Enhancing Sustainability of the International Trade in Seahorses with a Single Minimum Size Limit

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Abstract: *Management tools are needed to help regulate the international trade in seahorses (*Hippocampus *spp.) under the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora. Given the limited understanding of seahorse population dynamics and fishing mortality, a single minimum size limit for all seahorse species appears to be a useful initial step toward adaptive management, both biologically and socially. We collected data on maximum height and size at first maturity for 32 seahorse species and cross-validated the data with results from an analysis across marine teleosts. A minimum height restriction of 10 cm would permit, based on calculated data, reproduction in 15 species before they recruited to the fishery. Of the remaining 17 species, 16 were essentially not in international trade, were safeguarded under domestic legislation, or were partly protected by this size limit. Only one species,* H. kelloggi*, was not well served by the 10-cm minimum size limit. The CITES technical committee on animals has now decided to propose this single size limit to all 167 signatory nations as one option toward sustainable trade. Complementary management measures for seahorses are also required, particularly for populations primarily exploited in bycatch.*

Key Words: adaptive management, CITES, exploitation, fisheries, *Hippocampus*, syngnathid

Incremento de la Sustentabilidad del Comercio Internacional de Caballitos de Mar con un Límite de Talla Mínima Único

Resumen: *Se requieren herramientas de gestión para ayudar a la regulación del comercio internacional de caballitos de mar (*Hippocampus *spp.) bajo la Convención Internacional en Comercio de Especies de Fauna y Flora Silvestres en Peligro (CITES). Dado el conocimiento limitado de la dinámica poblacional y la mortalidad por la pesca de caballitos de mar, un límite de talla mínima único parece ser un paso inicial útil hacia el manejo adaptativo, tanto biológica y socialmente. Recolectamos datos sobre la altura y talla máximas a la primera madurez de 32 especies de caballitos de mar y los convalidamos con resultados de un análisis de teleósteos marinos. Con base en los datos calculados, la restricción de altura mínima a 10 cm permitiría la reproducción en 15 especies antes de ser reclutados por la pesquería. De las 17 especies restantes, 16 estaban esencialmente fuera del comercio internacional, o estaban protegidas por legislación doméstica o estaban parcialmente protegidas por este límite de talla. Solo una especie,* H. kelloggi*, no fue favorecida por el límite de talla mínima de 10 cm. El comité técnico para animales de CITES ha decidido proponer este límite de talla mínima a las 167 naciones firmantes como una opción de comercio sustentable. También se requieren medidas complementarias para la gestión de caballitos de mar, particularmente para poblaciones explotadas primariamente por la captura incidental.*

Palabras Clave: CITES, explotación, *Hippocampus*, límite de talla, manejo adaptativo, signátido

Introduction

The Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora recently began regulating export of some marine fishes of commercial importance. Animals and plants are added to one of the CITES Appendices when there is concern that their wild populations are, or might become, threatened by

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international trade (Wijnstekers 2001). If necessary listings were effectively implemented for marine fish species, CITES could help achieve sustainable marine fisheries. Many countries and agencies have, however, expressed anxiety about CITES involvement with marine fishes, arguing that the United Nations Food and Agriculture Organization (FAO) is in a better position to manage fisheries, despite the latter's lack of enforcement capacity and its willingness to work with CITES on such matters (FAO 2000). Identifying pragmatic means of managing international fish exports for sustainability should help CITES enhance its credibility with respect to marine fish listings.

Seahorses (*Hippocampus* spp.) were among the first marine fish species of commercial importance to be listed on CITES, along with the basking shark (*Cetorhinus maximus*) and whale shark (*Rhincodon typus*) (CITES 2003). All known species of seahorses were added to CITES Appendix II in 2002 (CITES 2003), and the listing became effective in May 2004. Continuing international trade must be regulated to ensure that it does not damage wild populations of the species listed under CITES. Seahorses currently represent one of the largest volume trade issues under CITES (T. De Meulenaer, personal communication). Implementation of the seahorse listing will be a challenge to CITES that must be met if pressures on seahorse populations are to be reduced.

Seahorses are threatened by direct exploitation, accidental capture (bycatch), and habitat degradation (Vincent 1996). Some of the world's poorest fishers make their living by targeting seahorses (Vincent 1996). Bycatch from trawlers, however, appears to be the largest source of seahorses in international trade (Vincent 1996; Baum et al. 2003). Most exploited seahorses are exported either dried for traditional medicines, tonic foods, and curiosities, or live for ornamental display. Traditional Chinese medicine and its derivatives account for the largest consumption of seahorses, with the global trade exceeding 20 million dried seahorses annually. Capture for the live aquarium trade is the main pressure in certain regions (Vincent 1996).

International trade appears to have depleted wild seahorse populations. A combination of official records, quantitative research, and qualitative information indicates that many seahorse catches diminished markedly, even when effort increased: estimated catch declines of between 15 and 50% over 5-year periods were common in the 1990s (Vincent 1996). Results of detailed studies of *H. comes* in the central Philippines show evidence of both recruitment and growth overfishing (Martin-Smith et al. 2004). The 2003 World Conservation Union (IUCN) Red List recognized one seahorse species as Endangered, nine as Vulnerable, and all other species as Data Deficient, denoting the need for more research (IUCN 2003). Domestic conservation assessments and trade regulations in many countries also acknowledged threats to seahorse populations (Lourie et al. 1999; Lourie et al. 2004).

Under the new Appendix II listing, CITES Parties wishing to export seahorses are formally required to ensure that such international trade is not detrimental to their wild populations. Before guaranteeing the sustainability of its exports—known as making a "non-detriment finding"—a Party has to overcome two challenges: (1) uncertainties about trade levels, population status, and management options and (2) taxonomic problems that make the mandatory species-level assessments and trade monitoring difficult. Yet, failure to declare the sustainability of its exports appropriately can lead CITES to propose an evaluation of a Party's trade (called a Significant Trade Review) and, eventually, to suspend the Party's right to trade (e.g., queen conch [*Strombus gigas*]; CITES 1999). In the absence of full information, therefore, nations will have to use general conservation and management paradigms to decide on permissible exports.

We explored the potential for a single minimum size limit for all exported seahorses as an early move toward sustainable international trade. Consultation with many groups involved in seahorse trade established that most of them favored minimum size limits as one means of regulating seahorse fisheries (Martin-Smith et al. 2004). After further scientific input, CITES Parties directed the CITES technical committee on animals to identify a single minimum size limit for all seahorses in international trade, hoping thereby to reduce both overfishing and taxonomic difficulties. We present the scientific information that prompted CITES to make its decision.

Methods

Difficulties with identifying seahorses and the large number of names (>120) used in the earlier literature (see Lourie et al. [1999] for synonyms) mean that seahorse nomenclature is often unreliable. We used the 33 species described in Lourie et al. (2004) partly because of difficulties in finding distinguishing characters for some proposed species (e.g., Kuiter 2000, 2001).

In collecting and collating data on seahorse size (Table 1; Foster & Vincent 2004), we found that height or standard length were the most commonly cited measures. Height was measured from the top of the coronet to the tip of the straightened tail, and standard length was measured as head + trunk + tail length (Lourie et al. 1999). We used metric conversions provided by researchers to standardize measurements to height.

We identified reproductive maturity as the smallest size at which a male had a fully developed brood pouch (e.g., Baum et al. 2003), even though this may not always represent physiological capacity to breed (e.g., Cai et al. 1984).

Table 1. Maximum recorded adult height (Ht_{max}) and height at first maturity (Ht_{mat}) for seahorses (*Hippocampus* spp.).[a, b]

Species	Ht_{max} *(cm)*	*Reference*	Ht_{mat} *(cm)*	*Reference*
H. abdominalis (Lesson 1827)	35.0	Francis 1988	8.7	C. Woods, unpublished
H. algiricus (Kaup 1856)[c]	19.2	Lourie et al. 1999	9.0	Lourie et al. 1999
H. angustus (Günther 1870)[c]	16.0	Kuiter 2000	7.8	Lourie et al. 1999
H. barbouri (Jordan & Richardson 1908)	15.0	Perez-Oconer 2002	8.0	Perez-Oconer 2002
H. bargibanti (Whitley 1970)	2.4	Gomon 1997	1.3	Whitley 1964
H. borboniensis (Duméril 1870)[c]	14.0	Lourie et al. 1999	8.0	Lourie et al. 1999
H. breviceps (Peters 1869)	10.0	Kuiter 2000	4.6	Moreau & Vincent 2004
H. camelopardalis (Bianconi 1854)[c]	10.0	Lourie et al. 1999	6.5	Lourie et al. 1999
H. capensis (Boulenger 1900)	12.1	Lockyear et al. 1997	5.1	Whitfield 1995
H. comes (Cantor 1850)	18.7	J.J. Meeuwig, unpublished	8.1	Perante et al. 1998
H. coronatus (Temmick & Schlegel 1850)[c]	12.7	Kaup 1856	6.0	Lourie et al. 1999
H. denise (Lourie & Randall 2003)[c]	2.1	Lourie & Randall 2003	1.1	Lourie & Randall 2003
H. erectus (Perry 1810)	19.0	Lourie et al. 1999	5.6	Baum et al. 2003
H. fisheri (Jordan & Evermann 1903)[c]	8.0	Lourie et al. 1999	5.0	Lourie et al. 1999
H. fuscus (Rüppell 1838)[c]	14.4	Golani & Fine 2002	8.0	Lourie et al. 1999
H. guttulatus (Cuvier 1829)	18.0	Lourie et al. 1999	9.9	J. Curtis, unpublished
H. hippocampus (Linnaeus 1758)	15.0	N. Garrick-Maidment, unpublished	7.7	J. Curtis, unpublished
H. histrix (Kaup 1856)[c]	17.0	Masuda et al. 1984	7.9	Lourie et al. 1999
H. ingens (Girard 1859)	31.0	Miller & Lea 1972	5.4	Groves & Lavenberg 1997
H. jayakari (Boulenger 1900)[c]	14.0	Kuiter 2000	11.0	Lourie et al. 1999
H. kelloggi (Jordan & Snyder 1902)[c]	28.0	Kuiter 2000	15.0	Lourie et al. 1999
H. kuda (Bleeker 1852)	17.0	Lourie et al. 1999	14.0	Jiaxin 1990
H. lichtensteinii (Kaup 1856)[c]	4.0	Lourie et al. 1999	3.0	Lourie et al. 1999
H. minotaur (Gomon 1997)	5.0	Lourie et al. 1999	-	
H. mohnikei (Bleeker 1854)	8.0	Lourie et al. 1999	5.5	Jiaxin 1990
H. reidi (Ginsburg 1933	17.5	Lourie et al. 1999	8.0	Vari 1982
H. sindonis (Jordan & Snyder 1902)[c]	8.0	Lourie et al. 1999	4.0	Lourie et al. 1999
H. spinosissimus (Weber 1913)	17.2	Nguyen & Do 1996	10.4	Nguyen & Do 1996
H. subelongatus (Castelnau 1873)[c]	20.0	Lourie et al. 1999	13.0	Lourie et al. 1999
H. trimaculatus (Leach 1814)	17.0	Masuda et al. 1984	14.0	Jiaxin 1990
H. whitei (Bleeker 1855)[c]	13.0	Lourie et al. 1999	6.0	Lourie et al. 1999
H. zebra (Whitley 1964)[c]	9.4	Whitley 1964	7.0	Lourie et al. 1999
H. zosterae (Jordan & Gilbert 1882)	2.5	Lourie et al. 1999	2.0	Lourie et al. 1999

[a] *The Ht_{mat} is the largest value recorded for that species (which may itself have been a mean within the particular source study).*
[b] *Table reprinted with permission from Foster and Vincent (2004),* Journal of Fish Biology, *Blackwell Publishing.*
[c] *Species for which the smallest recorded adult height was used as an estimate because no records of Ht_{mat} could be found.*

The alternative, using the size of the smallest recorded pregnant male (e.g., Nguyen & Do 1996), would have meant ignoring a male's capacity to reproduce even before he necessarily finds a mate. We would have preferred to use the size at which 50% of the animals have developed ripe gonads, as calculated for other teleosts (Froese & Pauly 2004), but such data were not available. Indeed, a dearth of sex-specific lengths at first maturity forced us to assume that both sexes matured at the same size. If more than one estimate of height at first maturity was available, we used the largest of these estimates (i.e., the most conservative). We validated our height at maturity estimates from primary sources by comparing these measurements against the length at maturity parameters derived for other marine teleosts ≤ 35 cm in size (Froese & Pauly 2004).

We gathered information on seahorse species in trade from extensive global trade surveys conducted between 1993 and 2003 (Vincent 1996; McPherson & Vincent 2004; A. C. J. V. & A. Perry, unpublished) and from an e-mail survey of professional aquarists with a particular interest in seahorses.

Results

Deriving the Size Limit

Seahorses had the same relationship between size at first maturity and maximum size as other marine teleosts (Foster & Vincent 2004). Combined data on marine teleosts ≤ 35 cm and seahorses revealed an overall significant positive linear relationship between $\log_e$ size at maturity (L_{mat}) and $\log_e$ maximum size (L_{max}) (t test: slope = 0.84 ± 0.05, $n = 107$, $p < 0.001$) and no evidence of difference in slopes between seahorses and other marine teleosts ($L_{max} \times$ group interaction: F test: $F = 0.30_{1,106}$, $p = 0.583$). Seahorses differed significantly from other marine teleosts in L_{mat}, controlling for L_{max} (F test: $F = 7.49_{1,106}$, $p = 0.007$); addition of group (seahorse or marine teleost), however, explained no additional variation in the data set (r^2 with group = 0.74, without group = 0.74). We could, therefore, use relationships among other teleosts to predict length at first maturity for seahorse species without adequate data.

Seahorse heights at first maturity were calculated using the regression between size at first maturity and maximum size: $\log_e(L_{mat}, \text{centimeter}) = 0.84 \times \log_e(L_{max}, \text{centimeter}) - 0.13$ ($r^2 = 0.72$). These were similar to estimates of heights at maturity derived from available ex situ and in situ research on seahorses (Fig. 1).

Based on these two sets of analyses, a minimum height of 10 cm would lie slightly above the largest currently inferred size at first maturity for most species but well below the maximum height of most species (Fig. 1). Such a size limit (easy to remember and measure) would work well for 15 species, allowing them to reproduce before recruiting to the fishery, and allowing continued trade.

This 10-cm size limit was also applicable to a further 10 species that do not reach this height as adults and thus would not recruit to the fishery (Fig. 1). International trade in these species would be eliminated unless Parties regulated trade in other ways, but only four such species are currently traded (*H. breviceps*, *H. camelopardalis*, *H. fisheri*, and *H. zosterae*), primarily in small volumes for aquarium display. Of these four, the limited trade in *H. breviceps* primarily involved captive-bred specimens, which would not be subject to the same restrictions as specimens from wild populations (CITES 2004). A second species, *H. fisheri*, was only traded domestically and so would not be subject to management under CITES. The remaining two species, *H. camelopardalis* and *H. zosterae*, enter international trade only in very small numbers (McPherson & Vincent 2004; P. LaFrance and A.C.J.V., unpublished), with the latter traded primarily in the domestic U.S. market.

The same 10-cm size limit would provide partial protection for six of the seven species that may reach maturity at heights > 10 cm and therefore would enter the fishery too early: *H. abdominalis*, *H. ingens*, *H. jayakari*, *H. kelloggi*, *H. kuda*, *H. subelongatus*, and *H. trimaculatus* (Fig. 1). Of these species *H. jayakari* and *H. subelongatus*

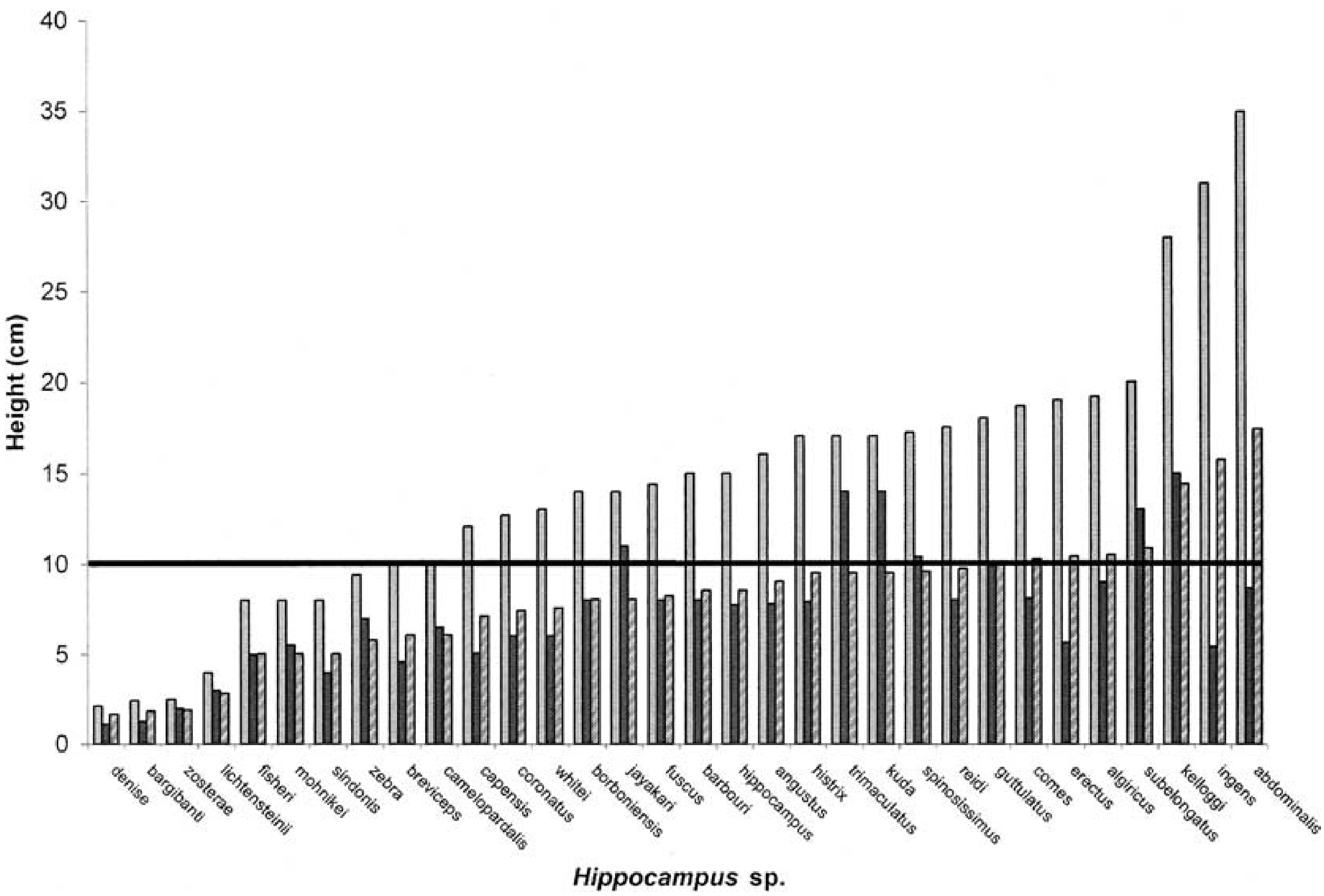

Figure 1. Maximum recorded height (gray bars), height at maturity obtained from literature (black bars), and calculated height at maturity (striped bars) for 32 of 33 seahorse species (no data available for Hippocampus minotaur, *with height of < 5 cm). The horizontal line indicates the suggested size limit of 10 cm for the trade in wild seahorses.*

were not found in international trade, and at least parts of populations of *H. abdominalis*, *H. ingens*, *H. kuda*, and *H. trimaculatus* matured at < 10 cm and thus would be afforded some protection. Australia's tight domestic controls on exploitation of *H. abdominalis* (endemic to Australia and New Zealand) and *H. subelongatus* (endemic to Australia) afforded these species protection beyond what CITES could offer. The species *H. kelloggi* would not be well served by the proposed 10-cm minimum size limit and would need other forms of management to ensure persistence of its populations.

Discussion

A single minimum size limit of 10 cm in height appears to offer a useful first approach toward securing a sustainable international trade for most seahorse species. The single limit can be applied to both the dried and live seahorse trades, should be relatively easy to enforce because the idea is already accepted by stakeholders, and will eliminate need for complicated species identification by enforcement officers. New knowledge will permit future modification of this size limit in an adaptive management context. The limit was determined using biological data that are available or can be calculated for most fish species.

The risk of minimum size limits leading to increasing fishing pressure on larger individuals or larger species (thus selecting for smaller fish that mature at smaller sizes; Sutherland 1990) is currently minimal in exploited seahorses. Fishers already take most seahorses they encounter, with particular preference for the larger animals, which fetch higher prices in traditional medicine (Vincent 1996). Individual fecundity is indeed positively correlated with adult size in several seahorse species (e.g., Nguyen & Do 1996; Teixeira & Musick 2001), but a maximum size limit is not tenable with stakeholders (Martin-Smith et al. 2004). For the moment, then, management measures that reduce catch in smaller seahorses, though not necessarily ideal, should be helpful in reducing overall exploitation while enhancing the pool of reproductively active individuals.

A single size limit should be relatively easy for a CITES Party to implement because it applies to all seahorses. It has been argued that well-established practices such as minimum size limits are impracticable in multispecies fisheries (Munro 1996), and research has shown that it is difficult to implement size limits where they differ across regions or species (Hill 1990). Our results suggest that a pragmatic approach, however, can render one such size limit tractable and useful (although not ideal) across species, populations, and sexes. A single size limit also precludes the need for complicated species identification by customs officers, particularly if most or all CITES Parties choose to adopt this regulation.

As a regulatory approach, minimum size limits appear to have the advantage of being easily understood and accepted by stakeholders (Kearney 1990). The ultimate effectiveness of any management measure depends on compliance and ease of implementation (Bohnsack 2000). During our consultations, six different sets of stakeholders (from Philippines fishers to Hong Kong traditional Chinese medicine traders to North American aquarium professionals) agreed that setting a minimum permissible height for seahorses in trade would be a both biologically appropriate and socially acceptable management tool (Martin-Smith et al. 2004). Their concerns about potential loss of income resulting from either maximum size limits alone or combined minimum and maximum size limits (slot sizes) would make implementation of such management measures difficult.

Application of This Research

The biological and socioeconomic arguments we advance have already produced a formal recommendation for the first broad size limit for marine fishes in international trade. The CITES technical committee on animals decided in 2004 to offer the 167 CITES Parties the option of setting a single minimum size limit of 10 cm for internationally exported seahorses (CITES 2004). Parties are also free to use other means of declaring their exports sustainable, but many are likely to accept the minimum size limit recommendation until they develop a greater understanding of their seahorse populations, fisheries, and trades.

Monitoring will be needed to assess the impact of the minimum size limit on seahorse populations, fisheries, and trades, particularly where these are associated with exports; CITES is not directly concerned with domestic markets. Although the size distribution of species in most existing fisheries is poorly understood, catch calendar data for the *H. comes* fisheries in the central Philippines suggest that 22% of all seahorses caught during 2002–2004 were $\leq$ 10 cm in height (D. McCorry et al., unpublished). In this particular fishery, higher prices per seahorse mean most of the larger animals go to the dried trade, leaving the live trade more vulnerable to the minimum size limit, perhaps to the extent that higher prices will be paid for larger animals.

CITES recognized that a single minimum size limit, although useful as an early component of an adaptive management plan, is unlikely per se to secure persistence of wild populations; complementary or replacement measures will be needed as knowledge improves. In particular, size limits alone will not preclude capture or retention (or damage or displacement) of smaller seahorses as bycatch (Hill 1990). Spatial management of nonselective gear may help reduce catch of smaller seahorses where they segregate spatially by size, sex, or reproductive status (e.g., Dauwe 1992; Perante et al. 1998; Baum et al. 2003), but nonselective extraction of seahorses will probably be best managed by spatial and temporal closures.

As a possible supplement to size limits, all stakeholder groups consulted on seahorses embraced no-take marine protected areas as a preferred management option (Martin-Smith et al. 2004). In particular, a CITES technical workshop on managing seahorse fisheries in 2004 noted that a CITES Party might justify initial declarations for sustainability of seahorse exports if a considerable portion of its range is protected from nonselective fishing gear and other forms of habitat damage (Bruckner et al., in press). At the very least, the existence of restrictions on international trade in smaller seahorses should help emphasize the nonselective nature of many fisheries, particularly shrimp trawling, and should add to pressures to reduce the waste therein.

Attention must still be paid to measurement techniques and trade of processed seahorses. CITES recognized that difficulties associated with measuring a seahorse's curled tail dictated the need to undertake research to develop a proxy for the height metric, perhaps using the easily measured distance from coronet to the top of the tail. As well, the increasing sale of seahorse compounds in pre-packaged traditional medicines (Vincent 1996) could pose problems for implementing a single size limit. Because export of powdered seahorses would pose yet greater regulatory problems, Parties may insist on retaining the current practice of seahorses being exported whole, especially because processing is undertaken after import (where the many ingredients in each prescription can all be accessed).

Conclusions

Despite the valid queries and concerns raised by the proposed minimum size limit for seahorses, it should offer some (incomplete) respite from fishing pressure while further research is conducted and adaptive management measures are agreed on. Certainly, the conservation impacts of size restrictions will be better evaluated with a greater understanding of seahorse life history, population dynamics, and selectivity of fishing with respect to size and sex. Any changes in size limits would then need to be adjusted at a pace that reduced short-term costs to fishers, if they were to be respected (Bohnsack 2000).

Our recommendation for a single minimum size limit across many closely related species has precedents. In the finfish fishery on Australia's Great Barrier Reef, a single minimum size limit is applied to most coral trout (*Plectropomus* spp., 38 cm), emperors (lethrinids, 25 cm), and snappers (lutjanids, 25 cm) (QFMA 1999). A single minimum size limit has been set for five species of parrot fish (sparids) in Hawaii (Department of Land and Natural Resources State of Hawaii 2002). Minimum size limits have also previously been set in international trade for imports of Atlantic swordfish (*Xiphias gladius*) into the United States (U.S. Department of Commerce 1998) and for all reef fish imports (from within the United States or internationally) into Florida (Florida Fish and Wildlife Conservation 2002). The lack of available evaluations of these measures makes it all the more important that resources be found to assess the impact of the seahorse minimum size limit.

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