giang (Phu Quoc only)
Divers	Our study***	Nov 2016–Jan 2017	5.2 (10)	No fleet data available	No fleet data available	Thua Thien-Hue, Phu Yen, Khanh Hoa
	Stocks *et al.* 2017 **	April–July 2014	1.3 (indiscriminate, 117) – 31.8 (target, 5)	36,420	46	Kien Giang (Phu Quoc only)

* n= number of boats monitored; **n = number of fishing trips sampled; ***n = number of interviews; ^ assumes that every boat participating in the study from 1995-1999 was a different boat; $^{+}$ = range across years.

Trade

Our estimated annual selling volumes for domestic retailers were 120-150 times higher than those reported in previous Vietnamese trade research (Giles *et al.* 2006; Table 26). Our study also estimated exporter annual selling volumes (per buyer per year) to be higher than previous research, but the discrepancy was not as large as for domestic retailers (Table 26).

Table 26. Comparison of seahorse selling volumes for domestic retailers and exporters from our study and previously published research from Viet Nam (n = number of interviews).

Study	Type of retailer (n)	Estimated annual mean # of seahorses (dead) sold year^{-1} buyer^{-1}	Provinces surveyed
Our study	Domestic (7)	71,520	Binh Thuan, Da Nang, Ho Chi Minh, Khanh Hoa, Kien Giang, Phu Yen, Thua Thien-Hue, Ba Ria-Vung Tau
	Exporter (1)	116,880	
Giles *et al.* 2006*	Domestic (72-77)	470-590	Bac Lieu, Binh Dinh, Binh Thuan, Ca Mau, Da Nang, Hai Phong, Ho Chi Minh, Khanh Hoa, Kien Giang, Ba Ria-Vung Tau
	Exporter (6)	90,000-102,000	

We were not able to scale up per exporter selling volumes into total annual export volumes, which meant we could not compare to previously published total export volumes for Viet Nam. Past research estimated 1.6 million seahorses to the main exporting centers in Viet Nam; this number was comparable to the volumes of seahorses caught as bycatch at that time (Giles *et al.* 2006). We were unable to estimate the number of seahorses exported from Viet Nam for two reasons. First, many respondents indicated participation at multiple levels of trade, which included at times both domestic retailer and exporter (Table 13; 16). We did not have the information to tease apart domestic versus exported trade for these individuals. Second, information was not available to us on the total number of exporters in any of the locations where we conducted buyer interviews.

The trade routes identified in our study seemed less straight forward than those identified by previous research. Previous research indicated that intermediate buyers bought from fishers or local buyers and sold to exporters in Ho Chi Minh, Hai Phong City, and Da Nang for export through unofficial and unregulated channels across the northern border into Guangxi province of China; documented domestic consumption was small at that time (Giles *et al.* 2006). On the other hand our study documented a more complex inter-provincial trade. Buyers in four of seven provinces reported sourcing seahorses from outside of their home province and numerous respondents also reported sending seahorses to provinces other than their own (Table 14). Furthermore, Ho Chi Minh, Mon Cai, and Phu Yen were commonly reported domestic destinations for seahorses in trade (Table 14). China was also the main reported export destination in our study.

The documented values of seahorses both per individual and per kilogram in our study were higher than those documented in previous research (Table 27), supporting fisher reported price increase in this study (Table 23). Fishers in our study reported getting paid between 25-50 times more per individual seahorse than they did 17 years ago (Table 27). Our fisher reported prices per seahorses were comparable to those reported in Stocks *et al.* (2017), obtained only three years prior (Table 27). Buyers reported buying seahorses at prices 79-474 times higher than in previous research, and selling them at prices 30-154 times higher (Table 27). If we assume every caught seahorse gets sold – then our estimated value of the seahorse trade for Viet Nam at the fisheries levels is at least VND 417 billion (USD $18 million; this estimate is based on price paid to fishers for individual dried seahorses – the price paid for live seahorses was much higher). This value is much higher than the estimated VND 2-10 billion (US$170,000-962,000) per year calculated by Giles *et al.* (2006) for higher levels of the trade.

Table 27. Comparison of (dry) seahorse sale and purchase prices reported by fishers and buyers from our study and previously published research from Viet Nam (n = number of interviews).

Study	Years of data collection	Fisher reported price received (VND1000) individual^{-1} (n)	Buyer purchase price (VND1000) individual $^{-1}$ (n)	Buyer selling price (VND1000) kg $^{-1}$ (n)	Provinces surveyed
Our study	Nov 2016-Jan 2017	25 (13)	237 (14)	15,477 (29)	Binh Thuan, Da Nang, Ho Chi Minh, Khanh Hoa, Kien Giang, Phu Yen, Thua Thien-Hue, Ba Ria-Vung Tau
Giles *et al.* 2005	1995-1999	0.5-1 (206)	0.5-3 (69)	100-500 (69)	Bac Lieu, Binh Dinh, Binh Thuan, Ca Mau, Da Nang, Hai Phong, Ho Chi Minh, Khanh Hoa, Kien Giang, Ba Ria-Vung Tau
Stocks *et al.* 2017	April – July 2014	11-38 (11)	---	---	Kien Giang (Phu Quoc only)

Changes over time

Fishers and traders in this study reported declines of 49-94% over ten year periods, which echoes the results of previous research. Most fishers and buyers surveyed across 10 provinces in central and southern Viet Nam in between 1995-1999 reported that seahorse catches had declined over time (Giles *et al.* 2006); 85% of fishers reported a decline in seahorse catch, estimated at 30–60% over 2–5 years; buyers also reported decreases in seahorse availability in most regions. Fishers interviewed on Phu Quoc Island in 2011 reported a "substantial" declined in seahorse catch compared to the previous five to ten years (Ut and Tam 2012). Most recently, fishers on Phu Quoc Island in Kien Giang province, interviewed in 2014 reported an 85-96% decrease in seahorse catch from 2004 to 2014, while the values reportedly increased 534% during the same time period (Stocks *et al.* 2017).

Discussion

Our study has updated and advanced our understanding of the scope and scale of seahorse exploitation and trade in Viet Nam. It revealed that many gears are catching seahorses, with varied catch rates adding up to huge

catch volumes due to intense fishing pressure. None of this catch is being monitored or regulated to any extent. Landed seahorses are entering a complex trade, with large domestic consumption of seahorses in Viet Nam for seahorse wine and tonics and considerable export; we could not discern the ratios that enter each. None of the domestic trade is regulated, and the dry seahorse exports, mainly to China, were not regulated properly under CITES restrictions; they were either exported illegally without permits or exported with permits that Viet Nam did not report to CITES. The only trade Viet Nam did report to CITES was for live F1 exports. Viet Nam reported most such exports as *H. kuda* until 2013, when CITES suspended exports of this species, after which Viet Nam's reports cited *H. comes*, in a switch that raises questions. The original dependence of farms on wild *H. kuda* for broodstock is unknown, but such aquaculture certainly exerts a small pressure relative to the much larger extraction in non-selective fishing and the undocumented and unregulated trade. Our interview-based study indicated greater CPUE than in earlier studies yet vast majority of fishers reported declines in seahorse catch over the past ten years; such a contradiction emphasizes the need for reliable catch and trade monitoring. Given that seahorses were the first marine fishes listed on CITES Appendix II, and continue to serve as pioneers for marine fish issues in CITES, our evaluation of Viet Nam's engagement with seahorses is of broad conservation importance.

Species

Our new trade survey documented exploitation of at least five seahorse species in Viet Nam's waters, as in previous research. All five species (*H. kelloggi, H. kuda, H. histrix, H. spinosissimus,* and *H. trimaculatus*) are included in the IUCN Red List as Vulnerable (IUCN 2017). In addition, we discovered just after our field surveys, through photographic evidence, that the sixth species previously documented in trade, *H. mohnikei* (listed as Data Deficient: IUCN 2015), is still landed in Phu Quoc Island; the catch of this species had previously been noted as highly seasonal (Meeuwig *et al.* 2006). In translating fishers' descriptions of seahorses to scientific classification, we deduced that their "black seahorse" typically refers to *H. kuda*, "Indonesian seahorse" refers to *H. kelloggi*, and "long seahorse" refers to pipefish. As well, "spiny seahorse" generally (but not always) refers to *H. spinosissimus* and "smooth seahorse" commonly refers to H. *trimaculatus*. We could not infer geographic distributions of these species in the wild from this study, as the focus was on landings and not on catch locations; fishers commonly travel considerable distances to fish.

Fisheries

Our new trade survey produces a much higher estimate of seahorse catch than previously reported. Our tally that Viet Nam lands 16.7 million seahorses annually in seven gears is 7.5 times higher than the estimate from the late 1990s (Giles *et al.* 2006), partly because we now included more gears. The previous study (20 years ago) focused only on single trawlers but other gears – especially the pair trawls that we include here for the first time – have higher catch rates.

We infer that the actual catch is much higher than our increased estimate: (1) there are more vessels than we documented; (2) there are more gears than we documented; (3) more provinces catch seahorses than we documented; and, (4) there are more gear/province combinations than we documented. First, we were missing fleet sizes for gears with some of the highest reported CPUEs, and for many coastal provinces. For example, basket diving had an estimated CPUE higher than that of single trawlers, but we could not find fleet size estimates for this type of gear. There is also a need to include catches from illegal and unrecorded vessels, which would certainly increase the tally. Second, other fishing gears also need to be considered. For example, crab traps have been documented to catch seahorses in Viet Nam (Stocks *et al.* 2017) and fish cages and squid traps obtain seahorses in Thailand (Aylesworth *et al.* 2017) but we included none of these. Third, our catch estimate needs to expand to include fishing activities from many central & northern coastal provinces that catch seahorses but where we did not survey (e.g. Co To and Cat Ba Islands, Project Seahorse 2017). Finally, we need to find a way to evaluate catch rates where we knew gears were used but we did not interview fishers in that province. For example, we only interviewed pair trawl fishers in Kien Giang province, although according to both provincial and national (RIMF) data they also operate in 14 other provinces. As another example, provincial data indicated purse seines for Phu Yen, Binh Thuan, Ba Ria-Vung Tau, and Kien Giang, but our lack of CPUE estimates for seines from these provinces means they are not included in our overall estimate.

The reliability of our catch estimates for Phu Quoc – and subsequent management interventions – would be improved by knowing what portion of the trawlers we interviewed were targeting seahorses (using different gear and behaviour, Stocks *et al.* 2017) and what portion were trawlers that fish indiscriminately. Past research found

that the vessels targeting seahorses in Phu Quoc have higher CPUE, but lower overall take because they are fewer in number than trawlers catching seahorses incidentally (Stocks *et al.* 2017).

Nationally, we needed to determine where seahorses that were landed in each province had been caught, by nation and by province, if we are to understand the trajectory of wild populations. Fishers/boats landing seahorses in one province may have travelled to other provinces to fish, Vietnamese boats fish in Cambodian and Indonesian waters, so some of the landings reported by Vietnamese fishers may not be caught in the Vietnamese EEZ. Local knowledge suggests about 10% of fishers from Kien Giang province (specifically Phu Quoc and Ha Tien) fish in Cambodian waters; and about 5% of fishers (trawls but also divers) from Kien Giang, Phu Yen, and Binh Thuan fish in Indonesia (Hoang pers. comm.). There is also the complication that the seahorses may have arrived on Phu Quoc from Vietnamese fishing in Cambodian waters or even from Cambodian boats, both of which are known to arrive in Phu Quoc Island.

Trade

Our analyses reveals a more complicated trade than documented in the past, identifying more inter-provincial trade and domestic consumption of seahorses in Viet Nam than had been previously recorded, and confirmed undocumented and unregulated export of seahorses into China. However, a dearth of Vietnamese data on the number of domestic retailers and exporters meant we were unable to scale up our estimates of volumes for each trader to national volumes, or understand the relative scales of domestic and export trade from Viet Nam. This is a worry for more than seahorses as many of these traders deal in other marine species that may be overexploited, and some which are subject to CITES controls (e.g. shark fin, Dulvy *et al.* 2008; Lawson *et al.* 2017).

We are confident that the many millions of seahorses landed in Viet Nam entered trade, in international trade but also in surprisingly high national trade. Viet Nam has an unusual overlap of domestic and international trade – with individuals acting as both local retailers and exporters, whereas these roles are separate in most other countries (e.g. McPherson and Vincent 2004; Perry *et al.* 2010). Domestic consumption had previously been assumed, correctly or incorrectly, to be minimal, with past research estimating total annual domestic consumption at 103-121 kg (Giles *et al.* 2006). In contrast, our study revealed sale of 120-150 times more seahorses in tonics and wine. Indeed, limited information from our retailer and exporter interviews suggested that domestic consumption volumes might total up to two-thirds those of estimated exported volumes, therefore involving a possible 40% of seahorses in trade.

Most seahorse exports were illegal, primarily to China although also to countries such as the USA. None of the dry seahorse exports we discovered during our trade surveys had been reported by Viet Nam to CITES. Trade in specimens of CITES Appendix II, such as seahorses, requires an export permit issued by the country of origin. Parties must designate a 'Management Authority' that is responsible for issuing permits and compiling annual reports on their international trade in specimens of CITES-listed species; this is a requirement under Article VIII, paragraph 7 (a), of the Convention. The annual report data are entered into the CITES Trade Database. So the fact that Viet Nam does not report any dry exports to CITES in its annual reports, leads us to infer it is not issuing export permits for said trade, in which case the exports are illegal. At the very least they are unreported and unregulated. Dry seahorses are easy to move illegally through unregulated channels. According to traders interviewed during the current study, China remains the main reported export destination for dry seahorses, although other counties, mainly the USA, reported seizures of dry seahorses reportedly coming from Viet Nam. Recent evidence also suggests that Viet Nam may be a country of transhipment for illegal dry seahorse trade from other countries. Customs officials in Viet Nam's northern port city of Hai Phong recently seized more than 300,000 dry seahorses smuggled from Peru (Chin 2017) – likely on their way across the border to China (Bat pers. comm.).

Export of live seahorses from Viet Nam is well documented in CITES data, probably partly because it is challenging to move live seahorses unnoticed. Our interviews with culturists suggest that the limited volumes of F1 export reported by Viet Nam to CITES – none were reported as wild - could indeed be coming from culture operations, rather than representing laundering of wild animals as occurs in other countries for other species (Lyons and Natusch 2011; Rosa *et al.* 2011; CITES 2014b; CITES 2017a). We only used CITES data to 2014, as delays in reporting made that the last year with comprehensive trade statistics for our analysis (UNEP-WCMC 2010). All but one culturist we spoke to reported having ended production in 2013/2014 in direct response to permitting difficulties. However, the CITES data that we downloaded on 11 June 2017 (after we had completed the analyses) contained 15 records of live exports from Viet Nam; most were *H. comes*, most (17,048) were F exported to Europe and US, and most were for commercial purposes. So, some trade is continuing.

Culture

We have some real doubts about the name of species declared in the CITES database as coming from culture operations. Reported exports of source code-F *H. comes* from Viet Nam in the CITES database (see previous paragraph) have increased more than 500% since CITES recommended a trade suspension for *H. kuda* from Viet Nam in 2013 under the CITES Review of Significant Trade. Reported exports of source code-F *H. kuda* decreased 99% over the same period, presumably because of the trade suspension. Such direct correlation clearly raises questions. Customs officers rarely have the skills, the time, or the inclination to make sure the species named on a permit matches the species in the shipment. The culturists we spoke to reported producing only very small volumes of *H. comes* in the past, and only one was still breeding seahorses supposedly for export - and it only had *H. kuda* on site. The Institute of Oceanography in Nha Trang reported having bred *H. comes* for export in the past, but the culturists there reported being unable to sell seahorses recently as exporters did not have necessary permits.

Culture operations in Viet Nam clearly depend on removing animals from the wild, yet Viet Nam has not assessed the impacts of such removal. Challenges controlling tank conditions in Viet Nam's usual open air, low-tech facilities mean that commercial operations are not likely to close the life cycle for seahorses to produce F2 animals. This means that commercial culture of seahorses in Viet Nam is reliant on wild broodstock. One culturist declared an estimated 1000 *H. kuda* we observed in a tank to be F1 broodstock, but the seahorses were small (8-10 cm), and in our expert opinion could not alone have produced the 50,000 juveniles that were also on site; they must have also come from males that were pregnant when captured from the wild.

CITES Parties have expressed formal concerns that commercial culture operations in Viet Nam may not account for the export volumes reported to CITES. CITES has included Viet Nam in the new CITES mechanism, Resolution Conf. 17.7 (Review of trade in animal specimens reported as produced in captivity, (CITES 2017a) because of (1) the lack of sustainability assessments for wild broodstock, and (2) the unreliability of declared production of source code-F *H. comes* by commercial culture operations in Viet Nam. Viet Nam will now need to respond to CITES' concerns. CITES has posed a number of questions to Viet Nam, as outlined in CITES document E-AC29-Com 11 (CITES 2017b). Viet Nam's response to these questions will be reviewed at the next CITES technical meeting (AC30 in 2018) to determine if trade is in compliance with CITES rules and procedures. If trade is in compliance, Viet Nam will be excluded from review. If trade is not in compliance, Viet Nam will be issued a set of recommendations that aim to promote capacity building and enhance Viet Nam's ability implement the relevant provisions of the Convention. As with RST, failure to meet the recommendations by the ascribed deadlines could result in a trade suspension.

Conservation

Our study elaborates concerns about the population status of seahorses in Viet Nam that contributed to the original Appendix II listing for seahorses. Fishers and traders in this study reported declines of 49-94% over ten year periods, echoing reported declines from previous research (Giles *et al.* 2006; Ut and Tam 2012; Stocks *et al.* 2017). Moreover, we found an exponential increase in reported prices for seahorses (*cf* Giles *et al.* 2006), always a potential indicator of inadequate supply to meet market demands; demand for Traditional Chinese Medicine (TCM) has increased with growing human population and rising affluence (Chen *et al.* 2007). It is clearly important that Viet Nam begin monitoring populations, catches or trade as soon as possible. Indeed such data are vital for Viet Nam to make Non-Detriment Findings, as required before issuing export permits.

Along with population declines, we are concerned about declining mean body size and proportion of mature individuals, both of which fishers reported and both of which are considered indicators of overfishing (Hutchings and Baum 2005; Meeuwig *et al.* 2006). Fishers reported declining body size in all but one province we surveyed. All measured individuals of *H. kuda* and *H. trimaculatus* were also very close to size at reproductive activity. These two findings raise concern for these species, particularly for *H. trimaculatus*, which also had highly skewed sex ratios in the photos we took.

We are surprised that so little trade in *H. trimaculatus* was reported in the CITES database. Viet Nam's reports to CITES show exports of fewer than 100 individual *H. trimaculatus* between 2004 and 2011. Yet, these and previous trade surveys have identified *H. trimaculatus* as one of the main seahorse species in Viet Nam's substantial trade (Giles *et al.* 2006 throughout Viet Nam from 1995 to 1999; Meeuwig *et al.* 2006 in central Viet Nam from 1995 to 1999; and Ut and Tam on Phu Quoc island in 2011). Moreover, given that *H. trimaculatus* is not among the species reported as cultured in Viet Nam, any exports would be wild sourced. The CITES review of

Significant Trade only examines trade reported to the CITES database so did not consider reliability and sustainability of Viet Nam's exports of this species. It may be time for the CITES Standing Committee – which deals with illicit trade and enforcement – to become involved in this and other aspects of Viet Nam's seahorse exports.

Management

For Viet Nam to make progress in conserving seahorses, it needs to pay attention to their fisheries, trades and conservation. The road map is there, the tools are in place, and the protocols are available to make considerable progress. In the final eventuality, political will for reconciling fisheries and conservation is the determinant of what happens next.

The large volume of unregulated and unreported dry trade may denote significant risks to Viet Nam's wild seahorses. Viet Nam clearly needs to identify, track, and assess its seahorse fisheries and exports, with a focus on evaluating trends in catch against effort. Gaining an understanding of trade over time will be important for discerning trends that might reflect the conservation status of wild populations. Converting trade from undocumented to documented will not, however, solve conservation problems of seahorses per se. The challenge in Viet Nam is that most seahorses that enter trade were caught incidentally, such that the fisheries may fuel the trade rather than the other way around.

The key to seahorse conservation in Viet Nam will lie in fisheries management, restricting removal from the ocean. Given that the primary threat to seahorses in Viet Nam is untrammelled bottom trawling – and that these gears catch a great many other species, even as they damage habitats – it clearly behoves Viet Nam to rein in these nonselective and destructive fisheries. Viet Nam will need to implement thoughtful spatial and temporal restrictions that limit the extent and intensity of damage these gears inflict. Much more also needs to be discerned about the impacts of the other, smaller, gears that also extract seahorses – and how they can be regulated. The focus may again be on the sheer magnitude of fishing effort, and the need to impose limitations.

In order to be confident that its exports (in this case driven by its fisheries) are not damaging wild populations, as required by CITES, Viet Nam needs to implement a robust monitoring plan for seahorses. Monitoring wild populations of seahorses is notoriously difficult and not likely to be feasible in Viet Nam. Instead, national agencies need to monitor landings and fishing effort repeatedly (developing a time series) at representative sites throughout the country – possibly using the protocols developed by Project Seahorse – and address conservation concerns as they emerge. This monitoring should cover all species caught in Vietnamese fisheries, and sample across all gear types that catch seahorses, anchored in information from the current analysis. It will be particularly important to monitor in Phu Yen, which all our data suggested had greatest diversity of seahorse species and fishing gears that catch them, and Phu Quoc, a notable seahorse fishing hot spot.

Our findings are relevant as Viet Nam addresses CITES' suspension of the country's exports of *H. kuda*. In seeking to make NDFs, it is vital that Viet Nam consider overall extraction of *H. kuda*, regardless of the animals' eventual use or destination. This means that the numbers caught must be tracked against effort for this species as for all others in trade. In conserving wild populations, it is immaterial whether seahorses removed from the ocean are sold dry or used as broodstock. That said, our data suggest that extraction of several thousand of wild *H. kuda* for broodstock each year (in total for the country, and not per aquaculture venture) may be tolerable, as long as there is oversight and adaptive management in response to indices relating to health of wild populations (notably CPUE). Project Seahorse and Viet Nam's Institute of Oceanography have already developed protocols for tracking use of wild broodstock by seahorse farms in Viet Nam.

As a conservation measure that will simultaneously manage fishing and promote seahorse populations, Viet Nam needs to establish and enforce many more effective MPAs. These would be valuable tools in developing capacity to make positive NDFs for seahorses. For trawling, mitigation of impacts depends very largely on excluding these non-selective and destructive gears from vulnerable and/or important areas. Viet Nam currently has 13 MPAs, focused primarily on coral reef habitats. In striving to reach Aichi Target 11, it is obliged to protect more of the marine environment to reach the required 10% threshold. Focusing the required new MPA coverage on inshore waters could facilitate fisheries recovery while also supporting seahorses.

Conclusions

Our trade research reveals findings of broad utility for the conservation of marine fishes and the implementation of CITES for such species listed on Appendix II. Seahorses were the first fully marine fishes to be listed on CITES Appendix II, and the first to be subject to a Review of Significant Trade (ensuring that the Convention is actually implemented). The CITES ban on Viet Nam exporting *H. kuda* was, moreover, the first for any marine fish globally. Experience with these fishes is thus generally informative.

Our work reminds us that field trade surveys are vital in probing CITES data, challenging CITES Parties to meet their obligations, and illuminating ways forward with fisheries management and marine conservation. We found large volumes of illegal trade, lack of attention to the source of broodstock in culture, and possible renaming of cultured species. We also recorded many reports of declining numbers, sizes, and proportion of mature seahorses allied to rising sale prices. Implementation of CITES Appendix II listings requires attention to fisheries management, ensuring that wild populations are not overexploited. Such attention is central to security of both national marine resources and biodiversity. In addressing concerns for seahorses, countries can do much for marine wildlife in general, particularly if they establish marine protected areas as part of their fisheries and marine management.

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References

Aylesworth, L., Phoonsawat, R., and Vincent, A.C.J. (2017) Effects of indiscriminate fisheries on a group of small data-poor species in Thailand. *ICES Journal of Marine Science* [In press].

CBD (The Convention on Biological Diversity). (2016) Aichi Biodiversity Targets. Available at: https://www.cbd.int/sp/targets Downloaded on 17 August 2017.

Chen, F.P., Chen, T.J., Kung, Y.Y., Chen, Y.C., Chou, L.F., Chen, F.J., and Hwang, S.J. (2007) Use frequency of traditional Chinese medicine in Taiwan. *BMC Health Services Research*, 7:26-36.

Chin, G. (2017) Vietnam seizes nearly 300,000 dead seahorses smuggles from Peru. VN Express International. Available at: http://e.vnexpress.net/news/news/vietnam-seizes-nearly-300-000-dead-seahorses-smuggled-from-peru-3553714.html Downloaded on 20 July 2017.

CITES (2002) The CITES species. Available at: http://www.cites.org/eng/disc/species.php Downloaded on 20 June 2017.

CITES (2014a) Twenty-seventh meeting of the Animals Committee: Review of Significant Trade in specimens of Appendix-II species. Available at: https://cites.org/sites/default/files/eng/com/ac/27/wg/E-AC27-WG-01.pdf Downloaded on: 25 July 2017.

CITES (2014b) Twenty-seventh meeting of the Animals Committee: Implementation of the convention relating to captive-bred and ranched specimens. Available at: https://cites.org/sites/default/files/eng/com/ac/27/E-AC27-17.pdf Downloaded on: 16 Aug 2017.

CITES (2016a) Sixty-sixth meeting of the Standing Committee. Available at: https://cites.org/sites/default/files/eng/com/sc/66/E-SC66-31-01.pdf Downloaded on 08 August 2017.

CITES (2016b) Sixty-seventh meeting of the Standing Committee: Review of significant trade in specimens of appendix-II species: Implementation of recommendations of the animals and plants committees. Available at: https://cites.org/sites/default/files/eng/com/sc/67/E-SC67-15.pdf Downloaded on 15 Aug 2017

CITES (2017a) Review of trade in animal specimens reported as produced in captivity. Available at: https://cites.org/sites/default/files/document/E-Res-17-07.pdf Downloaded on 07 November 2017.

CITES (2017b) Twenty-ninth meeting of the Animals Committee: Captive Breeding. Available at: https://cites.org/sites/default/files/eng/com/ac/29/com/E-AC29-Com-11-R.pdf Downloaded on 07 November 2017.

Cochrane, K.L. (2000) Reconciling sustainability, economic efficiency, and equity in fisheries: the one that got away? *Fish and Fisheries*, 1:3-21.

Cochrane, K.L. (2015) Use and misuse of CITES as a management tool for commercially-exploited aquatic species. *Marine Policy*, 59:16-31.

Dulvy, N., Baum, J., Clarke, S., and Domingo, A. (2008) You can swim but you can't hide: the global status and conservation of ocean pelagic sharks and rays. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 18:459-482.

FAO (2012) The State of World Fisheries and Aquaculture 2012. *FAO*, Rome, Italy, 209 pp.

Foster, S.J., and Vincent, A.C.J. (2005) Sustainability of the international trade in seahorses with a single minimum size limit. *Conservation Biology*, 19:1044-1050.

Foster, S.J., Wiswedel, S., and Vincent, A.C.J. (2014) Opportunities and challenges for analysis of wildlife trade using CITES data-seahorses as a case study. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26: 154-172.

Foster, S.J. (2016) Seahorses (*Hippocampus* spp.) and the CITES Review of Significant Trade. *Fisheries Centre Research Reports*, 24(3):48 pp.

Foster, S.J., and Vincent, A.C.J. (2016) Making non-detriment findings for seahorses-a framework. Version 4.0/ Project Seahorse, Fisheries Centre, The University of British Columbia, Vancouver, Canada.

Giles, B.G., Truong, S.K., Do, H.H., and Vincent, A.C.J. (2006) The catch and trade of seahorse in Vietnam. *Biodiversity and Conservation*, 15:2497-2513.

Gubrium, J. F., and Holstein, J.A. (2002) Handbook of interview research: Context and method, xiii edition. Sage Publications, Thousand Oaks, CA. 981pp.

Hamilton, H., Saarman, N., Short, G., Sellas, A.B., Moore, B., Hoang, T., Grace, C.L., Gomon, M., Crow, K., and Simison, W.B. (2017) Molecular phylogeny and patterns of diversification in syngnathid fishes. *Molecular Phylogenetics and Evolution*, 107:388-403.

Han, S., Kim, J., Kai, Y., and Senou, H. (2017) Seahorses of the *Hippocampus coronatus* complex: taxonomic revision, and description of *Hippocampus haema*, a new species from Korea and Japan (Teleostei, Syngnathidae). *Zookeys*, 712:113-139.

Hutchings, J.A., and Baum, J.K. (2005) Measuring marine fish biodiversity: temporal changes in abundance, life history and demography. *Philosophical Transactions of the Royal Society B*, 360:315-388.

IUCN (2016a) Implementing Appendix II listings for marine fishes: important considerations when making non-detriment findings. Information document for the 17th meeting of the CITES Conference of the Parties. (CoP17 Inf. 52 (Rev. 1)). Available at: https://cites.org/sites/default/files/eng/cop/17/InfDocs/E-CoP17-Inf-52-Rev1.pdf Downloaded on 15 August 2017

IUCN (2016b) Implementation of CITES Appendix II listings for marine fishes. Information document for the 17th meeting of the CITES Conference of the Parties. (CoP17 Inf. 52 (Rev. 1)). Available at: https://cites.org/sites/default/files/eng/cop/17/InfDocs/E-CoP17-Inf-64.pdf Downloaded on 09 August 2017.

IUCN (2016c) Assisting Parties to meet their commitments: CITES review of significant trade for seahorses (*Hippocampus* spp.), a taxon traded in high volumes. Information document for the 17th meeting of the CITES Conference of the Parties (CoP17 Inf. 53 (Rev. 1)). Available at: https://cites.org/sites/default/files/eng/cop/17/InfDocs/E-CoP17-Inf-53-Rev1.pdf Downloaded on 01 August 2017.

IUCN (2017) IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org Downloaded on 12 July 2017.

Kuiter, R.H. (2000) Seahorses, pipefishes and their relatives: a comprehensive guide to Syngnathiformes. TMC Publishing, Chorleywood, England.

Lawson, J.M., Foster, S.J., Lim, A.C.O., Chong, V.C., and Vincent, A.C.J. (2015) Novel life-history data for threatened seahorses provide insight into fishery effects. *Journal of Fish Biology*, 86:1-15.

Lawson, J.M., Fordham, S.V., O'Malley, M.P., Davidson, L.N.K., Walls, R.H.L., Heupel, M.R., Stevens, G., Fernando, D., Budziak, A., Simpfendorfer, C.A., Ender, I., Francis, M.P., Notarbartolo di Sciara, G., and Dulvy, N.K. (2017) Sympathy for the devil: a conservation strategy for devil and manta rays. *PeerJ*, 5:e3027 https://doi.org/10.7717/peerj.3027

Lourie, S.A., Vincent, A.C.J., and Hall, H.J. (1999) Seahorses: an identification guide to the world's species and their conservation. Project Seahorse, London, UK.

Lourie, S.A., Foster, S.J., Cooper, E.W., and Vincent, A.C.J. (2004) A guide to the identification of seahorses. Washington, DC: The University of British Columbia and World Wildlife Fund.

Lourie, S.A., Pollom, R.A., and Foster, S.J. (2016) A global revision of the Seahorses *Hippocampus* Rafinesque 1810 (Actinopterygii: Syngnathiformes): Taxonomy and biogeography with recommendations for further research. *Zootaxa*, 4146(1):001-066.

Ludwig, D., Hilborn, R., and Walters, C. (1993) Uncertainty, resource exploitation, and conservation: lessons from history. *Ecological Applications*, 3(4):547-549.

Lyons, J.A., and Natusch, D.J.D. (2011) Wildlife laundering through breeding farms: illegal harvest, population declines and a means of regulating the trade of green pythons (*Morelia viridis*) from Indonesia. *Biological Conservation*, 144(12):3073-3081.

Mason, C.F., Butle, E. H., and Horan, R.D. (2012) Banking on extinction: endangered species and speculation. *Oxford Review of Economic Policy*, 28(1):180-192.

McPherson, J.M., and Vincent, A.C.J. (2004) Assessing east African trade in seahorse species as a basis for conservation under international controls. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 14:521-538.

Meeuwig, J.J., Hoang, D.H., Ky, T.S., Job, S.D., and Vincent, A.C.J. (2006) Quantifying non-target seahorse fisheries in central Vietnam. *Fisheries Research*, 81(2-3):149-157.

Meyers, R.F. (1991) Micronesian reef fishes. Second Ed. Coral Graphics, Barrigada, Guam. 298p.
Mitchell, R.B. (2003) International environmental agreements: a survey of their features, formations, and effects. *Annual Review of Environment and Resources*, 28:429-461.

Perry, A. L., Lunn, K.E., and Vincent, A.C.J. (2010) Fisheries, large-scale trade, and conservation of seahorses in Malaysia and Thailand. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 20:464-475.

Project Seahorse (2015) Report to Viet Nam's CITES Authorities on joint activities in support of implementing CITES for seahorses. Annex A: Agreed plan of action following "Building Viet Nam's capacity to under-take Non-Detriment Findings for seahorses", May 29-31, 2013. Available at: http://www.projectseahorse.org/ndf-vietnam Downloaded on 10 June 2017.

Project Seahorse (2017) Implementing CITES for seahorses in Viet Nam: A consultative meeting, 5 April 2017, Hai Phong, Viet Nam. Available at: http://www.projectseahorse.org/ndf-vietnam Downloaded on 01 August 2017.

Randall, J.E. (1995) Coastal Fishes of Oman. University of Hawaii Press, Honolulu, Hawaii, 439pp.

Rosa, I.L., Oliveira, T.P.R., Osorio, F.M., Moraes, L.E., Castro, A.L.C., Barros, G.M.L., and Alves, R.R.N. (2011) Fisheries and trade of seahorses in Brazil: historical perspective, current trends and future directions. *Biodiversity and Conservation*, 20(9):1951-1971.

Schneider, C.A., Rasband, W.S., and Eliceiri, K.W. (2012) NIH image to ImageJ: 25 years of image analysis. *Nature Methods*, 9:671-675.

Shihata, I.F.I. (1997) Corruption: a general review with an emphasis on the role of the world bank. *Journal of Financial Crime*, 5(1):12-29.

Stocks, A., Foster, S.J., Bat, N.K., and Vincent, A.C.J. (2017) Catch as catch can: targeted and indiscriminate small-scale fishing of seahorses in Vietnam. *Fisheries Research*, 196:27-33.

Vincent, A.C.J. (1996) The international trade in seahorses. Traffic International, Cambridge, UK. vii+163pp.

Vincent, A.C.J., and Hall, H.J. (1996) The threatened status of marine fishes. *Trends in Ecology and Evolution*, 11(8):360-361.

Vincent, A.C.J., Sadovy de Mitcheson, Y.J., Fowler, S.L., and Lieberman, S. (*2014)* The role of CITES in the conservation of marine fishes subjected to international trade. *Fish and Fisheries*, 15(4):563-592.

Vincent, A.C.J., and Foster, S.J. (2017) Setting precedent in export regulations for marine fishes with seahorses. *Fisheries*, 42(1):40-43.

UNEP-WCWC (2010) A guide to using the CITES trade database. Version 7: 1-21.

UNEP-WCWC (2017) CITES Trade Database. Available at: http://trade.cites.org/ Downloaded on 06 January 2017.

Ut, V.N., and Tam, T.C. (2012) Species composition and fishing status of seahorse (*Hippocampus* spp.) in Phu Quoc Island, Vietnam. Proceedings of International Conference on Bien Don 2012.

Zhang, Y.H., Qin, G., and Lin, Q. (2016) A new species of seahorse (Teleostei: Syngnathidae) from the South China Sea. *Zootaxa*, 4170(2):384-392.