Available online at www.sciencedirect.com
ScienceDirect
Fisheries Research 86 (2007) 207–215
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Characterizing a small-scale, data-poor, artisanal fishery: Seahorses in the central Philippines

Amanda C.J. Vincent[a,b,*], Jessica J. Meeuwig[a,1], Marivic G. Pajaro[b,c], Nelson C. Perante[c]

[a] Project Seahorse, Department of Biology, McGill University, 1205 Ave. Dr. Penfield, Montréal, Que. H3A 1B1, Canada
[b] Project Seahorse, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC V6T 1Z4, Canada
[c] Project Seahorse, Haribon Foundation for the Conservation of Natural Resources, 2 Nacua Apartments, 895 V. Rama Ave, Cebu City, Cebu, Philippines

Received 6 December 2006; received in revised form 29 May 2007; accepted 6 June 2007

Abstract

Small-scale artisanal fisheries that target sedentary stocks have been largely ignored by fisheries management agencies, despite their great importance for food security and livelihoods. We characterized the fishing effort and biological parameters of one such fishery for seahorses in the central Philippines from 1996 to 1999. We found that catch-per-unit-effort (CPUE) was very low, particularly when compared with historical accounts. There were significant seasonal differences in CPUE, with higher catches and more juveniles in February–April. Fishers differed in their skill at catching seahorses but fishing grounds did not differ in seahorse catches. We found increases in the mean size of landed seahorses during the study but decreases in the proportion of brooding males. We interpret these data in terms of potential co-management options for the fishery.

Keywords: Coral reef; CPUE; *Hippocampus comes*; Seasonality; “S”-fisheries; Spatial patterns

1. Introduction

Most fisheries policy and management practices around the world have been prompted by industrial fisheries, but there are increasing calls to develop new paradigms based on artisanal fisheries (Castilla and Defeo, 2005; Orensanz et al., 2005). These are typically coastal and differ markedly in structure and function from large-scale, offshore fisheries. Orensanz et al. (2005) have described what they call artisanal “S”-fisheries—small-scale, spatially structured and targeting sedentary stocks. This concept has provided a useful framework for considering the very different approaches required when assessing and managing artisanal fisheries (e.g. Defeo and Castilla, 2005; Campbell and Pardede, 2006).

In socio-economic and food security terms, artisanal fisheries are critically important; estimates suggest that 50 million small-scale fishers operate in developing countries, up to 250 million people rely directly on artisanal fisheries for food, income and livelihoods, and a further 150 million people work in associated sectors, such as boat building (Berkes et al., 2001; FAO, 2004). The proportion of these individuals dependent on S-fisheries has not been estimated but is likely to be considerable given their taxonomic and geographic range; for example, artisanal fisheries land shellfish in South America (Defeo and Castilla, 2005), holothurians and trochus shell in the Pacific (Lincoln-Smith et al., 2006) and octopus, crab and fishes in Spain (Freire and García-Allut, 2000). The majority of global fish production is consumed in developing countries and fish may make up more than 60% of protein intake in some countries (Barut et al., 2003; Delgado et al., 2003).

Coral reefs provide examples of the problems and challenges posed by S-fisheries. Typically, coral reef fisheries are located in developing countries and involve large numbers of fishers widely dispersed over large areas, who cumulatively capture hundreds of species with a variety of gear types (e.g. Green et al., 2004; Ochiewo, 2004; Kuster et al., 2005). These fisheries provide food and income for tens of millions of people, many of who are among the poorest and most marginalized in their communities (Pauly, 1997; Cesar et al., 2003). Half of the world’s coral reefs

* Corresponding author at: Project Seahorse, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC V6T 1Z4, Canada.
Tel.: +1 604 827 5137; fax: +1 604 827 5199.
E-mail address: a.vincent@fisheries.ubc.ca (A.C.J. Vincent).
[1] Present address: School of Plant Biology, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia.

0165-7836/$ – see front matter
doi:10.1016/j.fishres.2007.06.006

are in immediate or long-term danger of collapse from human pressures, of which overfishing and associated habitat damage are significant components (McManus, 1997; Wilkinson, 2004). The growth of non-food fisheries – for ornamental fish, curiosities, traditional medicine and many other uses – is adding to the pressures on reef resources (Vincent, 2006).

Fisheries resources in southeast Asia in general, and the Philippines in particular, have declined substantially since the 1970s (Lichuanan and Gomez, 2000; DeVantier et al., 2004; Stobutzki et al., 2006). Recent assessments have concluded that overfishing is severe in the Philippines and predicted to remain so until at least 2020 (UNEP, 2006). Conventional fisheries management capacity is limited, with few resources for stock assessment or the development of management plans (Lichuanan and Gomez, 2000). There appears to be a consensus that sustainability in these fisheries will only be achieved through a combination of capacity reduction and co-management with fishers (DeVantier et al., 2004; Orensanz et al., 2005; Stobutzki et al., 2006).

Against this background, we investigated one coral reef fishery in the central Philippines- that for seahorses taken by free diving. These animals are collected as a cash commodity for export as non-food items, either dried as traditional medicines and curiosities, or live for the aquarium trade (Vincent, 1996). Although almost all seahorses are caught in small-scale fisheries, the cumulative international trade has been estimated as considerable—at least 20 million dried animals per year in 1995 with evidence of increased numbers in the early 2000s (e.g. Vincent, 1996; Baum and Vincent, 2005; Giles et al., 2005; Salin et al., 2005). Similarly, seahorses were the most important ornamental fish exported by Brazil over the period 1999–2001 (Gasparini et al., 2005). Concerns over unsustainable international trade led to all seahorse species being listed in Appendix II of the Convention for International Trade in Endangered Species of Flora and Fauna (CITES) in November 2002 with implementation in May 2004. As a consequence, signatories to CITES (169 nations) are required to ensure that all seahorse exports are sustainable.

Seahorse catches throughout the Philippines have apparently declined, although quantitative data are rare. Surveys throughout the country during from 1998 to 2001 showed that the Philippines was a major exporter of seahorses, supplying millions of animals to the dried trade and hundreds of thousands to the live aquarium trade (Pajaro and Vincent, in press). However, many small-scale fishers and buyers of seahorses reported declines in supply (Pajaro and Vincent, in press). These reports accorded with declines in biomass of 10–64% and exploitation ratios of >0.5 for more than half of all demersal fish stocks (Stobutzki et al., 2006).

Our objectives in this study were to determine the temporal and spatial patterns of seahorse catches in a Philippines' seahorse fishery as a basis for future management action. Rigorous stock assessments have not been undertaken for any seahorse fishery, such that the CITES Parties are currently advised to consider interim measures, such as a single minimum size limit for all the diverse species (Foster and Vincent, 2005). Given the dispersed nature and relatively low priority of the fisheries to management authorities, it is unlikely that traditional stock assessments and fisheries modeling will be undertaken. Under these circumstances, characterizing the fishery through quantitative observational data is one of the only available options for collecting information and has the additional benefit of involving fishers in management (Berkes et al., 2001).

We used daily logs to quantify catch-per-unit-effort (CPUE) for seahorse fishers and catch landings measurements to estimate biological parameters for seahorses caught in the fishery. We analyzed these data to look for seasonal and yearly temporal patterns in CPUE and changes in biological parameters of the exploited seahorse populations.

2. Materials and methods

2.1. Study location, study species and fishery

We conducted this study on the seahorse fishery operating out of the barangay (village) of Handumon on Jandayan Island in the central Philippines (Fig. 1) over the period 1996–1999. The most extensive coral reef in this area is Danajon Bank, a double barrier reef that stretches about 150 km along the northwestern coast of Bohol island (Fig. 1). Seahorse fishing began in the Danajon Bank region in the 1960s and rapid growth in international demand for seahorses from the mid-1980s meant that seahorses became an important component in a local subsistence fishery.

The authors and their Project Seahorse team have been working with the local community at Handumon since 1996, undertaking a variety of conservation initiatives. These include initiating community development of a small marine reserve, assistance with capacity building and community organization, consultation about potential management options for the seahorse fishery, and high school apprenticeship programmes (Martin-Smith et al., 2004).

The target seahorse in this fishery is the tiger-tail seahorse *Hippocampus comes*, a medium-sized (to 15 cm height), smooth, dark seahorse often with a yellow-and-black striped pattern on the tail, found around the South China Sea (Lourie et al., 1999). *H. comes* is found on coral reefs, sponge and seaweed habitats down to 20 m depth, emerging from crevices at night onto predominantly coral holdfasts (Perante et al., 2002; Morgan and Lourie, 2006). While life history parameters for *H. comes* have not been comprehensively ascertained, the species is thought to live 2.6–3.7 years, reaching a maximum size of 264 mm SL (Meeuwig and Lafrance, 2001 quoted in Morgan and Lourie, 2006). Half the males are mature at 96 mm SL although reproduction has not been confirmed in individuals smaller than 105 mm SL (Morgan and Lourie, 2006). About 400 young are released per brood and many *H. comes* maintain prolonged, monogamous pairings for reproduction (Perante et al., 2002).

2.2. Daily logs

We estimated the catch-per-unit-effort (CPUE) of seahorses using logs in which fishers noted their daily landings. These were distributed by our Project Seahorse team members – all

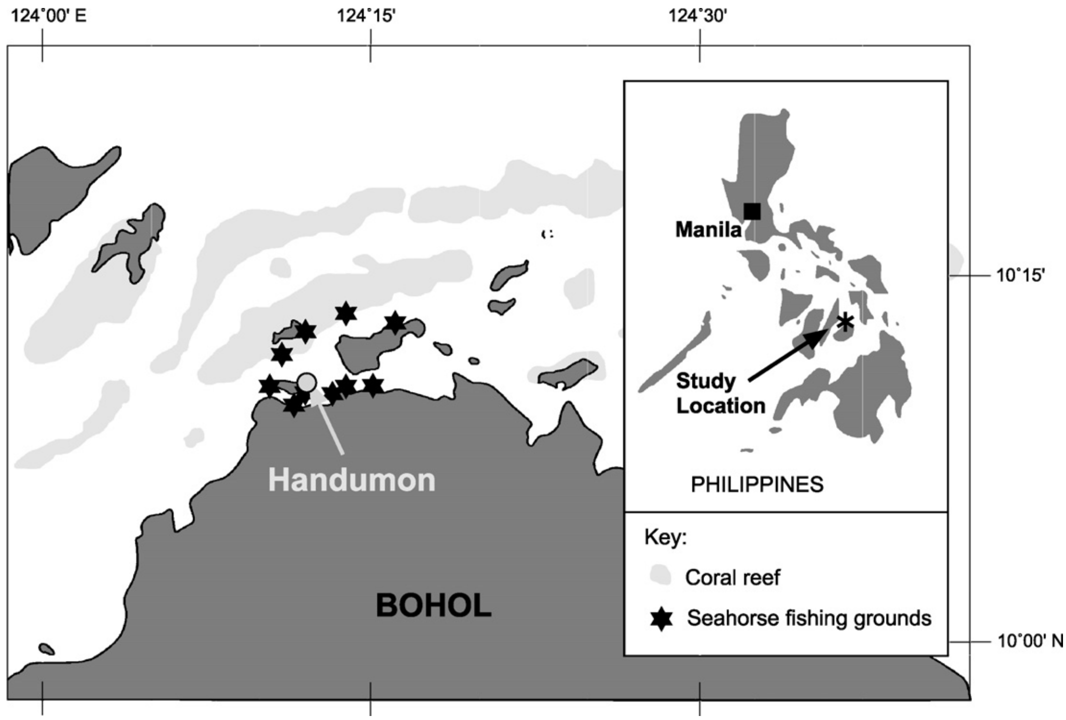

Fig. 1. Map of study location in the central Philippines showing Handumon village and approximate locations of seahorse fishing grounds. Light shaded areas indicate the main coral reefs of Danajon Bank.

Filipino and fluent in the local language – who followed up with discussions and log collection at the end of each month. Fishers recorded: (1) whether they went fishing, (2) the number of seahorses caught, (3) the price received for their seahorse catch, (4) the type and weight of other species caught, and (5) the name of the fishing ground (from January 1999 onwards). Daily logs were completed by 33 different fishers between 1996 and 1999 with a mean (±S.E.) participation rate of 19.8 (±1.6) fishers year^{-1} and 9.1 (±0.6) month^{-1}. This level of participation represented almost 50% of the fishers in Handumon. Despite the high level of fisher participation, the log data were unbalanced because fisher participation varied by month.

Fishers seldom recorded whether they were trying to catch seahorses on a particular fishing expedition. Thus, nights or months with zero seahorse catch may have arisen either from an inability to find seahorses or from a decision to target other organisms.

2.3. Catch landings

Filipino biologists and local assistants collected landings data, complementing the logs completed by fishers. Each day, team members recorded biological data for a subsample of the seahorses caught by fishers earlier that morning: standard length (SL; see Lourie et al., 1999), sex, and male reproductive state (pregnant or not). We could not define life history stage (adult or juvenile) directly for all individuals because of difficulties in distinguishing between juveniles and small females. Thus, we used a calculated size at 50% maturity, SL_{M50} (as in Meeuwig et al., 2006), assuming that adult males were accurately identified (from the presence of a brood pouch) and that the sex ratio of mature seahorses in each size class was equal (see Section 3). Thus, any excess of individuals recorded as “females” in smaller size classes were in fact juveniles. We then used a logistic regression of juvenile size against proportion of juveniles to define SL_{M50}. Following this, all individuals with $SL < SL_{M50}$ were designated as “juveniles” while all individuals with $SL \geq SL_{M50}$ were designated “adults”.

Landings data were collected for 33 months (12 months in 1996, 10 months in 1997, and 11 months in 1998). Data were collected intensively from January 1996 to December 1997 (an average of 14 days per month) and less frequently in 1998 (an average of 3 days per month).

2.4. Statistical analyses

We used general linear models to analyze temporal and fisher effects on CPUE and size data. For CPUE we used analysis of covariance (ANCOVA) in which our independent variables were Year, which was treated as a categorical variable, while Month and Lunar Phase were treated as circular, continuous variables (Zar, 1999). This type of analysis is more sensitive and robust than categorical ANOVA for the detection and description of cyclical relationships (deBruyn and Meeuwig, 2001). Our response variable was calculated using two different methods: (1) $CPUE_T$—we retained all zero-catch months and calculated a single monthly mean from all fishers’ individual CPUEs; (2) $CPUE_F$—we calculated mean CPUE for each fisher for each month but then removed all zero-catch fisher-months as the data were highly skewed towards zero and could not be normalized. While $CPUE_F$ could potentially overestimate catch rates, it allowed us to examine fisher effects which was not possible with

$CPUE_T$. Both $CPUE_T$ and $CPUE_F$ were log-transformed to meet GLM requirements of normal distribution and homoscedastic residuals.

We wanted to ensure that variation among years did not arise merely from inter-annual differences among fishers, and thus in seahorse collecting skills. We therefore selected a subset of individuals who had participated for at least 10 months of the total study and ranked them by mean CPUE. This gave us overall rankings from most skilled to least skilled fisher across all years (S_F). For each calendar year (Y), we then calculated each fishers' contribution by multiplying their overall rank by the number of months of participation in that year (N_Y). The sum of these values divided by the number of fishers (N_F) was designated as the mean skill level for that year (S_Y), i.e.

$$S_Y = \frac{\sum_{n=1}^{F} S_F \times N_Y}{N_F}$$

We then used χ^2 goodness-of-fit to test for differences among years.

Spatial patterns in CPUE were evaluated for a subset of eleven fishing grounds visited by at least three fishers during 6 months between January and December 1999, the first year for which fishers recorded their fishing grounds. We used analysis of variance (ANOVA) to test for significant differences in CPUE among fishing grounds.

We also used ANCOVA to examine patterns in size distributions of seahorse landings over time. Mean seahorse SL was calculated for all seahorses collected each month and for adults only (those greater than SL_{M50}) and used as the dependent variable in similar analyses to those described above for CPUE.

Individual-based data on life history stage, sex and male reproductive state were transformed to monthly population ratios of juveniles to adults, males to females, and pregnant versus not pregnant, respectively. Temporal patterns in these ratios were tested using (1) the heterogeneity goodness-of-fit *G*-test when there was an expected distribution (e.g. a 1:1 sex ratio) or (2) the *G*-test of association with the William's correction (Sokal and Rohlf, 1995). We used logistic regressions to investigate the relationship between size and the proportion of males or the proportion of pregnant males.

Where ANOVA and ANCOVA were used, we present the model for which main effects, covariates and interaction terms were significant at $p < 0.05$. We only retained interaction terms when main effects and covariates were both found in the model. All means are reported ±standard errors.

3. Results

Seahorses were caught as one component of a multi-species subsistence fishery conducted by a total of approximately 70 fishers from Handumon over the course of the study. Fishing was conducted in numerous different fishing grounds around Handumon (Fig. 1). Fishers departed Handumon around 0100–0200, each in a small (3 m) wooden outrigger boat powered by paddles or small motors. Travel to fishing grounds took between 15 min and 2 h. Fishers worked alone, swimming beside the boat as they towed it, under the light of a low-slung lantern. They typically spent approximately 4 h (until dawn) free-diving to spear food fish and squid, and collecting seahorses and invertebrates (sea cucumbers, abalone, crabs) by hand. Fishers returned in the few hours after dawn, selling their smaller seahorses to a buyer serving the (live) aquarium trade, who kept them alive, and larger seahorses to a shopkeeper serving the (dried) traditional medicine trade. Prices for live seahorses over the course of the study were about 3 Philippine Pesos (PP) each (approx. 0.10 USD), while prices for dried seahorses were 7–12 PP (0.21–0.37 USD). Seahorses comprised an important component of fishers' cash income.

3.1. Daily logs

We recorded a total of 4249 *H. comes* caught over 1447 nights of fishing during the study, giving a mean $CPUE_T$ of 2.94 ± 0.11 seahorses fisher^{-1} night^{-1} and a range of 0–44 seahorses caught night^{-1}. Excluding zero-catch nights, the mean $CPUE_F$ was 3.43 ± 0.13 seahorses fisher^{-1} night^{-1}. There were clear temporal patterns in the data using either $CPUE_T$ or $CPUE_F$ with significantly more seahorses caught during 1999 than in previous years (Fig. 2a; Table 1). Although seahorses were caught throughout the year, there were also significant seasonal patterns with a high season of seahorse catches in February–June and a low season from July to October (Fig. 2b; Table 1). There was a weak interaction between Year and Month suggesting that the seasonal pattern varied somewhat from year to year (Fig. 2c; Table 1). However, there were no significant lunar effects on seahorse catches.

When our analyses enabled us to test the effect, we found a strongly significant influence of fisher on $CPUE_F$, indicating that fishers differed in ability to catch seahorses (Table 1). This effect was not related to differential fisher participation in the catch calendar program as there was no significant difference in mean skill level among years ($\chi^2 = 0.333$, d.f. = 3, $p > 0.05$). For fishers with at least 3 months of data, mean $CPUE_F$ varied from 1.2 to 6.9 seahorses fisher^{-1} night^{-1}. Thirty-one fishing grounds were recorded by fishers in 1999 but only 11 and 5 of them met our criteria for inclusion in quantitative analyses for low season and high season, respectively. There was no apparent effect of fishing ground on seahorse catch rates with no significant differences among areas fished in either low or high season.

Table 1
Results of ANCOVA for temporal and fisher effects on catches of seahorses

Variable	d.f.	*F*-ratio	*p*
(a) $CPUE_T$: $r^2 = 0.73$, $n = 48$			
Year	3	17.5	<0.001
Month (sine function)	1	64.2	<0.001
Year × month (sine)	3	2.6	0.060
(b) $CPUE_F$: $r^2 = 0.42$, $n = 297$			
Year	3	5.4	0.001
Month (sine function)	1	53.1	<0.001
Year × month (sine)	3	3.1	0.028
Fisher	31	3.8	<0.001

Only significant effects and interactions are shown.

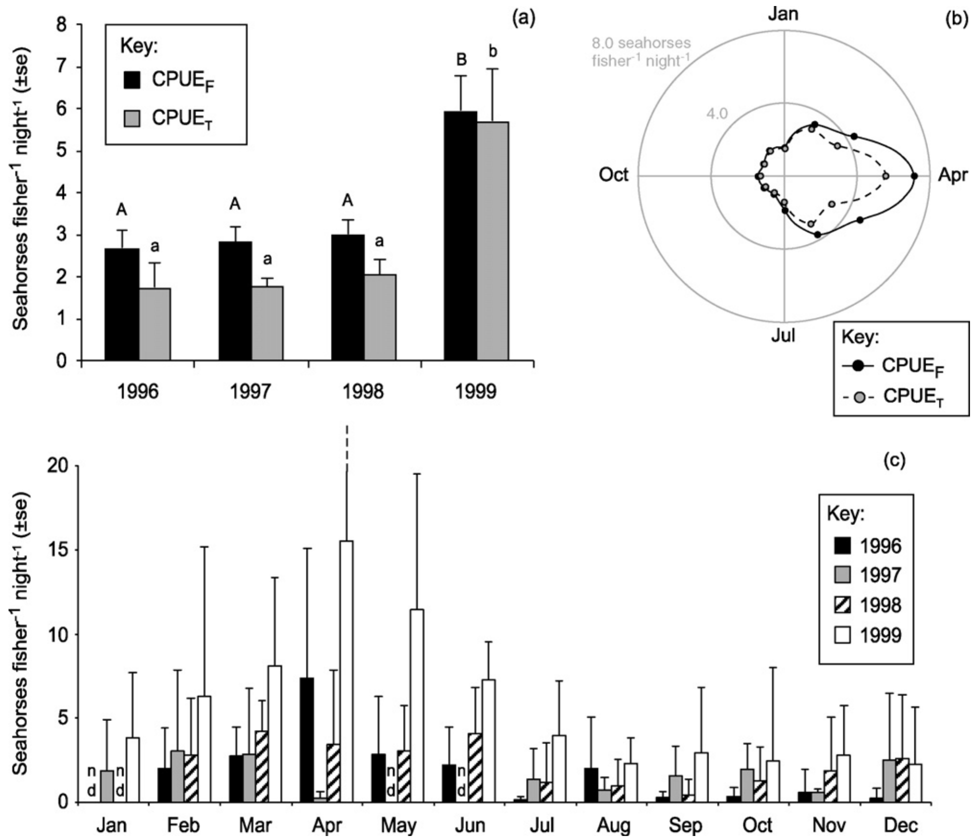

Fig. 2. Temporal variation in seahorse catches. (a) Yearly variation in mean CPUE for the period 1996–1999. Within each set of CPUE data, different letters indicate significant differences between values. (b) Polar plot of monthly variation in mean CPUE across all years. (c) Mean CPUE by month and year.

3.2. Catch landings

The size of seahorses caught over the course of the study increased significantly from 1996 to 1997 to 1998, regardless of whether we considered all seahorses or adults only (Fig. 3a; Table 2). There was also a significant seasonal effect with smaller seahorses landed in February–April (Fig. 3b; Table 2). This effect was due to a greater proportion of juvenile seahorses being landed at this time of year as the effect was much weaker when adults only were considered (Fig. 3b; Table 2). There were no significant lunar patterns in size of seahorses landed. The size distribution of seahorses landed was bimodal in 1996 with peaks in the 80–90 mm and 140–150 mm SL sizes classes (Fig. 4), whereas the distributions were unimodal in 1997 and 1998, dominated by seahorses in the 150–160 mm SL size class (Fig. 4).

Table 2
Results of ANCOVA for temporal and fisher effects on size of seahorses landed

Variable	d.f.	*F*-ratio	*p*
(a) All seahorses: $r^2 = 0.30$, $n = 333$			
Year	2	35.8	<0.001
Month (sine function)	1	7.1	0.008
Year × month (sine)	2	4.5	0.011
(b) Adult seahorses only: $r^2 = 0.17$, $n = 333$			
Year	2	35.8	<0.001
Month (sine function)	1	7.1	0.017

Only significant effects and interactions are shown.

Life history stage was well described by logistic regression ($r^2 = 0.99$, $n = 15$, $p < 0.001$) giving $SL_{M50} = 102 \pm 0.3$ mm. Using this definition, the proportion of juveniles varied significantly from 34% in 1996 to 4% in 1997 and 0% in 1998 (Fig. 4). In 1996 there was a significant seasonal pattern in the occurrence of juveniles with a peak in February–April ($G = 339.7$, d.f. = 10, $p < 0.001$) but this pattern was not found in 1997 with fewer juveniles (Fig. 5a). No analysis was possible in 1998.

Sex ratio did not vary significantly from 1:1 nor were there any significant effects of year, season or lunar phase (all $p > 0.05$). However, sex ratio did vary with size, with progressively fewer males in the larger size classes above 170 mm SL, and only 25% of males in the largest size class (logistic regression: $r^2 = 0.87$, $n = 11$, $p < 0.001$). The proportion of pregnant males declined significantly over the course of the study from 48% in 1996 to 39% in 1997 and 31% in 1998 (Table 3). The proportion of pregnant males also varied significantly with

Table 3
Results of *G*-test of association for yearly and seasonal effects on the proportion of pregnant male seahorses

Variable	G_{adj}	d.f.	*p*
Years	28.6	2	<0.001
Months (1996)	28.0	11	<0.001
Months (1997)	130.0	9	<0.001
Months (1997)	12.6	10	0.025
Months (all years)	83.7	11	<0.001

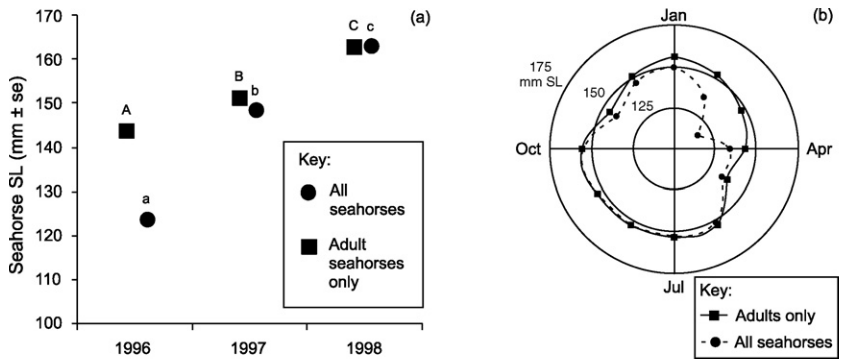

Fig. 3. Temporal variation in size of landed seahorses. (a) Yearly variation in mean SL (note that se for all points lies within the symbol). Within each data set, different letters indicate significant differences between values. (b) Polar plot of monthly variation in mean SL across all years.

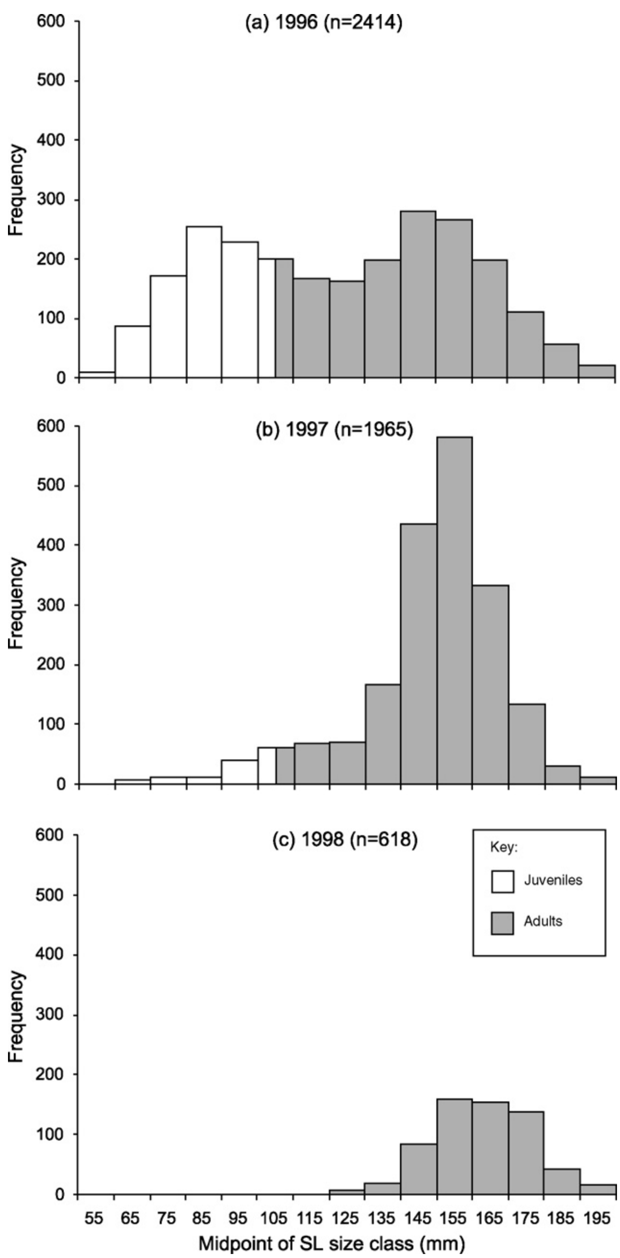

Fig. 4. Size–frequency histograms for seahorses landed in (a) 1996; (b) 1997; (c) 1998. Juveniles and adults were defined using SL_{M50} (see Section 2). Note that sampling effort in 1998 was approximately 1/4 of that in the other 2 years.

season in 1996 and 1997, with more pregnant males found in January–March and August–October (Fig. 5b). We found no effect of lunar phase on the proportion of pregnant males. However, we did find a significant positive relationship between male size and the proportion of pregnant males (logistic regression: $r^2 = 0.93$, $n = 11$, $p < 0.001$).

4. Discussion

Our characterizations of the fishery allow us to infer seahorse population dynamics and suggest management strategies. The seahorse fishery operating from Handumon village was strongly seasonal with catches also dependent on the skill of the fisher, but with no real spatial structure at the scale of our analyses. The fishery was spatially extensive, dispersed and catch rates were low in absolute terms. We also found changes in biological parameters of the catch over the study with an increase in the size of captured seahorses and reductions in the proportions of juveniles and pregnant males in the catch.

Concerns have been raised about the effectiveness of CPUE data to measure changes in exploited populations as changes in catchability or fisher behaviour can inflate or mask real patterns (e.g. Richards and Schnute, 1986; Harley et al., 2001). The opportunistic nature of seahorse capture as part of a multi-species fishery may also affect the accuracy of CPUE data. However, our CPUE data are probably robust indicators of seahorse population size, for the following reasons: (1) patterns in seahorse catch were similar between our two calculated measures of CPUE, one incorporating all fishing nights, the other only those nights when seahorses were caught; (2) the hand capture method means that there was no reason to expect ‘gear’ or fishing unit saturation; (3) there was no apparent extension of the area covered by the fishery; (4) there was no evidence of serial spatial depletions (and thus hyperstability in catches); (5) we found no significant differences in mean fisher skill (an indication of catchability) across years; (6) our regular contact with fishers allowed us to monitor other potential drivers of change in fisher behaviour (as discussed below). Nevertheless our CPUE data only provide us with relative, not absolute, measures of change in seahorse populations.

For artisanal fisheries CPUE is a relatively straightforward and cost-effective index of abundance. It is particularly use-

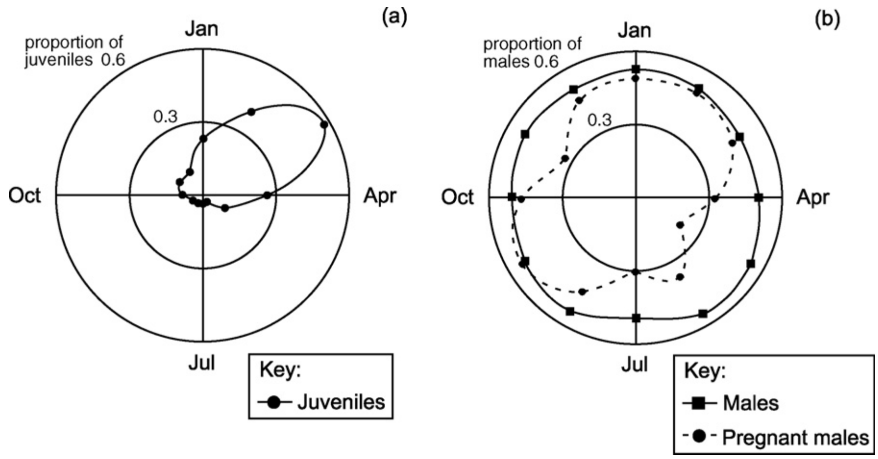

Fig. 5. Temporal variation in life history stage and reproductive state for landed seahorses. (a) Polar plot of month variation in proportion of juveniles for 1996 only. (b) Polar plot of month variation in proportion of males and pregnant males.

ful when data are collected on an appropriate spatial scale for the organisms being targeted (Freire and García-Allut, 2000; Castilla and Defeo, 2001). Despite potential problems, measurement of CPUE also has the advantage of engaging fishers with managers and researchers through log book or creel surveys as a first step towards co-management (Wilson et al., 2003).

The higher seahorse CPUE in 1999 may be attributed in part to a sudden boom in seaweed farming. High market prices lured many people to this activity in 1998, while dropping prices in 1999 led many to leave the business. Were increased engagement in seaweed farming to reduce fishing effort, then seahorse populations might have been less intensely fished in 1998, with the possibility of higher catches when fishers returned to seahorse extraction in 1999. Realistically, though, it appears that an earlier boom in seaweed farming in Bohol did not lead to less fishing (Sievanen et al., 2005). Moreover, subsistence fishers generally seek to accumulate livelihood options, not merely exchange them (Sen, 2003). And finally, booms in seaweed farming in other areas of the Philippines and in Indonesia have attracted new migrants to the area, adding to pressures on local resources (references in Sievanen et al., 2005).

It is possible that seaweed farming provoked increased seahorse CPUE by providing juvenile habitat rather than by diverting fishing pressure. Juvenile *H. comes* are known to inhabit reef-flat macroalgal beds (Morgan and Lourie, 2006). If seaweed farms provided an anthropogenic analogue to these habitats then juvenile survival would have been enhanced in 1998 and subsequent recruitment of this cohort to the fishery in 1999 would have led to increased CPUE. Based on the available estimates, *H. comes* appears to be a short-lived, fast-growing species which would recruit to the fishery in such a time scale (Meeuwig and Lafrance, 2001 in Morgan and Lourie, 2006). It would be necessary to investigate whether the species of red seaweed involved in farming, *Eucheuma* and *Kappaphycus*, can act as similar habitat to the species of *Sargassum* that normally provide shelter for juveniles (Morgan, unpublished data).

Seahorse catches over the course of the study were considerably lower than historical estimates provided by fishers. Fishers reported catches of 50–100 seahorses fisher^{-1} night^{-1} in the 1960s and 1970s, declining to 10–50 fisher^{-1} night^{-1} from 1980 to 1985 (Pajaro et al., 1997). A similar trend is reported for CPUE for other marine resources in the central Visayas (Green et al., 2004) and for demersal fisheries resources throughout the Philippines (Stobutzki et al., 2006). The decline in seahorses may be related to the very high density of fishers in northern Bohol, the highest in the central Visayas region (Green et al., 2004).

Although it would appear that the fishery was severely depleted, fishing on seahorses persisted. The most likely explanation is that fishers could obtain seahorses opportunistically while targeting many other species of nutritional or economic value, so would seek them whenever they went out spearfishing. Seahorses were perceived by fishers to make an important contribution to family income, as one of the few species always sold for cash (Vincent et al., unpublished data). The dearth of other income earning options and/or the relatively good economic returns for seahorses might also explain why they were persistently targeted.

The strongest temporal signal in seahorses catches was seen across seasons with high CPUE in February–June. This period of higher catches correlated with the local dry season which may have influenced the patterns through one or more of the following mechanisms: (1) better fishing conditions (visibility, wind etc.); (2) increased targeting of seahorses; (3) improved seahorse recruitment (Morgan and Vincent, in press); (4) changes in seahorse behaviour or migration (see Vincent and Sadler, 1995); (5) *Sargassum* die-back making animals more visible (Ang, 1986). Our observations and fishers' knowledge suggest some support for all of these hypotheses. No lunar patterns were observed in contrast to those known for many fisheries, including some for seahorses (Salini et al., 2001; Meeuwig et al., 2006).

In contrast to temporal patterns, we found no significant differences in catches among different fishing grounds in 1999. This consistency in CPUE across the 11 most fished sites conforms to a model of ideal free distribution in allocating fishing effort as might be expected in an open-access fishery (Gillis et al., 1993). The spatial distribution of fishing effort may arise from a relatively limited geographic extent of the fishery and fishers' good access to information on resource status. Over larger spatial scales or with increasing uncertainty about resource distribution, patterns of fishing effort will instead become aggregated (Pet-Soede et al., 2001). We anticipate that the closure of any fishing ground as a marine protected area would probably create a reallocation of fishing effort across the narrower suite of fishing grounds and a consequent drop in CPUE.

The apparent disappearance of juveniles and small seahorses from the catch during 1997 and 1998 is probably an artifact arising from a change in buyer availability. Fishers sold all seahorses in Handumon in 1996, the smaller ones live and the larger ones dead. The local live seahorse buyer then ceased operations in 1997, forcing fishers to sell their smaller seahorses (approximately less than 120 mm SL) in a neighbouring village before landing the remaining catch, including larger seahorses, in Handumon. The increase in standard length of adult seahorses over 1997 and 1998 would thus be reflect this decline in catch of juveniles.

Decreases in the proportion of brooding males over the study may be an indication of Allee effects, with males unable to find mates easily at low population densities (Gascoigne and Lipcius, 2004). However, an alternative explanation is that our conservation initiatives in Handumon had discouraged fishers from taking pregnant males. Some support for this hypothesis is provided by the deficit of males in the larger size classes, where they were more likely to be pregnant.

Co-management, as opposed to top–down regulation, has been strongly advocated for artisanal fisheries, with knowledge transfer a key element of the process (DeVantier et al., 2004; Orensanz et al., 2005). In developing co-management plans for seahorses, one of the first responsibilities is to provide fisheries data to the community for its assessment and use. Our study here suggests a number of possible management options: (1) no-take zones (reserves) would protect adults of this sedentary species (Perante et al., 2002) but could lead to intensification of fishing effort outside the reserve; (2) temporal closures during the period of high catch and recruitment (February–April) could reduce growth overfishing; (3) minimum size limits could also reduce growth overfishing; (4) maximum size limits might have disproportionate benefits for reproductive output if larger males were more fecund and more frequently pregnant (Foster and Vincent, 2004); (5) leaving pregnant males in the ocean would also increase reproductive output by at least one brood. Another obvious option, to reduce fishing capacity, will be difficult to achieve because of the economic distress of most fishers and their tendency to incorporate new income earning opportunities into their range of family activities, rather than using them to replace fishing (Sen, 2003).

Our analysis of seahorse catches provides biological knowledge and a fisheries-dependent resource assessment. However, social, economic and cultural factors are significant real determinants of success in managing marine resources (Salas and Gaertner, 2004). Management decisions – and community willingness to support them – will be based on an integration of information on all species in the lantern fishery, and a consideration of the effects on the entire multi-species fishery. Seahorses may be disproportionately influential in deciding management policy because of their cash value in a very impoverished region. In that way, they may serve as catalysts in the paradigm shift required to manage the world's artisanal fisheries.

Acknowledgements

This is a contribution from Project Seahorse. We thank Keith Martin-Smith for his assistance in analyzing data and drafting the manuscript. We sincerely thank the fishers of Handumon, the village captain, council, and citizens for their generous and kind support. We also thank Jonathan Anticamara, Rosemarie Apurado, Rosendo Bonghanoy Jr., Rosendo Botero, Delma Buhat, Erwin Brunio, Dale Marsden, and all of our Filipino scholars for their assistance with this work. We acknowledge with pleasure our partner in the Philippines, the Haribon Foundation for the Conservation of Natural Resources. This programme was launched with support from the Darwin Initiative for the Survival of Species (UK) and the 1994 Whitley Award. It has been maintained thanks to generous assistance from the John G. Shedd Aquarium (Chicago, USA), People's Trust for Endangered Species (UK), National Geographic Society (USA), Whitley Animal Protection Trust (UK), and WildInvest (UK), with in-kind support from Toshiba Computers and British Airways Assisting Conservation. J.M. was funded by the National Lottery Charities Board/Community Fund (UK) and by Guylian Chocolates Belgium.

References

Ang, P.O., 1986. Analysis of the vegetation structure of a *Sargassum* community in the Philippines. Mar. Ecol. Prog. Ser. 28, 9–19.

Barut, N.C., Santos, D.M.D., Mijares, L.L., Subade, R., Armada, N.B., Garces, L.R., 2003. Philippine coastal fisheries situation. In: Silvestre, G., Garces, L., Stobutzki, I., Luna, C., Ahmed, M., Valmonte-Santos, R.A., Lachica-Aliño, L., Munro, P., Christensen, V., Pauly, D. (Eds.), Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings, vol. 67. Penang, pp. 885–914.

Baum, J.K., Vincent, A.C.J., 2005. Magnitude and inferred impacts of the seahorse trade in South America. Environ. Cons. 32, 305–319.

Berkes, F., Mahon, R., McConney, P., Pollnac, R., Pomeroy, R., 2001. Managing Small-Scale Fisheries. IDRC, Toronto.

Campbell, S.J., Pardede, S.T., 2006. Reef fish structure and cascading effects in response to artisanal fishing pressure. Fish. Res. 79, 75–83.

Castilla, J.C., Defeo, O., 2001. Latin American benthic shellfisheries: emphasis on co-management and experimental practices. Rev. Fish Biol. Fish. 11, 1–30.

Castilla, J.C., Defeo, O., 2005. Paradigm shifts needed for world fisheries. Science 309, 1324–1325.

Cesar, H., Burke, L., Pet-Soede, L., 2003. The Economics of Worldwide Coral Reef Degradation. Cesar Environmental Economics Consulting, Arnhem, http://test.panda.org/downloads/marine/cesardegradationreport100203.pdf.

deBruyn, A.M.H., Meeuwig, J.J., 2001. Detecting lunar cycles in marine ecology: periodic regression versus categorical ANOVA. Mar. Ecol. Prog. Ser. 214, 307–310.

Defeo, O., Castilla, J.C., 2005. More than one bag for the world fishery crisis and keys for co-management successes in selected artisanal Latin American shellfisheries. Rev. Fish Biol. Fish. 15, 265–283.

Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S., Ahmed, M., 2003. Fish to 2020: Supply and Demand in Changing Global Markets. International Food Policy Research Institute/The WorldFish Center, Washington, DC/Penang, http://www.fishforall.org/outcomes/pdf/fish2020_policyreport.pdf.

DeVantier, L., Alcala, A., Wilkinson, C., 2004. The Sulu-Sulawesi Sea: environmental and socioeconomic status, future prognosis and ameliorative policy options. Ambio 33, 88–97.

FAO, 2004. The State of World Fisheries and Aquaculture 2004. Food and Agriculture Organization of the United Nations, Rome.

Foster, S.J., Vincent, A.C.J., 2004. The life history and ecology of seahorses, *Hippocampus* spp.: implications for conservation and management. J. Fish Biol. 65, 1–61.

Foster, S.J., Vincent, A.C.J., 2005. Enhancing sustainability of the international trade in seahorses with a single minimum size limit. Cons. Biol. 19, 1044–1050.

Freire, J., García-Allut, A., 2000. Socioeconomic and biological causes of management failures in European artisanal fisheries: the case of Galicia (NW Spain). Mar. Policy 24, 375–384.

Gascoigne, J., Lipcius, R.N., 2004. Allee effects in marine systems. Mar. Ecol. Prog. Ser. 269, 49–59.

Gasparini, J.L., Floeter, S.R., Ferreira, C.E.L., Sazima, I., 2005. Marine ornamental trade in Brazil. Biodivers. Conserv. 14, 2883–2899.

Giles, B.G., Truong, S.K., Huang, D.H., Vincent, A.C.J., 2005. The catch and trade of seahorses in Vietnam. Biodivers. Conserv. 15, 2497–2513.

Gillis, D.M., Peterman, R.M., Tyler, A.V., 1993. Movement dynamics in a fishery: application of the Ideal Free Distribution to spatial allocation of effort. Can. J. Fish. Aquat. Sci. 50, 323–333.

Green, S.J., Flores, J.O., Dizon-Corrales, J.Q., Martinez, R.T., Nuñal, D.R.M., Armada, R.B., White, A.T., 2004. The Fisheries of Central Visayas: Status and Trends. Coastal Resources Management Project of the Department of Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, Cebu City, www.oneocean.org/download/db_files/cv_fish_profile.pdf.

Harley, S.J., Myers, R.A., Dunn, A., 2001. Is catch-per-unit-effort proportional to abundance? Can. J. Fish. Aquat. Sci. 58, 1760–1772.

Kuster, C., Vuki, V.C., Zann, L.P., 2005. Long-term trends in subsistence fishing patterns and coral reef fisheries yield from a remote Fijian island. Fish. Res. 76, 221–228.

Lichuanan, W.Y., Gomez, E.D., 2000. Philippine Coral Reefs, Reef Fishes, and Associated Fisheries: Status and Recommendations to Improve their Management. Global Coral Reef Monitoring Network, Townsville. http://www.reefbase.org/download/download.aspx?type=1&docid=6068.

Lincoln-Smith, M.P., Pitt, K.A., Bell, J.D., Mapstone, B.D., 2006. Using impact assessment methods to determine the effects of a marine reserve on abundances and sizes of valuable tropical invertebrates. Can. J. Fish. Aquat. Sci. 63, 1251–1266.

Lourie, S.A., Vincent, A.C.J., Hall, H.J., 1999. Seahorses: An Identification Guide to the World's Species and their Conservation. Project Seahorse, London.

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 Coast. Manage. 47, 165–193.

McManus, J.W., 1997. Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. Coral Reefs 16 (Suppl.), S121–S127.

Meeuwig, J.J., Hoang, D.H., Truong, S.K., Job, S.D., Vincent, A.C.J., 2006. Quantifying non-target seahorse fisheries in central Vietnam. Fish. Res. 81, 149–157.

Morgan, S.K., Lourie, S.A., 2006. Threatened fishes of the world: *Hippocampus comes* Cantor 1850 (Syngnathidae). Environ. Biol. Fishes 75, 311–313.

Morgan, S.K., A.C.J., Vincent. The ontogeny of habitat associations in the tropical Tiger Tail seahorse (*Hippocampus comes*). J. Fish Biol., in press.

Ochiewo, J., 2004. Changing fisheries practices and their socioeconomic implications in South Coast Kenya. Ocean Coast. Manage. 47, 389–408.

Orensanz, J.M., Parma, A.M., Jerez, G., Barahona, N., Montecinos, M., Elias, I., 2005. What are the key elements for the sustainability of "S-fisheries"? Insights from South America. Bull. Mar. Sci. 76, 527–556.

Pajaro, M.G., Vincent, A.C.J. The catch, export and conservation implications of the seahorse trade in the Philippines, pre CITES. Fish. Manage. Ecol., in press.

Pajaro, M., Vincent, A.C.J., Buhat, D., Perante, N., 1997. The role of seahorse fishers in conservation and management. In: Proceedings of the First International Symposium in Marine Conservation, Hong Kong, pp. 118–126.

Pauly, D., 1997. Small-scale fisheries in the tropics: marginality, marginalization, and some implications for fisheries management. In: Pikitch, E.K., Huppert, D.D., Sissenwine, M.P. (Eds.), American Fisheries Society Symposium 20 Global Trends: Fisheries Management. Bethesda, MD, pp. 1–10.

Perante, N.C., Pajaro, M.G., Meeuwig, J.J., Vincent, A.C.J., 2002. Biology of a seahorse species, *Hippocampus comes* in the central Philippines. J. Fish Biol. 60, 821–837.

Pet-Soede, C., Van Densen, W.L.T., Hiddink, J.G., Kuyl, S., Machiels, M.A.M., 2001. Can fishermen allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia. Fish. Manage. Ecol. 8, 15–36.

Richards, L.J., Schnute, J.T., 1986. An experimental and statistical approach to the question: is CPUE an index of abundance? Can. J. Fish. Aquat. Sci. 43, 1214–1227.

Salas, S., Gaertner, D., 2004. The behavioural dynamics of fishers: management implications. Fish Fish. 5, 135–167.

Salin, K.R., Yohannan, T.M., Nair, C.M., 2005. Fisheries and trade of seahorses, *Hippocampus* spp., in southern India. Fish. Manage. Ecol. 12, 269–273.

Salini, J., Brewer, D.T., Farmer, M.J., Jones, P., 2001. Lunar periodicity of prawns and by-catch in trawls from the Gulf of Carpentaria, northern Australia. Mar. Biol. 138, 975–983.

Sen, B., 2003. Drivers of escape and descent: changing household fortunes in rural Bangladesh. World Dev. 31, 513–534.

Sievanen, L., Crawford, B., Pollnac, R., Lowe, C., 2005. Weeding through assumptions of livelihood approaches in ICM: seaweed farming in the Philippines and Indonesia. Ocean Coast. Manage. 48, 297–313.

Sokal, R.R., Rohlf, F.J., 1995. Biometry: The Principles and Practice of Statistics in Biological Research, third ed. W.H. Freeman and Co., New York.

Stobutzki, I.C., Silvestre, G.T., Abu Talib, A., Krongprom, A., Supongpan, M., Khemakorn, P., Armada, N., Garces, L.R., 2006. Decline of demersal coastal fisheries resources in three developing Asian countries. Fish. Res. 78, 130–142.

UNEP, 2006. Challenges to International Waters—Regional Assessments in a Global Perspective. United Nations Environment Programme, Nairobi.

Vincent, A.C.J., Sadler, L.M., 1995. Faithful pair bonds in wild seahorses, *Hippocampus whitei*. Anim. Behav. 50, 1557–1569.

Vincent, A.C.J., 1996. The International Trade in Seahorses. TRAFFIC International, Cambridge.

Vincent, A.C.J., 2006. Non-food and luxury reef fisheries, and their potential management. In: Côté, I.M., Reynolds, J.D. (Eds.), Coral Reef Conservation. Cambridge University Press, Cambridge, pp. 183–236.

Wilkinson, C. (Ed.), 2004. Status of Coral Reefs of the World 2004. Australian Institute of Marine Science, Townsville.

Wilson, D.C., Nielsen, J.R., Degnbol, P. (Eds.), 2003. The Fisheries Co-management Experience. Kluwer, Dordrecht.

Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice Hall, New Jersey.