Fisheries Management Options For Seahorses

Keith Martin-Smith
Project Seahorse
Keith.MartinSmith@utas.edu.au

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Executive Summary

This document presents approaches to managing syngnathid fisheries that might be alternatives to, or compatible with, trade controls. Eleven management options were identified by biologists and presented to stakeholder groups involved with an artisanal seahorse fishery in the central Philippines. These consisted of five input controls (number of fishers, gear restriction, temporal closures, spatial closures, and tenurial systems) and six output controls (total allowable catch, minimum, maximum, and slot size limits, sex-selective fishing and caging pregnant males). Feedback from fishery experts, fishers, resource managers, aquarium and traditional medicine groups was obtained. The degree of preference for each of the options from the different stakeholder groups was used to identify management options that had broad support. Highly favoured options from all groups were spatial closures (no-take Marine Protected Areas) and minimum size limits. Tenure over marine estate and temporal closures were also generally supported but may be difficult to implement whilst sex-selective fishing (leaving pregnant males) had moderate support but may be easy to introduce.. All the options are discussed in detail with examples from work on other species. Finally, we consider the functional equivalence of these management options to trade controls, and their application to other syngnathid fisheries. This consultative exercise will be continued, including thorough discussion at the CITES workshop.

Introduction

Purpose of this Document

This document has been prepared by Project Seahorse for a technical workshop convened by the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to be held in Cebu, Philippines from 27-29 May 2002. The purpose of the workshop is to examine what action CITES might best take to advance conservation of syngnathids (seahorses, pipefishes and their relatives), including possible implementation of trade controls. This document present a range of management options for one particular seahorse fishery, developed by Project Seahorse in conjunction with stakeholder groups. These management options are neither comprehensive in themselves, nor incompatible with certain possible CITES trade controls.

Detailed consideration is given to outcomes of the consultative process for this focal fishery from the Philippines. Such dialogue reveals needs for information and for stakeholder involvement, both considered essential if management objectives are to be achieved successfully. A synthesis of stakeholder feedback is presented and conclusions for this particular fishery are drawn. Finally, the application of the management options to other syngnathid fisheries is considered.

It should be emphasised that the trade controls (under CITES Appendix listings) and the potential management options outlined here would probably operate in fundamentally different ways. CITES trade controls are essentially a 'top-down' form of management wherein regulation is primarily at an international level, enforced by national authorities. The potential management options are primarily designed as 'bottom-up' regulation, although they could benefit from associated national legislation. This means that the responsibility for compliance or enforcement lies primarily with the stakeholders: fishers or traders.

Definition of Terms and Abbreviations

Artisanal fisheries – Low-technology, low-capital fisheries that catch organisms primarily for subsistence use.

Bycatch – Non-target organisms that are caught by fishing gears with low selectivity. These may be discarded or retained.

CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora

Input controls – Restrictions on fishing effort.

Output controls – Restrictions on fish that can be retained by the fishery.

Syngnathids – Fishes belonging to the family Syngnathidae. These include seahorses, pipefishes, sea dragons and pipehorses.

Syngnathid Fisheries and World Trade

Syngnathids are widely distributed in temperate and tropical waters, although their diversity is greatest in tropical areas (see Briefing Document on Seahorse Biology for more details). They are caught both in target fisheries and as bycatch in a large proportion of their range. Syngnathids that are caught and retained are part of global trades in fish for non-food purposes, including fishmeal production (FAO, 2000; Bimbo, 2000), ornamental display (Green and Shirley, 1999; Wood, 2001), traditional medicines and curios (Wood and Wells, 1988; 1995). Dead syngnathids are traded for use as marine medicinals and curios while live syngnathids are traded as marine ornamental aquarium fishes (Vincent, 1990; see Briefing Document on Syngnathid Trade).

Current Management Arrangements

Generally, management of syngnathid fisheries around the world is not well developed. The majority of syngnathids in trade come from developing countries in the tropical Indo-Pacific where even the food fisheries are not strongly managed. Furthermore, much of the catch is from artisanal, multi-species fisheries and bycatch, both of which are extremely difficult to manage. The most-developed management arrangements in 2002 are probably in Australia.

Export of syngnathids from Australia is only permitted from fisheries operating under an approved management plan. However, the vast majority of syngnathids exported from Australia are bycatch from the Queensland east coast trawl fishery and there is controversy over the effectiveness of current arrangements to ensure sustainability of bycatch species (Imogen Zethoven, WorldWide Fund for Nature, in litt. 13 Dec 2001). For most other countries syngnathid fisheries are effectively unmanaged in any direct way. Syngnathids may, however, benefit from general policies that establish marine protected areas and/or control certain gear (e.g. trawling) in particular times and places (see Briefing Document on Syngnathid Trade).

Consultative Process On Managing A Seahorse Fishery In The Central Philippines

The Fishery

The seahorse fishery in the central Philippines has been studied intermittently by researchers from Project Seahorse and the Haribon Foundation since 1995, with a focus on catch characteristics and socio-economic importance (see Briefing Document on the Philippines Seahorse Fishery). All seahorse species are sought but the vast majority of the catch (over 90%, Perante *et al.,* 2002) is the tiger-tail seahorse, *Hippocampus comes*, the biology of which is summarized in Table 1.

The Management Challenge

The challenge of managing syngnathids is representative of fisheries issues globally, as we struggle to secure the long term future of fish populations in general. New forms of collaborative management are becoming essential as fisheries resources decline around the world (Watson and Pauly, 2001), with documented failures in sustainable utilization, economic efficiency and equity in access to resources (Botsford *et al.,* 1997; Cochrane, 2000). For marine capture fisheries, half of the world's stocks are considered to be fully exploited, a further 15-18% overexploited and 10% depleted or recovering from depletion (FAO, 2002). Overfishing is considered to be one of the three most significant threats to coral reef ecosystems (Roberts, 1995).

Management and conservation of resources in artisanal fisheries remain an enormous challenge, especially given the dearth of livelihood alternatives to fishing (for food and/or income) and of data with which to formulate management decisions (Jennings and Polunin, 1997, Johannes, 1998b, Mosquera *et al.,* 2000). Yet, faced with declines in resources and threats to species or populations, management measures have to be instituted. A further challenge is that many of the fisheries catch a wide range of species and are spatially dispersed (Pauly, 1997). In such circumstances, focal species often have to be used for conservation and management purposes as it is impractical to collect data for all species or to attempt to manage the ecosystem (Zacharias and Roff, 2001). Co-management, wherein stakeholders have a large involvement in decisions affecting the fishery, is increasingly considered to be essential to successful management of fisheries (Katon *et al.,* 1999; Westmacott, 2002). Cochrane (2000) urges that "*responsible management requires setting unambiguous objectives in co-operation with users and other interest groups*".

For this seahorse fishery the following management objectives were considered very important:

1. Increases in populations of seahorses;
2. Long-term sustainability of populations of seahorses (i.e. low probability of extinction);
3. Maintenance or increase in catch-per-unit-effort of seahorses;
4. Maintenance or increase in income for seahorse fishers.

Developing management options

Most information reported here comes from Project Seahorse consultative research, undertaken during 2001 and 2002 (Martin-Smith *et al.,* in review). We have explored management options for the *H. comes* fishery with six groups of stakeholders (Figure 1).

These stakeholder groups were as follows:

1. **Fisheries Technical Workshop.** Summaries of available information were presented at a scoping workshop comprising 13 scientists with a wide range of experience in fisheries modeling, fisheries management and socio-economic analysis. This group developed a list of possible management options, and ranked them qualitatively for their inferred overall utility (Table 2). The first ten of these options are employed in other fisheries, but the 11th is distinct to seahorses. Project Seahorse then presented the same options to other stakeholder groups, adjusting the language and format to be appropriate for each.

2. **Seahorse fishers in the Philippines.** Forty-six subsistence fishers from 18 villages were interviewed over a two day period in various groups about their suggestions for management options with no prior knowledge of the work of the biologists in (1). Over 70% of responses were for options suggested by the biologists, so fishers were then asked to indicate and explain their level of support for each of these options (Table 2).

3. **Syngnathid policy group in the Philippines.** A new management unit (Syngnathid Technical Working Group) comprising thirteen people from the Philippines Bureau of Fisheries and Aquatic Resources, three universities, the South East Asian Fisheries Development Center, the National Museum of the Philippines and the Project Seahorse/Haribon Foundation conservation team was presented with the options devised by the biologists in (1) and similarly asked to indicate and explain their level of support.

4. **Aquarium professionals in the USA.** Forty-eight participants at the Regional Aquarium Workshop of the American Zoo and Aquarium Association were presented with a reduced list of six management options applicable to acquisition of aquarium specimens and asked to indicate and explain their level of support.

5. **Traditional Chinese medicine community in Hong Kong.** Fifty questionnaires were distributed to members of a TCM trade association with detailed questions on a reduced list of management options that would impact on syngnathid trade. Additional informal discussions were held on minimum and maximum size limits.

6. **CITES technical workshop.** Thirty-six participants from a diverse range of backgrounds were involved in this workshop. Management options were considered in detail by a subset of 12 participants who reported back to a plenary session. Qualitative assessment of preferences was assigned from rapporteur notes.

Table 1: Preliminary summary of the biology of *Hippocampus comes*

Distribution	Central Philippines, Singapore, Vietnam, Malaysia
Maximum Recorded Size	205 mm standard length (SL); 21 g weight
Standard Length-height conversion	Standard length (mm) = 1.16 * Height (mm) + 1.2
Sexual dimorphism	Mature males with brood pouch; males have greater exponent in length/weight relationship
Habitat	Coral reefs, soft corals and sponges, seagrasses, soft sediments, Sargassum, mangroves??
Depth range	0 to >20 m
Estimated size at first reproduction	102 mm SL
Reproductive system	Male incubates brood, monogamous pair bonds, breeding year round with peaks in Sep-Oct, Dec-Feb in Philippines
Broodsize	Mean = 489 (range 223-758)
Gestation period	14-21 days
Estimated parameters of von Bertalanffy growth equation	L_{inf} = 26 cm k = 0.89 yr^{-1}
Estimated longevity	2.7-3.6 years
Estimated generation time	1.0-1.2 years
Estimated natural mortality	0.8-1.6 yr^{-1}

Sources: Lourie *et al.,* 1999; Perante *et al.,* 2002; Meeuwig *et al.,* in prep

Stakeholder Input

At a broad scale, the four stakeholder groups that we have already consulted agreed on priority management options (Fig. 2, Table 3). Marine Protected Areas and minimum size limits were highly preferred by all groups, while tenurial systems, sex-selective fishing and caging pregnant males were highly preferred by one or more groups. Only one option (slot sizes) elicited widely divergent responses. Four groups of options (high, moderate-high, moderate and low-moderate preference) were identified (Fig. 2, Table 3).

These composite rankings were obtained by using the frequency of each group response given in Table 3.

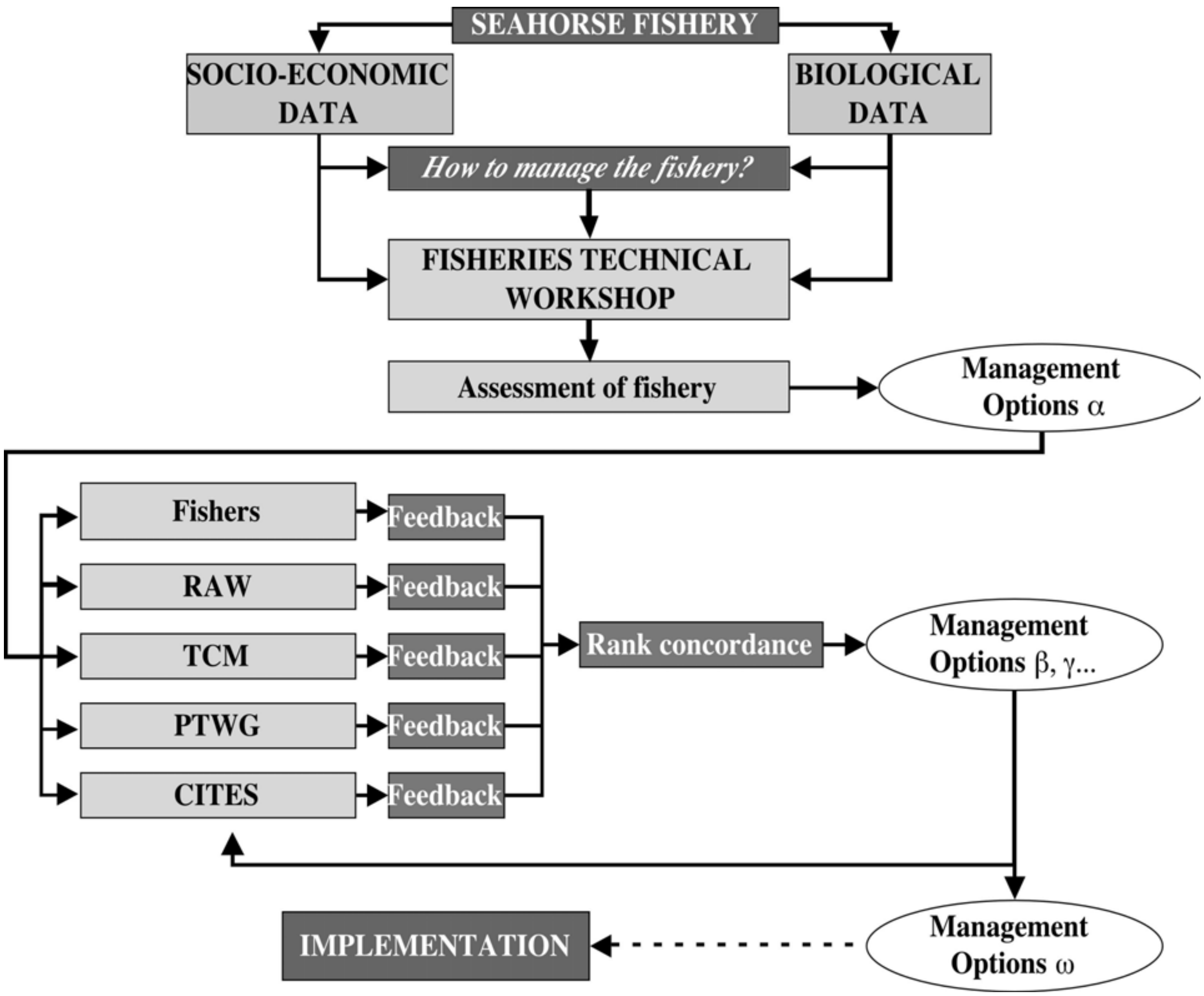

Figure 1. Flow diagram showing consultative process for developing management options for a seahorse fishery. Solid arrows indicate passage of information, dotted arrow the final phase in translating the recommended options to implementation in the fishery. Abbreviations for groups consulted: RAW – Regional Aquarium Workshop of the American Zoo and Aquarium Association, TCM – Traditional Chinese Medicine traders association, PTWG – Philippines Technical Working Group on syngnathids, CITES – workshop on syngnathids mandated by the Convention on International Trade in Endangered Species.

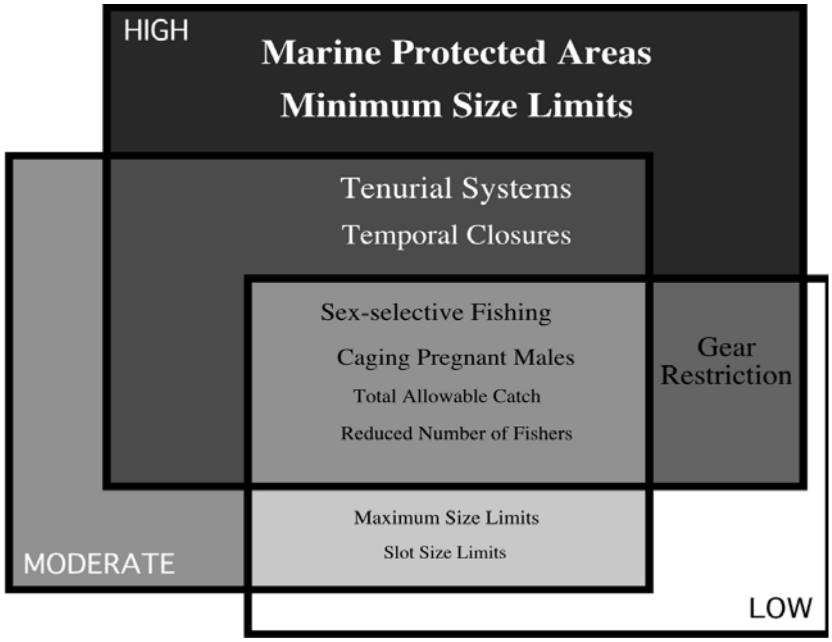

Figure 2. Graphical representation of preferences for management options in a seahorse fishery by stakeholder groups. Each large shaded box represents one of three preference levels: High, Moderate or Low. Areas of overlap indicate different preferences levels by different groups e.g. Temporal closures lie in an area of overlap between High and Moderate preference (see Table 3). Deeper shading represents higher preference levels. Font size for each option is proportional its level of support with maximum size indicating High preference from all stakeholder groups consulted for that option.

A. Options ranked universally High by all stakeholders

A (1). Marine Protected Areas (MPAs)

All stakeholder groups identified no-take MPAs as offering a refuge from exploitation, thus helping to providing an 'insurance policy' for seahorse populations in heavily-fished areas. Mosquera *et al.* (2000) used meta-analyses to review the use of MPAs as conservation tools and concluded that they offered significant protection for fish populations; overall abundance was 3.7 times greater within MPAs compared with adjacent areas. MPAs have been demonstrated to provide spatial refuges for fish populations in many coral reef fisheries around the world including the Philippines (Russ and Alcala, 1996; 1999), Tanzania (McClanahan *et al.,* 1999) and the Caribbean (Chapman and Kramer, 1999).

It would appear difficult to be confident about the population response of seahorses to MPAs. Although it seems clear that no-take zones are very valuable conservation tools, response of individual species to protection can be difficult to predict (Mosquera *et al.,* 2000). For example, target species showed greater increases in abundance in MPAs than non-target species, with a significant positive correlation between body size and increase in abundance (Mosquera *et al.,* 2000). Furthermore, there were significant differences among species within the same family or feeding guild (Mosquera *et al.,* 2000). The size, shape and location of protected areas may well influence their effectiveness for particular species (Chiappone and Sealey, 2000; Dahlgren and Sobel, 2000; Hyrenbach *et al.,* 2000).

Despite uncertainties about specific responses, MPAs are considered to be particularly useful for managing fisheries that lack data, as with *H. comes* and most other seahorses. For example, where the intrinsic rate of population increase (*r*) is unknown, as, then rates of population recovery in MPAs might be predicted from maximum body size or age-at-maturity instead (Jennings, 2001).

Some life history parameters for seahorses (Table 1) suggest that they should show a reasonably quick response to the creation of MPAs. Other species that, like seahorses, are site-attached and have small home ranges have shown rapid rates of recovery (deMartini, 1993; Russ and Alcala, 1998; Kramer and Chapman, 1999). The probable dispersal of newborn young (currently under study) suggests that this may be the stage that replenishes depleted populations.

Tentative evidence to date indicates that seahorses can respond well to the elimination of fishing pressure. A population of *H. comes* showed good recovery in one MPA facilitated by Project

Seahorse in the central Philippines: after an isolated poaching event, for example, the number of adults rose from three to >30 individuals within 6 months (Project Seahorse, unpublished data).

If they are to persist, MPAs need to enhance nearby fisheries sufficiently to compensate for the fishing area lost in the creation of the no-take zone; compensation probably need not come from seahorses *per se* in this multi-species fishery. The efficacy of MPAs as fisheries management tools has been the subject of considerable debate. There has been conflicting evidence over the 'spillover' or export of fish from MPAs to surrounding exploited areas (Russ and Alcala, 1996; Chapman and Kramer, 1999; McClanahan and Mangi, 2000; Jennings, 2001) and the effect of concentrating fishing effort into a smaller total area (Beverton and Holt, 1957; Guénette *et al.,* 1998; Sutinen, 1999; Nowlis, 2000). The amount of spillover to adjacent, exploited areas will depend on attributes of the MPA (e.g. shape and habitat availability within and outside) and attributes of particular species (e.g. rates of movement and density-dependent responses, Jennings, 2001). Although Guénette *et al.* (1998) found that theoretic models predicted increased yield with MPAs, a review in Chapman and Kramer (1999) found only weak evidence of coral reef fishes spilling into areas outside the MPA.

MPAs must have broad acceptance to work as conservation or fishery management measures. Local support of the MPAs is crucial to effective enforcement of protected areas (Russ and Alcala, 1999). Where local support breaks down, benefits of MPAs may be rapidly lost (Russ and Alcala, 1999). In the Philippines, MPAs have had considerable public acceptance and may be more readily adopted than other management measures (Pajaro *et al.,* 2000; Gulayan *et al.,* 2000). Nevertheless, economic issues will be important: a model presented by Nowlis (2000) suggested that income initially declined less with the establishment of an MPA is less than with the introduction of other management measures, although it took longer before income increased (Nowlis, 2000).

A (2). Minimum Size Limit

All groups recognised that that a minimum size limit would help address the evident recruitment overfishing in *H. comes* (where animals are caught before they have the opportunity to start reproducing). Minimum size limits are common in a many different fisheries (Pitcher and Hart, 1983; King, 1995), although often established in conjunction with other measures (e.g. Kruse *et al.,* 2000; Hutton *et al.,* 2001).

As fishing mortality for *H. comes* in the central Philippines is estimated to be very high (Table 1), minimum size limits may have a high probability of increasing stock size: a yield-per-recruit model by Lowe *et al.* (1991) suggested that minimum size limits are most effective when fishing mortality is greater than 0.2, with little effect at lower values.

Fishers suggested limiting *H. comes* catches to greater than about 10 cm in standard length, which is approximately the mean length at which they start to breed. This idea accords well with research showing that minimum size limits need to be set at sizes greater than mean size at first reproduction if they are prevent recruitment overfishing (Nowlis, 2000). Bohnsack (2000) suggested that acceptance of minimum size limits was greatest when they were introduced gradually over a number of years, thus effectively reducing short-term losses (Nowlis, 2000; Bohnsack, 2000).

The Philippines policy group suggested that minimum size limits could prove very difficult to implement if each seahorse species required a different size limit: other fisheries in the Philippines catch primarily *H. barbouri*, *H. kelloggi*, *H. kuda* and/or *H. spinosissimus*. A general minimum size limit could probably be applied as all of these species except *H. kelloggi* are similarly sized (Lourie *et al.,* 1999). This problem of devising minimum size limits for many species caught in the same fishery has already been tackled in the coral trout fishery on Australia's Great Barrier Reef: all species were managed under one size limit. Recent recognition that one species matures at a substantially larger size than the others has led to a new and specific size limit: fortunately, this species is easily recognised by fishers (QDPI, 2002).

B. Management options with general support – ranked Moderate-High preference by stakeholders

B (1) Temporal closures

Stakeholders considered this management option to be potentially useful, although reservations were expressed by some groups. Little evidence suggests that seahorses are vulnerable at particular life-history stages although dieback of *Sargassum* in Mar-Apr may increase visibility and thus catches of *H. comes* (Vincent *et al.,* in prep). In addition, temporal closures are generally complicated and require a high level of knowledge of the biology of the target species (Sutinen, 1999). Furthermore, temporal closures have been insufficient to prevent the collapse of fish stocks even where the biology was well understood (Orensanz *et al.,* 1998; Sutinen, 1999). Models of different management measures indicated that temporal closures did not ensure long-term sustainability of populations (Nowlis 2000).

Given the subsistence nature of the seahorse fishery, temporal closures for seahorses may prove extremely difficult to enforce. Nevertheless, the national policy group recommended that if the fishery is critically overexploited there should be a temporary moratorium (total closure for 1-2 years), an option also recommended by seahorse fishers during interviews across northern Bohol (Meeuwig *et al.*, 2003). Temporal closures have been generally used as fishery management tools to protect certain life-history stages of the population, such as aggregations of spawning adults (Beets and Friedlander, 1999; Sala *et al.,* 2001). These fisheries are extremely vulnerable to overfishing as a large proportion of the population is concentrated in a small area at certain times of the year.

B (2). Tenurial Systems

Tenurial Systems, offering stewardship or ownership of local marine resources to local resource users, were considered essential for effective management of seahorses by the biologists and the Philippines policy group. Indeed Johannes (1978, 1998a) has argued that sustainability has only been achieved in systems with customary tenure. Similarly, Mantjoro (1996) considered tenure of local fisheries resources to be crucial to the success of management in Indonesia. Interestingly, however, seahorse fishers did not consider tenurial systems important, perhaps because of open-access traditions for exploiting marine resources or because of skepticism about the feasibility of local ownership.

Tenurial Systems should generally be used in conjunction with other forms of management. Some of these may not be explicitly stated but if, for example, fishing rights are only granted to resource owners, these will result in de facto reductions in fishing effort (Johannes, 1978).

Tenure may be difficult to implement in areas that lack social tradition for ownership or that have experienced significant breakdown of social structures from population growth or migration. Moreover, tenurial systems take longer to become effective than MPAs and minimum size limits.

C. Management options producing divergent responses.

C (1). Reduction in total number of fishers

This management option was ranked low by most groups for its unworkability and probable negative social effects (i.e. creating unemployment among fishers). A reduction in the number of fishers would decrease total fishing effort if, and only if, remaining fishers maintained or decreased their rate of fishing. However, the fishery is open-access and there are few alternative livelihoods for fishers. Even if some fishers did leave the fishery, those remaining would expect greater catches as fishers left the fishery and the population of seahorses increased. Restriction in total effort requires strong enforcement capability and only appears to have been successfully achieved with community ownership of resources (Johannes, 1978). One hopeful (and surprising) sign is that the fishers themselves ranked this option as being of moderate interest, suggesting receptivity to alternative means of earning income that neither the biologists nor the policy group had expected.

C (2). Gear restriction (ban or reduction of 'hookah' surface supplied breathing apparatus)

Only limited gear restriction is possible in the *H. comes* fishery, but it might be helpful. In the central Philippines, seahorses are caught by hand while spearfishing for food and marketable commodities. Most fishers free dive holding their breath but a small proportion use compressed air supply from the surface (hookah) to work in deeper waters. The reduction or elimination of such hookah rigs would provide a spatial refuge for seahorses.

Gear restriction might produce similar results to the implementation of a maximum size limit (see below). Length-based analysis suggests that *H. comes* may show an ontogenetic habitat shift from shallow to deep water at larger adult sizes, where hookah is used (Meeuwig *et al.,* in prep). If so, then the restriction of hookah would leave larger seahorses in situ, with potential benefits for reproductive output and recruitment to shallow areas.

Alternatively, restricting hookah rigs could have an effect similar to that produced by spatial closures (see above). If, as an alternative hypothesis suggests, seahorses in deeper water represent self-recruiting populations, then gear restrictions on deeper fishing would merely leave those populations intact without much benefit for neighbouring areas. Clearly, more research is needed on the abundance, distribution, and recruitment of seahorses in deeper water before the potential impacts of hookah restrictions can be predicted.

Enforcement of a gear restriction would be difficult. Fishers that were interviewed were moderately supportive of gear restriction but few (if any) of those present have used hookah. Hookah divers have invested enough in their equipment to reduce options for alternative livelihoods.

C (3). Total Allowable Catch (TAC)

Fishers were the only group that showed high preference for this option, although their support was by no means unanimous. It is unclear why TACs should have higher levels of support among the fishers when compared with reduction in the number of fishers, but perhaps it was perceived as more equitable. All the other groups consulted showed lower preference because of the potential to restrict fishers' income if TACs could be enforced and associated scepticism about the possibility of enforcement. Although TACs are designed to reduce the overall fishing mortality, they lead to scramble competition between fishers to exploit the resource as rapidly as possible (Sutinen, 1999). If enforcement breaks down after a TAC is reached, then overall fishing effort actually increases. It appears very unlikely that TACs could be successfully enforced in the seahorse fishery, given the resources available, their spatial distribution and the ease of hiding small animals. Furthermore, TACs lead to market gluts which could depress prices and lead to lower income for fishers (Sutinen, 1999).

C (3). Sex-selective fishing (leaving pregnant males)

Fishers were strongly supportive of this management option while the TCM community was recorded as being strongly opposed. Such an apparent difference may represent a real divergence of opinion may between these groups. Alternately, however, our phrasing of the question in the present tense may mean that the TCM community saw it as reasonable to sell pregnant males under current trade practice. The latter is more likely:

(a) pregnant males have the same economic value as females or non-pregnant males in TCM;

(b) three representative Hong Kong importers called on Philippines fishers and exporters not to take pregnant male seahorses during a November 2000 workshop in Cebu (B. Kwan in litt. Nov. 2000); and

(c) seven TCM trade associations in Hong Kong called for colleagues "*not to purchase seahorses during their breeding seasons, so that their resources can be sustainable*" on 25 March 2002 (S. Lee in litt. 13 Apr. 2002). We need to explore the response of TCM community to sex-selective fishing further before we can fully gauge the efficacy of this management option

Fishers tacitly acknowledge recruitment overfishing by favouring the conservation option of leaving pregnant males in the sea. It is unclear whether they realised that such a policy would result in a substantial catch reduction: the sex ratio is 1:1 and males are pregnant approximately 50% of the time. An alternative option to achieve the same ends without this cost would be to cage pregnant males (see below).

The biological and economic consequences of sex-selective fishing on seahorses will be dependent on the frequency of fishing effort, the rate at which they repair, and the frequency of pregnant animals in the population (Martin-Smith, unpublished data). If most seahorses are pair-bonded and males are pregnant for the majority of each reproductive cycle (Vincent and Sadler, 1995; Perante *et al.,* in press), then leaving pregnant males in the sea might significantly enhance total reproduction, and also increase short-term economic losses. If, however, overall population densities are so low that males have difficulty finding a partner, then leaving the pregnant males may not help much, although it would still cause economic loss.

The unusual nature of seahorse reproduction makes it difficult to predict the impact of protecting one sex rather than the other. In seahorses, although the male bears the young, the female makes a significant contribution through her eggs, to the extent that female size is a key determinant in reproductive output (Vincent, 1990; Vincent and Giles, unpublished data). Removing either sex will skew the population sex ratio, perhaps problematically given the apparently monogamous pairing in *H. comes* (Perante *et al.,* in press). Given the open access nature of the seahorse fishery, it may not be very easy to ensure that fishers do leave pregnant males. Certainly, the race to fish in large industrialised fisheries in developed countries did not diminish with sex-selective fishing, despite high enforcement costs (Sutinen, 1999).

C (4). Caging pregnant males

This is the management option most specific to seahorses. Rather than leaving a pregnant male in situ, the fisher takes him back to his village and puts him in a holding pen in the sea until he releases young. The young escape through the cage to the sea, and fisher then sells the empty male. The biological effect of caging pregnant males is to allow males to release one more brood of young before they are removed from the sea. In theory, the fisher gets virtually the full price for the male seahorse, and thus suffers no economic loss.

Some of the seahorse fishers had already been involved in a project to cage pregnant males prior to sale (Vincent and Pajaro, 1997). Somewhat surprisingly, fishers with previous experience were more supportive of the option than those without. Biological difficulties included the need to site the cages near the village, where water quality and environmental parameters were often poor, and the lack of certainty as to the fate of the newly released young. Economic issues included capital costs of cage construction, deferred realisation of the money for the male, potential (albeit low) mortality in the cage, and the loss of weight when the young were released (with consequent drop in income if buyers purchased the seahorses by weight). Social difficulties arose from the from the fishers' inexperience with self-organisation: they found it difficult to co-ordinate action to construct the cages, check them regularly, and arrange sale of the empty males. All of these factors suggest high uncertainty about the utility of this option, although organisational capacity has certainly improved.

D. Management options of lowest preference

D (1/2). Maximum size limit and slot sizes

The benefits of maximum size limits for seahorse management, as for other fisheries (McCann and Shuter, 1997), depend on the relationship between fecundity and body size. In theory, maximum or slot sizes allow larger and more fecund animals to survive to reproduce. Large individuals contribute disproportionately to spawning success in some species (Plan Development Team, 1990; Roff, 1992). In seahorses, however, this relationship is unlikely because of (a) extended parental care, and (b) small maximum body size (Lourie *et al.,* 1999). Brood size was not related to size in *H. comes* over the size range of animals caught in the fishery (Meeuwig *et al.,* in prep). The proportion of pregnant males did show a strong relationship with body size over the range 105-200 mm SL (Vincent *et al.,* in prep), but increased total reproductive gain from this relationship was likely to be modest (Vincent *et al.,* in prep).

It appears very unlikely that any form of maximum size limit could be enforced for *H. comes* except through trade bans. Above 12 cm standard length, seahorses become more valuable as they get larger, with payment varying by weight or length. Fishers thus feared considerable decline in income if maximum size limits were implemented. The same argument was presented by fishers for opposition to slot sizes, with the additional handicap that smaller catches of smaller individuals further reducing their income. A summary of the discussion on each of the management options is provided in Table 4.

Conclusions

The collaborative process described in this paper has produced clear suggestions as to management options for this seahorse fishery. We recommend that a combination of the highly preferred options (MPAs, minimum size limits and a tenurial system) is instituted to ensure the management objectives for the fishery are achieved. Use of multiple management measures should help to spread the risk if some of the biological or economic assumptions are invalid. In addition, the three most highly preferred options have different temporal scales for their implementation and subsequent effects.

There appears to be consensus that MPAs are an important precautionary measure for conservation in general, with MPAs having significant effects on the whole ecosystem (Mosquera *et al.,* 2000; Jennings, 2001). Certainly, MPAs enhance protection and habitat for other fished species (Rogers-Bennett and Pearse, 2001), for which spillover and export of larvae may be greater than for seahorses. Such gains can help seahorses, which are just one part of a multi-species fishery. The introduction of a tenurial system would be another important contribution to long-term sustainability of seahorse populations and other marine fauna too. However, implementation would take time and would not of itself create security for seahorse populations. Minimum size limits would be very specific to one or a few seahorse species but might operate more quickly than MPAs in re-building seahorse populations (Bohnsack, 2000; Nowlis, 2000), and potential loss of income could be mitigated by gradual introduction (Bohnsack, 2000).

Equivalence of Management Options to CITES Trade Controls

A number of output controls suggested in this paper would lead to a reduction in the total number of seahorses caught in the fishery, in sympathy with the intent of trade controls. Within the list of management options we explored, reduction in TACs most closely approximated trade controls.

However, TACs were not seen as promising options by the biologists or the policy group, largely because of concerns about feasibility and enforcement issues. Fishers and aquarium dealers were slightly more receptive to the idea, but the fishers would want other livelihood options to be available if TACs were to be reduced.

Given that mandatory reduction in TACs would probably not be effective by itself, any plan to reduce seahorse catches (with or instead of trade controls) will have to explore and promote other options that are ranked more highly by stakeholders, such as minimum size limits. The same management outcomes (sustainability of exploitation) may be attained through different mechanisms that are more or less socially, economically or legally acceptable and feasible. It should be remembered that the traditional Chinese medicine community is, for example, receptive to minimum size limits, as articulated in a joint statement issued by seven TCM trade associations on 25 Mar 2002 (Samuel Lee, TRAFFIC East Asia, in litt, 13 Apr 2002).

Application to Other Syngnathid Fisheries

This paper has explored management options for one seahorse species, *H. comes*, but similar approaches should be useful for other target fisheries, if modified with respect to such parameters as size limits. Managing bycatch of syngnathids will, by comparison, be very problematic. Marine Protected Areas can be used for both target and bycatch species and have been advocated for both fisheries management and conservation purposes (Bohnsack, 1998; Mosquero *et al.,* 2000). Other input controls such as the number of fishers, or temporal and spatial closures, are also often part of management regimes for non-selective gear types. Technical changes to fishing gear might also allow escapement of certain sizes and/or sex, although they would work where the target species were similar in size or exhibited similar behaviour to the bycatch species. The non-selective nature of bycatch means that output controls such as size limits or sex-selective fishing would be extremely difficult to implement, and might not even serve a conservation goal, if the fish were landed dead anyway. Other and innovative management options of particular utility to bycatch fisheries, such as mandatory use of sorting hoppers, will need to be considered.

In all protocols, we need to avoid managing seahorses in a way that deflects fishing pressure onto other vulnerable species. Marine conservation must be holistic even as it addresses specific issues.

Table 2: List of management options presented to stakeholder groups

Management Option	Description, in the context of the H. comes fishery	Examples of this approach for other fisheries
1. Reduction in number of fishers	Fishers exit the fishery leading to reduction of total effort. Necessitates alternative livelihoods.	Valentini *et al.*, 1991; McManus *et al.*, 1992; Muller *et al.*, 1997
2. Restriction of gear type	Reduction or ban on compressor divers who catch seahorses in deeper waters than breathhold divers.	Karpov *et al.*, 1998
3. Spatial closures: No-take Marine Protected Areas (MPAs)	Permanent ban on fishing in specified areas.	Roberts and Polunin, 1991; Rowley, 1994; Roberts, 1995; Russ and Alcala, 1996; 1999; Wantiez *et al.*, 1997; Bohnsack, 1998; Guénette *et al.*, 1998; Chapman and Kramer, 1999; McClanahan *et al.*, 1999; Mosquera *et al.*, 2000; Jennings, 2001
4. Temporal closures	Temporary ban on fishing in particular areas for specified period of time.	Attwood and Bennett, 1990; Beets and Friedlander, 1999; Sala *et al.*, 2001
5. Tenurial systems	Local ownership of marine resources. Normally used in conjunction with other options.	Johannes, 1978; 1998a; Adams, 1998; Cooke *et al.*, 2000
6.Total Allowable Catch	Quota on total number of seahorses that can be caught.	Sissenwine and Mace, 1992; Nakken, 1998
7. Minimum size limit	Restriction on landings and sales of seahorses smaller than specified size.	Foale and Day, 1997; Kruse *et al.,* 2000; Hutton *et al.,* 2001
8. Maximum size limit	Restriction on landings and sales of seahorses larger than specified size.	Eckert *et al.,* 1992; QFMA, 1999
9. Slot size	Restriction on landings and sales of seahorses to a specified size range.	Alam *et al.,* 1993; Power and Power, 1996; Hicks *et al.,* 1995; Williams, 1997; QFMA, 1999
10. Sex-selective fishing	Restriction or ban on landing pregnant male seahorses, although could also apply to egg-bearing females.	[leaving females] Vaughan *et al.,* 1995; Orensanz *et al.,* 1998
11. Caging pregnant males	Pregnant male seahorses held in sea cages until they give birth	M. Pajaro (unpub. data)

Table 3: Possible management options for an artisanal seahorse fishery in the central Philippines. Preference for each option was assessed as described in the text. N/a indicates that the option was not applicable or not assessed by a stakeholder group. Abbreviations: FTW – Fisheries Technical Workshop; RAW – Regional Aquarium Workshop (North America); TCM – Traditional Chinese Medicine traders (Hong Kong); PTWG – Philippines Technical Working Group; CITES – international policy workshop held to discuss potential listing of seahorses under the Conventional on International Trade in Endangered Species.

	Preference assessment by stakeholder group						Recent examples of application
Management Option	FTW	Fishers	RAW	TCM	PTWG	CITES	
Input Controls (acting to regulate fishing effort)							
Reduction in the number of fishers	Low	Moderate	High	N/a	Low	Low	[38,39]
Restriction of gear type (reduction or ban on compressor divers)	Low	High	N/a	N/a	High	N/a	[40]
No-take Marine Protected Areas	High	High	N/a	N/a	High	High	[20,32,41-46]
Temporal closures	Moderate	High	N/a	High	Moderate	Moderate	[47,48,49]
Tenurial systems (village/barangay ownership)	High	Moderate	N/a	N/a	High	N/a	[50,51,52]
Output Controls (acting to regulate catches)							
Total Allowable Catch	Low	High	Moderate	Moderate	Low	Low	[53,54]
Min. size limit	High	High	High	High[a]	High	High	[55,56,57]
Max. size limit	Moderate	Low	Moderate	Low	Moderate	Moderate	[58,59]
Slot size (combo of min. and max. size limits)	Moderate	Low	Moderate	Low	Moderate	Low	[59,60,61]
Sex-selective fishing (restriction on capture of pregnant males)	Moderate	High	High	Low[a]	Moderate	Moderate	[62.63]
Caging pregnant males to allow them to release brood before being sold	Moderate	High	n/a	n/a	Moderate	Low	-

[a] Translation errors mean that questions on both of these options were phrased in terms of current practice. Whilst future minimum size limits appear to be acceptable to the TCM community, opposition to sex-selective fishing is at odds with our longer-term understanding of TCM receptiveness to management change (see Synthesis).

Table 4: Summary of pros and cons for seahorse management options

Management Option	Pros	Cons
1. Reduction in number of fishers	• Reduced total catch of seahorses • Reduced catch of other organisms • May increase income for remaining fishers	• Loss of livelihood for some fishers • Problems of enforcement • May increase effort by remaining fishers • Low level of support
2. Restriction of gear type	• Deep-water refuge for some seahorses • May protect larger, reproductive individuals	• Problem of enforcement – hookah divers unlikely to give up their gear • Smaller seahorses still vulnerable to breathhold divers
3. Spatial closures: No-take Marine Protected Areas (MPAs)	• Permanent protection of some seahorse populations • High level of support from all stakeholders • General benefits for other species	• Cannot predict response of seahorses to MPAs • Level of 'spillover' to areas outside MPAs unknown • Potential increase in effort outside MPAs • 'Lag' period before effect of MPA observed
4. Temporal closures	• Protection during certain periods of increased vulnerability – reproduction, recruitment of juveniles	• Difficult to determine appropriate period for closure • Loss of income during closure – cannot be sustained by subsistence fishers
5. Tenurial systems	• Local ownership provides vested interest in sustainability • Promotes local involvement in management process	• Political implications of re-allocating ownership • No tradition of tenure • Variable responses by different tenure-holders
6.Total Allowable Catch	• Total (sustainable) quota can be set	• Problem of enforcement • 'Scramble' competition for resources • Market gluts with reduced income
7. Minimum size limit	• Protection of juveniles, allowing them to reach reproductive size • High level of support from all stakeholders • Most effective method of rebuilding populations suffering recruitment overfishing	• Loss of income • Determination of minimum size limit • 'Lag' period before effect of minimum size limit observed
8. Maximum size limit	• Protection of reproductive adults • Increased reproductive output per pair because larger individuals have larger broods and shorter inter-brood interval?	• Substantial loss of income because large seahorses most valuable • Low level of support • Determination of maximum size limit
9. Slot size	• Protection of juveniles and reproductive adults • Increased reproductive output	• Substantial loss of income from large and small seahorses • Low level of support
10. Sex-selective fishing	• Pregnant males allowed to release brood in natural habitat • High level of fisher support	• Produces skewed sex ratio in adult population • Reproduction may be reduced if males cannot find new partner
11. Caging pregnant males	• Pregnant males allowed to release brood • No loss of income for fisher	• Location of cages may not be optimal for juvenile survival or recruitment • Mortality of males in cages • Logistic and organization requirements for successful operation of cages

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Assessing A Seahorse Fishery For Overfishing

Keith Martin-Smith
Project Seahorse
Keith.MartinSmith@utas.edu.au

This document was originally prepared by Project Seahorse for the CITES Secretariat for the Technical workshop on seahorses and other members of the family Syngnathidae (Cebu, Philippines), 27-29 May 2002), and has been revised by Project Seahorse for the CITES Secretariat for the International workshop on seahorse fishery management (Mazatlán, Mexico), 3-5 February 2004).

Determining whether a fishery is overfished is the first step before any management decision can be made. The following document prepared by Project Seahorse represents the summary of a discussion at a Fisheries Technical Workshop (see Briefing Document on Fisheries Management), at which a particular seahorse fishery in the Central Philippines was assessed qualitatively and semi-quantitatively for evidence of overfishing.

Seahorses may be particularly vulnerable to heavy exploitation due to the low potential reproductive rate, small home range, and limited swimming abilities observed in many species (Lourie *et al*., 1999). At least 20 million dried seahorses were traded annually by 1995, and local fishers and buyers reported substantial declines in catches of *Hippocampus comes*, in the order of 70% over ten years to 1995 (Vincent, 1996; Vincent and Pajaro, in prep.). The fishery for *H. comes* described in the document Summary of the Central Philippines Seahorse Fishery was assessed against various qualitative and semi-quantitative definitions of overfishing.

At least six different qualitative categories of overfishing have been proposed in the literature (Table 1). For all categories, there was some evidence that the fishery was overexploited (Table 2). A semi-quantitative assessment of the fishery was also conducted using catch data from the fishery (Vincent *et al.,* in prep), fishery-independent biological data (Perante *et al*., in press), and estimates of fisheries parameters from a yield-per-recruit model. There was direct and indirect evidence of overfishing in all of the criteria used (Table 2).

There were considerably more data available for this fishery than many other nearshore, coral reef fisheries. In line with the conclusions of Johannes (1998), who advocated precautionary management in data-poor or data-less situations, we considered that there was a high probability that the seahorse fishery in the central Philippines was overfished, and that management action should be taken on this basis.

For more information, we refer you to the following analysis: Full citation is Martin-Smith, K.M., Samoilys, M.A., Meeuwig, J.J. & Vincent, A.C.J. (2004) Collaborative development of management options for an artisanal fishery for seahorses in the central Philippines. Ocean & Coastal Management 47: 165-193

Table 1: Qualitative assessment of a central Philippines seahorse fishery for evidence of overfishing

Type of overfishing	Definition	Assessment of seahorse fishery	Conclusion
Economic	"fishing at levels beyond an economically optimal level. The latter optimum usually occurs at levels of fishing effort below those based on the other types of overfishing" (McManus, 1997)	Economic optimum for seahorse fishery is unknown. Reported historical declines in CPUE leading to decreased income	Almost certainly overfished
Growth	"harvesting of individual organisms at sizes which are sub-optimal with respect to potential yield" (McManus, 1997)	High proportion of juveniles taken and strong size-dependent value	Almost certainly overfished
Recruitment	"refers to fishery-induced reduct number of young fish entering fi ground." (Pauly, 1994). "a level of fishing in which the adult stock is reduced to the extent that recruits produced are insufficient to maintain the population" (King, 1995)	Level of recruitment required to maintain population is unknown. Adult standing stock v. low (640 km^{-2}) and high proportion of catch is juveniles (Vincent et al., unpub.; Samoilys et al., unpub.)	Probably overfished
Biological	"a combination of growth and recruitment overfishing which leads to a decline in catch as fishing effort increases." (McManus, 1997)	Time series (1996-2001) for CPUE not really sufficient to evaluate biological overfishing. Although CPUE was stable for 3 years and then increased, fishers report declines from historical CPUE (Vincent et al., unpub.)	Probably overfished as both growth & recruitment overfishing appear to be taking place
Ecosystem	"Ecosystem overfishing causes a shift in community structure from a fishery dominated by valuable species to one dominated by species of less economic value or utility" (Pauly, 1979)	Historical declines in proportion of species from higher trophic levels. Declines in catches of piscivores (McManus, 1997).	Total fishery suffering ecosystem overfishing. Effects on seahorse component unknown
Malthusian	"overfishing occurs at when poor fishermen, faced with declining catches and lacking any other alternative, initiate wholesale resource destruction in their effort to maintain their incomes." (Pauly et al., 1989)	Seahorses are not caught with gears that are destructive. However there is abundant evident that these gears are being used for other species in the same fishery (McManus, 1997). Effects of degraded habitat on seahorse populations are unknown	Total fishery suffering Malthusian overfishing. Effects on seahorse component unknown

Table 2: Semi-quantitative assessment of seahorse fishery for evidence of overfishing (Unpublished criteria developed by Carl Walters, Fisheries Centre, U.B.C.)

Criterion	Direct Evidence	Indirect (Inferred) Evidence
1. High proportion of individuals of at least one life-history stage must be accessible to fishery.	High levels of fishing effort across known seahorse habitat	Fishers' knowledge of habitat preferences of *H. comes*. Reported historical declines in CPUE
2. Age/size at recruitment to fishery substantially less than age/size at first maturity.	Calculated size at 50% maturity = 102 mm Smallest individual recorded in fishery = 52 mm 18% of catch recorded as juveniles (Vincent *et al.*, unpub.)	None
3. Current biomass substantially less than virgin biomass	None (no surveys of virgin biomass were undertaken)	Reported declines of 15-50% over 5 years to 1995 from fishers and traders (Vincent, 1996; Perante *et al.*, 1998) Population densities of only ~640 km^{-2} in 2000 very low, even for rare coral reef species (Samoilys *et al.*, unpub.)
4. Fishing mortality (F) greater than approx. 0.6x natural mortality (M)	None (estimates of F and M from catch data only)	Estimates of F range from 1.7-2.5 yr^{-1} from catch data Estimates of M range from 0.8-1.6 yr^{-1} (Meeuwig *et al.*, unpub.)
5. Population biomass will increase in response to lower F.	Increases in population size within Marine Protected Areas	Increased CPUE in 1999 following period of reduced fishing pressure (seaweed farming).

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