

Using patrol records and local perceptions to inform management and enforcement in a marine protected area in Cambodia

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មូលនិយមសង្ខេប

ការយល់ពីភាពមិនអនុលោមទៅតាមច្បាប់ដែលបានចែងស្តីពីការអភិរក្សគឺ មានសារៈសំខាន់ណាស់ សម្រាប់ការគ្រប់គ្រងតំបន់ការពារធម្មជាតិដែនសមុទ្រមានប្រសិទ្ធភាព។ ទោះជាយ៉ាងណាការតាមដានសកម្មភាពខុសច្បាប់គឺជាបញ្ហាប្រឈមដ៏សំខាន់មួយ ហើយអ្នកអនុវត្តការតាមដានទាំងនោះ ទាមទារឲ្យមានវិធីសាស្ត្រមួយដែលអាចកាត់បន្ថយភាពលម្អៀង និង ការចំណាយថវិកាច្រើន។ យើងបានធ្វើការអង្កេតពីទំហំ របាយ និង ដើមហេតុនៃសកម្មភាពនេសាទខុសច្បាប់ ព្រមទាំងកម្រិត និង របាយនៃកិច្ចប្រឹងប្រែងក្នុងការរារាំងល្បាតនៅ “តំបន់គ្រប់គ្រងធនធានជលផលសមុទ្រ ប្រជុំកម្រងកោះរ៉ុង” ក្នុងអំឡុងពេលមួយឆ្នាំក្រោយការចេញប្រកាសនៅក្នុងប្រទេសកម្ពុជា។ បន្ទាប់មកយើងបានបញ្ជូលគ្នានូវព័ត៌មាន ដែលបានកំណត់ត្រាអំពីការល្បាតចំនួន១៦១លើក ធ្វើឡើងនៅចន្លោះខែមិថុនា ឆ្នាំ២០១៦ និង ខែមីនា ឆ្នាំ២០១៧ រួមជាមួយនឹងលទ្ធផលទទួលបានពីការស្រាវជ្រាវសេដ្ឋកិច្ចសង្គម ដែលត្រូវបានធ្វើឡើងក្នុងអំឡុងខែមីនា ឆ្នាំ២០១៧។ ចំនួន១៦៣គ្រួសារត្រូវបានជ្រើសរើសសម្រាប់ការស្រាវជ្រាវផ្នែកសេដ្ឋកិច្ចសង្គម ដែលក្នុងនោះមាន៣៣គ្រួសារគឺជាអ្នកនេសាទ។ ចម្លើយដែលបានពីគ្រួសារទាំងនោះត្រូវបានយកមកប្រៀបធៀបនឹងទិន្នន័យសម្ភាសន៍បែបពាក់កណ្តាលមានរចនាសម្ព័ន្ធ (semi-structured interviews) ដែលផ្តល់តាមការសម្ភាសន៍ជាមួយជនបង្គោលសំខាន់ៗចំនួន២១នាក់រួមមាន៖ អ្នកនេសាទនៅមូលដ្ឋាន ប្រតិបត្តិករទេសចរណ៍ និង អង្គការក្នុងតំបន់ដើម។ លទ្ធផលរកឃើញបានបង្ហាញថា អ្នកនេសាទខុសច្បាប់ភាគច្រើនគឺជាប្រជាជនមកពីតំបន់ផ្សេង ដែលភាគច្រើនពួកគេចូលមកនេសាទនៅពេលយប់(នៅពេលមិនសូវមានសកម្មភាពល្បាត) សកម្មភាពនេសាទខុសច្បាប់ទាំងនោះមានរបាយមិនស្មើគ្នាទេ និង នៅពេលពេញផ្ទៃសមុទ្រ។ ការអនុលោមទៅតាមច្បាប់នៃតំបន់ការពារធម្មជាតិកើតមានឡើងដោយសារ ការយល់ដឹង និង ភាពស្របច្បាប់នៃការនេសាទ រីឯកត្តាចម្បងៗដែលបង្កឲ្យមានសកម្មភាពនេសាទខុសច្បាប់រួមមាន ការលើកទឹកចិត្តផ្នែកសេដ្ឋកិច្ចជីវភាពគ្រួសារ និង កង្វះខាតការយល់ដឹង។ តាមលទ្ធផល យើងសូមផ្តល់អនុសាសន៍ឲ្យមានការបង្កើនការផ្សព្វផ្សាយចំណេះដឹង និង ជួយទ្រទ្រង់ផ្នែកអនុវត្តច្បាប់នៅតំបន់ការពារធម្មជាតិ ព្រមទាំងបង្កើនសកម្មភាពល្បាតឲ្យកាន់តែមានប្រសិទ្ធភាព ដើម្បីបំបាត់អាកប្បកិរិយាមិនគោរពច្បាប់។ យើងក៏សូមផ្តល់យោបល់ ឲ្យមានការល្បាតធ្វើឡើងនៅតំបន់គោលដៅសំខាន់ៗដែលគ្មានការគោរពច្បាប់ កាត់បន្ថយការព្យាករណ៍របស់ពួកគេ (សកម្មភាពល្បាត)ដោយបង្កើនសកម្មភាពល្បាតនៅពេលយប់។ ការសិក្សាស្រាវជ្រាវរបស់យើងក៏បានលើកឡើងពីបញ្ហាប្រឈមមួយចំនួននៅក្នុងការពិនិត្យតាមដានបញ្ហាមិនគោរពច្បាប់នៅក្នុងតំបន់ការពារធម្មជាតិដែនសមុទ្រ ព្រមទាំងបង្ហាញពីវិធីដែលអាចប្រើប្រាស់គំនិតយោបល់របស់សហគមន៍មូលដ្ឋាន ទៅបំពេញបន្ថែមទិន្នន័យដែលបានពីការល្បាត និង ធ្វើអត្តសញ្ញាណពីភាពទន់ខ្សោយនៅក្នុងប្រព័ន្ធគ្រប់គ្រង។

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Abstract

Understanding non-compliance with conservation rules is crucial for effective management of marine protected areas. However, monitoring illegal activities is challenging and practitioners require practical methods that minimise biases and costs. We investigated the scale, distribution and motivations for illegal fishing and the level and distribution of patrol effort in the Koh Rong Archipelago Marine Fisheries Management Area one year after its proclamation in Cambodia. To this end, we combined information from records of 161 patrols undertaken between June 2016 and March 2017 and the results of a socio-economic survey conducted in March 2017. One hundred and sixty-three households participated in the socio-economic survey, including 33 fishers. Their responses were compared with data provided by semi-structured interviews with 21 key informants including local fishermen, tourism operators and local organisations. Our results suggest that illegal fishing is mostly conducted by outsiders, occurs mainly at night (when patrols are rare), and is unequally distributed across the seascape. Compliance with the rules of the protected area appeared to be driven by awareness and perceived legitimacy of the rules, whereas the main motivations for illegal fishing included economical or livelihood incentives and a lack of awareness. Drawing from our results, we recommend increasing awareness of and support for the laws of the protected area and improving the efficiency and effectiveness of patrols to discourage rule-breaking behaviour. We also suggest that patrols should target important areas of non-compliance, decrease their predictability and that the proportion of night patrols should be increased. Our study highlights some of the challenges in monitoring non-compliance in marine protected areas and demonstrates how local perceptions can be used to complement data from patrols and identify weaknesses in management systems.

Keywords Illegal fishing, law enforcement, local knowledge, marine protected areas, non-compliance, patrols.

Introduction

The Convention on Biological Diversity's targets for 2020 (CBD, 2010) and more recent Sustainable Development Goals for 2030 (UN, 2015) have led to an increase in the coverage of marine protected areas worldwide (Chape *et al.*, 2005; Roberts *et al.*, 2005; Wood *et al.*, 2008). However, legal designation of marine protected areas cannot be effective without adequate management and high and widespread compliance with their rules and regulations (Campbell *et al.*, 2012; Pieraccini *et al.*, 2017). Non-compliant behaviours such as illegal fishing must be addressed to prevent negative impacts on food security, economic losses, social conflicts, over-exploitation and environmental degradation (MRAG, 2005; BOBLME, 2015).

Constant adaptation and a good knowledge of local context are required to effectively manage non-compliance and combat illegal fishing. It is therefore crucial that protected area managers have an in-depth and current understanding of the specific factors that describe, influence and prevent compliance with the rules of their site (Arias, 2015). However, limited funds (James *et al.*, 2001) and the sensitive and covert nature of non-compliance (Gavin *et al.*, 2010; Arias, 2015) hinder effective monitoring and research of illegal activities in protected areas.

In most protected areas, ranger patrols routinely record information on illegal activities which can be used

to determine the scale and characteristics of illegal activities, as well as their spatial and temporal distributions (Gavin *et al.*, 2010). Despite its availability, such data has historically been rarely used to inform management due to the lack of standardisation in collection practices, imprecise spatial references, laborious data-entry and a lack of skills for analysis (van Cayzeele, 2017).

Recently developed systems such as MIST (Management Information System) and SMART (Spatial Monitoring and Reporting Tool) facilitate and standardize data collection, analysis and reporting of patrol records to encourage their use within adaptive management frameworks (www.ecostats.com, <http://smartconservationtools.org>). However, patrol records are still vulnerable to significant biases that may limit their utility, partly because they are collected opportunistically and because the main objective of patrols is to deter rule-breaking (Keane *et al.*, 2011).

In June 2016, Cambodia designated its first formally established multiple-use marine protected area (i.e. Marine Fisheries Management Area, MFMA) in the Koh Rong Archipelago (KRA) (Mizrahi *et al.*, 2016). Its designation came after more than five years of baseline social and biophysical research alongside intensive consultations and collaborative work with government agencies, NGOs, local authorities, tourism operators and community fisheries (CFis). Across Cambodia, CFis are legally

recognised community-based organisations representing local marine resource users (RGC, 2005) and these played a central role in the design and management of the KRA MFMA (Mulligan & Longhurst, 2014; Mizrahi *et al.*, 2016). Due to the absence of regular government patrols, community patrol teams were formed by elected members of CFIs within the KRA. Unless accompanied by staff of the Fisheries Administration (FiA), Royal Navy or police, CFI patrol members do not have the authority to enforce the MFMA rules (i.e., give sanctions or arrest offenders) beyond giving verbal or written warnings to offenders. Patrol targets (e.g., total number of patrols to be conducted in the MFMA or parts of the MFMA) are established with support from the FiA and conservation NGOs in monthly and quarterly meetings, whereas the specific routes and timing of patrols is decided by the local CFIs and when present on patrols, FiA officers. During patrols, teams record information on illegal activities using a logbook and a hand-held GPS and inform fishers and other users of the rules of the MFMA. All data collected by the patrol teams are later uploaded to a SMART database. These data are analysed by FiA with support from Fauna & Flora International and are reviewed during CFI and management meetings to inform subsequent patrol strategies.

Since the adoption of SMART monitoring, weaknesses associated with poor data collection practices and biases inherent to patrol data have been identified. As the management plan for the KRA MFMA specifies that regular social surveys must be conducted (Mizrahi *et al.*, 2016) to monitor changes in the socio-economic circumstances, perceptions and behaviours of local communities, it was decided to use these to complement non-compliance data obtained from patrol records.

Social surveys using direct questioning are regarded as a cost-effective method to assess illegal exploitation of natural resources and can provide information on many aspects that describe illegal behaviour (Arias, 2015). However, these can experience bias due to the social, legal, or moral controversy of non-compliance (Gavin *et al.*, 2010; St. John *et al.*, 2010; Solomon *et al.*, 2015). While indirect questioning techniques have been developed to reduce respondent sensitivity and minimise such biases, these often require large sample sizes and sophisticated analyses and can be misunderstood by participants (Nuno *et al.*, 2013; Nuno & St. John, 2014). As a consequence, an easier and less costly alternative to reduce sensitivity is to ask respondents about their perceptions of the behaviour of others instead of their own engagement in illegal activities (Bergseth *et al.*, 2015).

Our study combined patrol records and social research methods to investigate illegal fishing in the KRA

MFMA and explores the biases and limitations of each approach as well as the benefits of combining multiple methods. Our objectives were to assess the prevalence of illegal fishing and to identify underlying motivations to ultimately inform future management strategies. We also aimed to determine weaknesses in the current enforcement system and to provide recommendations for its improvement by exploring the spatial and temporal distributions of illegal fishing and patrols in the MFMA.

Methods

Study site

The KRA MFMA lies 20 km off the coastal town of Sihanoukville in the Gulf of Thailand and encompasses 403.69 km² including fringing coral reefs, seagrass beds and mangroves (Fig. 1). Declared by the Royal Government of Cambodia's Ministry of Agriculture, Forestry and Fisheries, the KRA MFMA aims to "protect, conserve, and use marine fisheries resources sustainably, [...] and contribute to poverty reduction" (Mizrahi *et al.*, 2016). The MFMA includes six different management zones

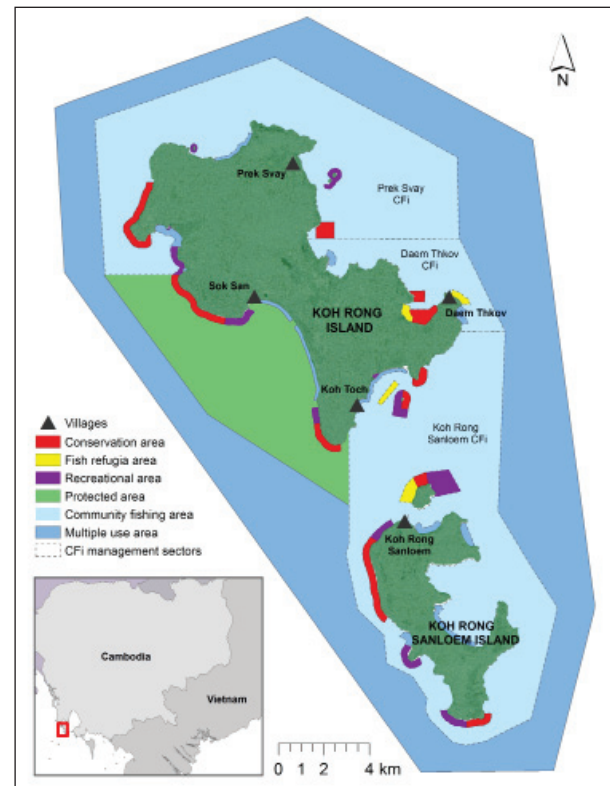


Fig. 1 Koh Rong Archipelago Marine Fisheries Management Area and its management zones.

(Fig. 1; Mizrahi *et al.* 2016). Some zones restrict access (e.g., conservation areas) or only allow non-extractive recreational activities (e.g., recreational areas), whereas others allow non-damaging small-scale fishing (e.g., protected area). Large-scale (i.e., industrial) fishing is forbidden within the entire MFMA, but non-damaging medium-scale fishing (i.e., use of middle-scale and individual fishing gears) is permitted in the outer multiple-use area surrounding the Community Fishing and Protected areas (Fig. 1) (FiA, 2007).

Approximately 546 permanent households occur in the archipelago in five main villages: Prek Svay, Daem Thkov, Koh Toch, Sok San and Koh Rong Sanloem (village chiefs, pers. comm. 2017). For most people, infrastructure for water supply and sanitation is generally poor although road networks and tourism facilities are rapidly increasing (Leng *et al.*, 2017; Mulligan & Longhurst, 2014). Livelihood strategies include fishing and tourism but vary significantly between the five villages (Leng *et al.*, 2017). The recent increase in tourism development, particularly in the villages of Koh Toch and Koh Rong Sanloem, is leading to diversification and changes in livelihoods (Leng *et al.*, 2017).

Although the KRA MFMA is a government-led initiative with a management structure at the provincial level (Preah Sihanouk Province), planning and implementation for the protected area has adopted a co-management approach, with extensive consultation and participation of local stakeholders (Mizrahi *et al.*, 2016). Communities are largely involved in the management and governance of the MFMA through CFis. Three CFis with four community patrol teams exist within the MFMA, one patrol team for the Prek Svay CFi, one for Daem Thkov CFi and two for the Koh Rong Sanloeam CFi (one around Koh Toch and one around Koh Rong Sanloem). The patrol team in Prek Svay occasionally visits waters in the vicinity of Sok San. Patrols typically last 2–3 hrs and occasionally up to 4 hrs. Although CFis members lead these patrols, they cannot enforce the law unless accompanied by officials from FiA (which occurs on approximately half of monthly patrols), the Royal Navy or the police force.

Social survey

A social household survey was conducted across the five main permanent settlements in the KRA in March 2017 as part of a study of local attitudes, awareness and perceptions regarding the MFMA. Structured face-to-face interviews were conducted by three Cambodian assistants, including university students and former staff of conservation NGOs. Overall, 163 households were randomly surveyed from the estimated 546 house-

holds present (village chiefs, pers. comm. 2017) (Table 1). Where possible, the survey targeted household heads (usually male, >70% of households). Participants ($n=51$ females and $n=112$ males) were permanent residents of the KRA and ranged between 18 and 73 years in age. These included 77 people working in small local businesses, 45 tourism operators, 33 fishers, two farmers, and six people with other occupations. All interviewees verbally consented to participate in the survey.

Our questionnaire was prepared in English and translated into Khmer language. It included questions on i) the demographics of the respondent and livelihood strategies of their household, ii) their perceptions on nature, timing, spatial distribution and drivers of non-compliance with MFMA rules, and iii) their perceptions on the spatial distribution of law enforcement. Questions were framed in the period since the creation of the MFMA and employed phrases such as “over the last year”. All questions were open-ended to avoid influencing respondent answers (Schaeffer & Presser, 2003), though potential responses were pre-coded to facilitate recording and minimize costs of data processing (Lavrakas, 2008). Responses not matching pre-coded options were recorded in Khmer and translated during data entry by bilingual staff. Sensitive questions investigating illegal fishing did not refer to a respondents’ engagement in illegal activities but to their perceptions regarding the behaviour of others (Bergseth *et al.*, 2015). This was considered appropriate to avoid bias and evasive answers associated with direct questioning (Warner, 1965; Fisher, 1993) and the technical and financial resources required by other indirect techniques (Nuno & St. John, 2014).

We used participatory-mapping to obtain spatially explicit information on the perceived distribution of illegal fishing and patrols. This entailed use of a gridded map with 511 coded grid cells measuring 1 km². Answers were recorded as specific references to grid cell numbers and less specific information such as local area names where the respondent was unable to indicate areas on the map. Ninety-nine participants provided spatial references on the distribution of illegal fishing in the MFMA, although the responses of four participants were excluded due to imprecise references (i.e., “south island” [$n=1$], “western south island” [$n=2$], “north of the north island” [$n=1$]). Our effective sample size thus comprised 95 participants (including 31 fishers and 18 boat and dive operators). Perceived patrol effort distribution was mapped in the same way based on an effective sample size of 65 participants (including 25 fishers and 12 tourism operators). This excluded the responses of 39 participants for being overtly vague (e.g., “everywhere” [$n=12$], “Koh Rong” [$n=16$], “Koh Rong Sanloem” [$n=6$]).

Table 1 Estimated number of households and study sample sizes for five villages in the Koh Rong Archipelago Marine Fisheries Management Area. Figures in parenthesis represent percentages.

	Prek Svay	Daem Thkov	Koh Toch	Sok San	Koh Rong Sanloem	Total
Number of households (village chiefs, pers. comm.)	145 (26.6)	78 (14.3)	103 (18.9)	109 (20)	111 (20.3)	546 (100)
Households interviewed	40 (24.5)	24 (14.7)	33 (20.3)	33 (20.3)	33 (20.3)	163 (100)
Key informant interviews	2	2	6	4	7	21

We complemented, contrasted and contextualised the results of the household survey through semi-structured interviews with 21 local key informants (Table 1). The objective of these interviews was to better understand results obtained from the structured household questionnaire. Foreign tourism operators ($n=8$) and members of local organisations ($n=2$) were recruited as key informants using “snowball sampling” (Patton, 1990). This began with a group of individuals known to the authors who were asked to introduce other individuals. In addition, local fishers ($n=7$) and tourism operators ($n=4$) interviewed for the household survey who were particularly talkative and knowledgeable on the issues raised were also interviewed as key informants. Key informants were considered to be less likely to blame outsiders and were thus useful to contrast information from local fishers and tourism operators. The questions posed to key informants were broad and open-ended and addressed the same topics as the household survey: i) background of respondent, ii) perceptions of illegal fishing, iii) perceptions of law enforcement, and iv) participatory mapping.

Patrol-based data

Patrol routes and illegal activities observed in the KRA MFMA have been systematically recorded using SMART since October 2015. Rangers register their patrol routes using a hand-held GPS and record infractions observed in logbooks. Information on infractions includes the type of offence, its location, actions taken by rangers and information on the offenders (e.g., number and origin of offenders). To ensure comparability with data obtained from the social surveys, only data from patrols undertaken between 16 June 2016 (i.e., the official proclamation of the MFMA) and 16 March 2017 (i.e., the start of the social survey) were included in the study. We also discarded observations which did not clearly refer to illegal fishing (e.g., illegal entry) where possible, because perception data were exclusively based on this infraction.

Data analysis

We used descriptive statistics to analyze data obtained from the household survey. Some responses were re-coded prior to data analysis (Appendix 1). Responses of fishers and other respondents were contrasted using Mann-Whitney U tests for ordinal variables and Chi-square tests for categorical variables, or Fisher’s exact test where test assumptions were not met (i.e., when the expected count cell for any combination of variables was <5). Data collected from key informant interviews were analysed qualitatively by scanning, ordering, summarising and comparing participant responses.

We calculated the number of infractions (i.e., illegal fishing) detected per hour of patrol (IDPH) and compared these between day and night patrols. Patrols that lasted less than one hour or over five hours ($n=15$) were excluded due to issues in the recording of their duration. We considered night patrols as those that included at least one hour of patrol effort between 18:00 and 06:00 hrs (i.e., sunset and sunrise). We used Kolmogorov-Smirnoff to test data normality and Mann-Whitney U to test for differences between night and day patrols, as data were not normally distributed.

To analyze the perceived distributions of illegal fishing and patrols, we used the number of people reporting a specific location (i.e., grid cell) as a proxy for the relative intensity of illegal fishing and awareness of patrol occurrence therein, respectively. Actual patrol effort was mapped using the number of patrols recorded per grid cell in SMART. Levels of illegal fishing reported by patrols were calculated as the number of infractions (i.e., illegal fishing) detected per patrol (IDPP). The IDPP map was restricted to a smaller area ($151 \times 1 \text{ km}^2$ grid cells) than other maps because IDPP could not be calculated for unpatrolled cells ($360 \times 1 \text{ km}^2$ grid cells). Other maps included all grid cells within the MFMA (Fig. 1). The overall spatial association between perceptions and patrol-data was calculated using Spearman correlation coefficients based on count and IDPP values.

To facilitate visual comparisons of maps, we transformed all variables (i.e., frequency of citations, number of patrols, IDPP) into a common scale with four categories: high, moderate, low and non-existent. We assigned the 3% of grid cells with the highest values to the “high” category and the 10% of cells with the next highest values to the “moderate” category. The remaining grid cells were classified as “low” or “non-existent” (i.e., where values were zero).

We systematically identified hotspot areas in each map. These comprised grid cells within the “high” category and a buffer totalling 35 km². Buffering was considered necessary to prevent unrealistic disagreement between maps because i) patrols surveying a particular location might detect infractions beyond the coordinates recorded due to the extended view-shed at sea, and because ii) spatial references provided by respondents can be imprecise. We assessed the overlap of hotspots between maps using the phi-coefficient statistic, which measures the strength of the relationship between two dichotomous distributions (i.e., presence/absence of hotspots; Brown *et al.*, 2017).

Maps were created using the ArcGIS software v. 9.3.1 (ESRI, USA) and spatial associations were analysed using R software v. 3.4.1 (R Development Core Team, 2017). All other analyses employed IBM SPSS Statistics for Windows v. 23.0 (IBM Corp., USA).

Results

Prevalence of non-compliance in the KRA MFMA

Excluding 17 and 31 respondents who did not know the prevalence of non-compliance among local fishers and outsiders respectively, the majority of respondents (88%) reported that rule-breaking was low among local fishers, whereas 68% reported it as medium or high among outsiders (Cambodians from the mainland, Vietnamese, and Thai) (Table 2). Similarly, all key informants reported low or average levels of illegal fishing among

locals but average to high levels among outsiders. One participant supported his statements by showing videos and pictures of non-Cambodian fishers using illegal techniques and fishing in restricted areas.

The perceptions of fishers significantly differed from other respondents (outsider compliance $\chi^2=13.24$, $p<0.01$; local compliance: $F=10.26$, $p<0.01$), with fishers reporting a higher prevalence of illegal fishing. However, the majority of both groups reported that non-compliance is rare among locals (72% of fishers and 93% of other respondents) and occasional or frequent among outsiders (94% and 60%, respectively) (Table 2).

Ranger patrols recorded 38 fishing offences within the MFMA during the study period. According to the SMART database for the MFMA, offenders originated from Sihanoukville Province ($n=31$), Koh Kong Province ($n=3$), unknown origin ($n=1$), and “other” ($n=1$). The two remaining records lacked information on the origin of the offenders.

Drivers of compliance and non-compliance

A total of 140 and 111 respondents shared their perceptions on the drivers of compliance and non-compliance, respectively (Fig. 2). Thus, 21 respondents reported to not be aware of the factors driving compliance, 35 reported to not know what drives non-compliance, whereas 15 participants did not believe that non-compliance existed in the KRA MFMA.

Legitimacy of the MFMA rules was by far the most reported driver of compliance in the KRA MFMA (82.1% of respondents). Law enforcement through sanctions was the next most cited driver for compliance (29.3%). Norms and morals and economic and livelihood-related incentives were mentioned only occasionally as reasons for compliance. However, economic and livelihood incentives were the most frequently cited drivers of non-compliance (cited by nearly half of respondents), followed by lack of knowledge of the rules, norms and

Table 2 Perceived prevalence of illegal fishing by outside and local fishers in the Koh Rong Archipelago Marine Fisheries Management Area. Figures represent percentages of the number of respondents.

	Illegal fishing by outsiders			Illegal fishing by locals		
	Fishers ($n=31$)	Others ($n=101$)	Total ($n=132$)	Fishers ($n=32$)	Others ($n=114$)	Total ($n=143$)
Low	6.5	39.6	31.8	71.9	93	88.4
Medium	35.5	29.7	31.1	21.9	4.4	8.2
High	58.1	30.7	37.1	6.3	2.6	3.4

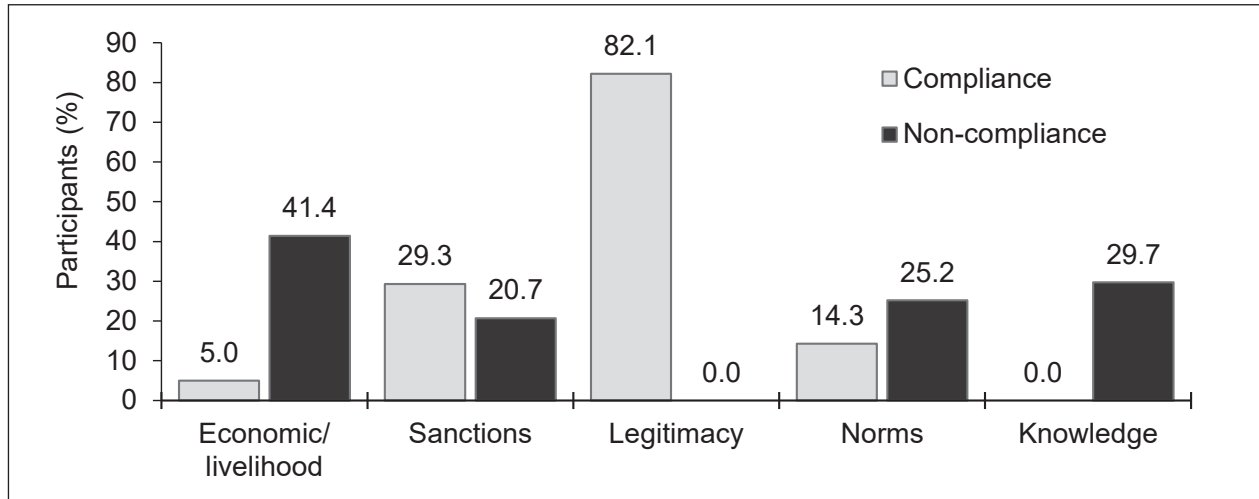


Fig. 2 Drivers of compliance ($n=140$) and non-compliance ($n=111$) among fishers as perceived by residents in the Koh Rong Archipelago Marine Fisheries Management Area.

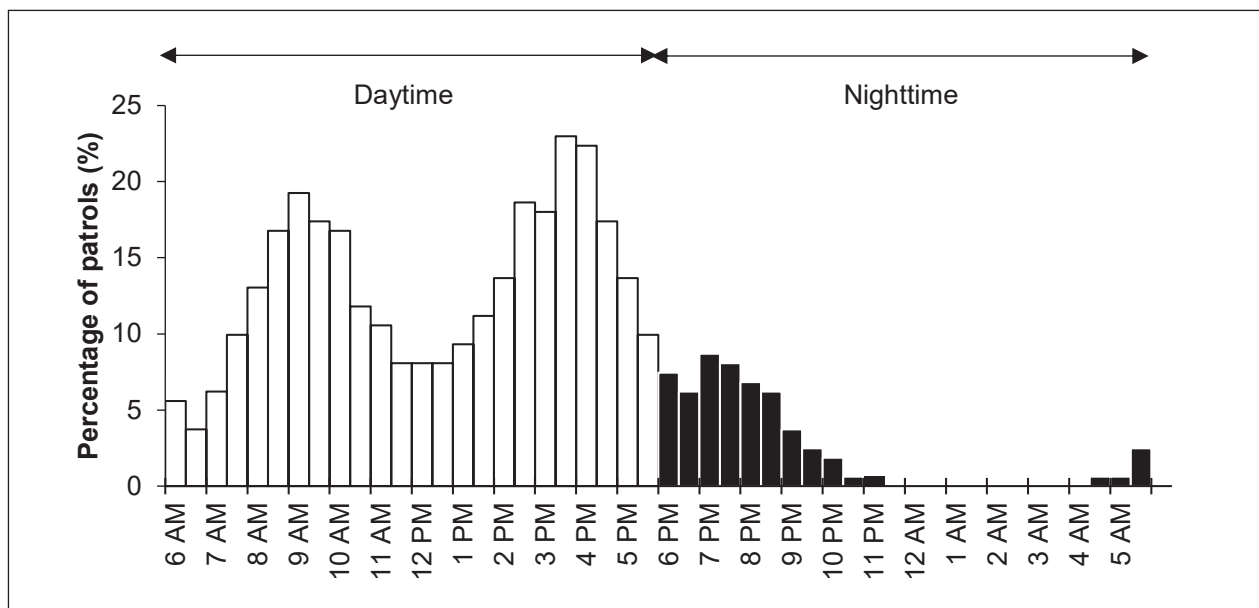


Fig. 3 Hourly distribution of patrols ($n=94$) between June 2016 and March 2017 in the Koh Rong Archipelago Marine Fisheries Management Area.

morals (e.g., “others do not follow the rules”, $n=23$) and weak enforcement.

Temporal distribution of non-compliance and enforcement effort

Of 121 respondents, 80.2% believed that illegal fishing occurs mainly at night, 11.6% in daytime and 8.3% perceived no differences between night and day.

There were 161 patrols since the formal proclamation of the MFMA, but only 94 were retained in analysis of patrol timing. The temporal distribution of patrols was highly skewed, with 84.6% occurring in daytime (Fig. 3). Only 6.4% of patrols included at least one hour of night patrolling. However, these registered more than four times as many infractions per patrol hour compared to day patrols (IDPH night= 0.711 ± 0.43 , IDPH day= 0.15 ± 0.34 ; $U=448.5$, $p=0.001$).

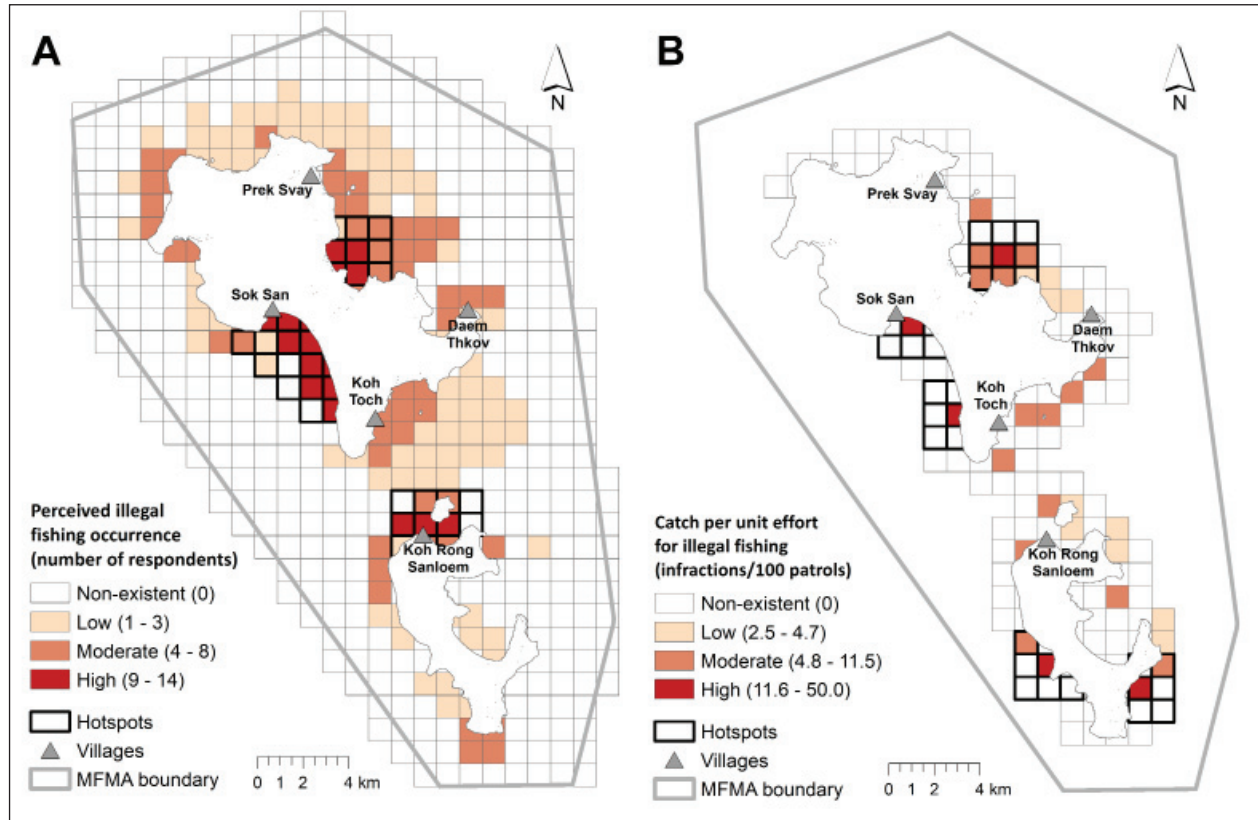


Fig. 4 Distribution of illegal fishing in the Koh Rong Archipelago Marine Fisheries Management Area according to A) local perceptions and B) patrol records.

Spatial distribution of non-compliance and enforcement effort

According to 99 respondents, areas in the vicinity of all villages and most of the coast of Koh Rong Island experienced at least moderate frequencies of illegal fishing (Fig. 4A). The highest levels of illegal fishing appeared to occur in three areas of the MFMA. Two of these were around Koh Rong Island (in the immediate vicinity of Sok San and between Prek Svay and Daem Thkov) and one around Koh Rong Sanloem Island (northern portion of the island).

Illegal fishing hotspots identified using patrol data (Fig. 4B) roughly coincided with those reported by respondents around Koh Rong Island, but no overlap of fishing hotspots around Koh Rong Sanloem Island was observed. There was no global association in the distribution of illegal fishing between patrol data and that reported by respondents (Fig. 4A and 4B; Spearman’s $\rho=0.15$, $p>0.05$), although hotspots showed low but significant convergence ($\phi=0.39$, $p<0.001$).

Most of the 161 ranger patrols undertaken since MFMA designation occurred in the proximity of the Daem Thkov, Koh Toch and Koh Rong Sanloem (Fig. 5B). The vicinity of Prek Svay village experienced moderate patrol effort, as did the eastern and north-western coast of Koh Rong Sanloem Island. Very low or no patrol effort was devoted to the rest of the seascape.

There was a moderate association between the number of people reporting high patrol effort in a grid cell with the actual number of patrols conducted there (Fig. 5A and 5B; Spearman’s $\rho=0.54$, $p<0.001$). The association was stronger with regard to hotspots of patrol effort and frequently cited grid cells ($\phi=0.69$, $p<0.001$).

Discussion

Although understanding illegal behaviour in protected areas is crucial for the design of effective management strategies, the sensitive nature of the topic (Gavin *et al.*, 2010; Arias, 2015) and funding deficits in low-income countries (James *et al.*, 2001) pose challenges to its study and monitoring.

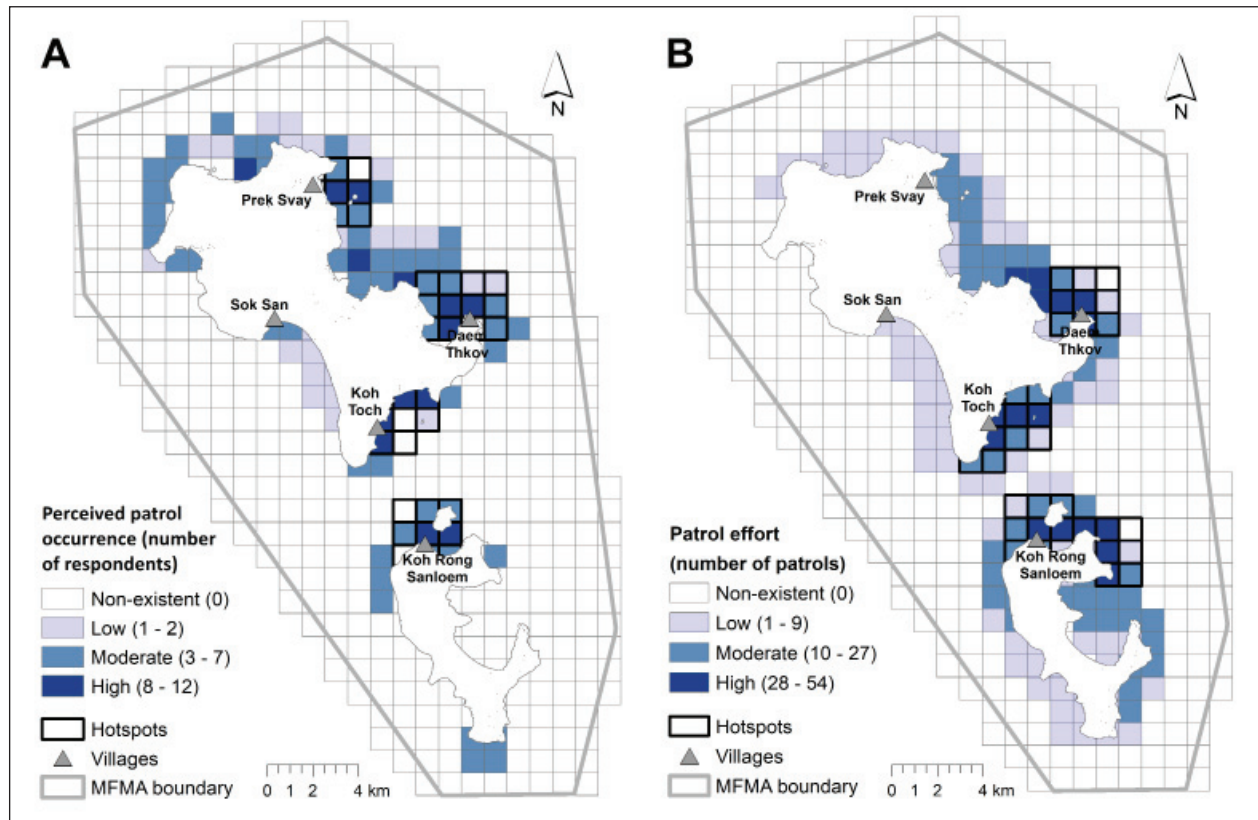


Fig. 5 Distribution of patrols in the Koh Rong Archipelago Marine Fisheries Management Area according to A) local perceptions and B) patrol records.

Our study highlights several challenges to monitoring non-compliance in marine protected areas in the global South and emphasises the need for multiple methods to overcome the weaknesses and biases of different approaches. We consequently discourage exclusive reliance on patrol records to inform management in protected areas because i) illegal activity must be well understood to inform management, including the motivations behind compliant and non-compliant behaviours, ii) the non-random distributions of patrols may lead to important biases in data, and iii) the main objective of patrols should be to deter non-compliance.

Our study is an example of how patrol data regularly collected in a standardised way can be complemented with data on local perceptions to inform strategies aimed at increasing compliance with the rules of marine protected areas. Local perceptions are a cost-effective tool for studying illegal behaviour, particularly in rarely or non-patrolled areas or during periods when patrols are not conducted. They can also be used to determine the drivers of compliant and non-compliant behaviours which are difficult to understand through patrol records

alone. Our study further demonstrates that they can be used to identify weaknesses in a management systems, such as the distribution of patrol effort.

Prevalence of non-compliance in the KRA MFMA

We assessed the prevalence of violations within the KRA MFMA using local perceptions and patrol data. The results of both indicate that illegal fishing is prevalent. The large majority of participants in the survey perceived non-compliance as rare among locals but moderately to highly frequent among outsiders, both nationals and foreigners. Although the fishers we interviewed perceived offences as more prevalent than other respondents, all groups rated non-compliance among locals as rare or non-existent. Other studies have also pointed to outside fishers as being responsible for the decline of turtles in the KRA (Diamond *et al.*, 2012) and have criticized the operation of large, foreign vessels in shallow waters (Hamilton, 2012). Our analysis of patrol records reveals a similar pattern, with none of the 38 violations recorded being committed by fishers from the KRA. Greater compliance by locals can be expected due to the

involvement of local communities and fishers prior to the MFMA's proclamation, as this likely resulted in higher levels of agreement and a perceived sense of legitimacy of the rules (e.g., Hatcher *et al.*, 2000; Raakjær Nielsen & Mathiesen, 2003; Viteri & Chávez, 2007). Nevertheless, our results must be interpreted cautiously as the two data sources we employed to assess the prevalence of illegal fishing risk underestimated the amount done by local fishers. Given the sensitivity of the subject and because the social survey only included the responses and perceptions of local communities, these could have deflected blame to outsiders to some extent as this has been observed in other marine protected areas (Fabinyi, 2012; von Heland & Clifton, 2015). In addition, as patrols are conducted by local CFIs, these could experience pressure to ignore or under-report offences committed by friends, family or neighbours (Abbot & Mace, 1999) or be involved in illegal activities themselves. Additional surveys or key informant interviews with fishers from outside the archipelago would help to further contrast our findings.

Regardless of possible underestimation of illegal fishing by local fishers, low compliance by outside fishers appears to be a major problem for the KRA MFMA. This was supported by statements from key informants with no social ties to local fishers who reported outsiders fishing illegally in the area and provided video and photographic evidence in some instances. The illegal operation of foreign boats in Cambodian waters is also recognised as an issue at the national level and there is generally poor monitoring, control and surveillance of national and foreign vessels in Cambodian waters (Staples, 2017).

Drivers of compliance and non-compliance

Designing effective strategies to address illegal fishing requires an understanding of the factors that motivate compliant and non-compliant behaviours (Gavin *et al.*, 2010; Arias, 2015). Our results indicate that the factors underlying non-compliance in the KRA MFMA include economic and livelihood-related incentives, lack of knowledge of the rules, low influence of norms and morals, and insufficient deterrence through sanctions.

We found economic or livelihood benefits were the most commonly reported driver of illegal fishing. According to rational models of behaviour, when economic gains drive rule-breaking, law enforcement can decrease non-compliance by increasing the costs of such behaviour through economic sanctions and prison sentences (Akella & Cannon, 2004). The need for and effectiveness of law enforcement to combat non-compliance has been previously reported in marine conserva-

tion (e.g., Kelaher *et al.*, 2015), and around one-fifth of our respondents believed that the existence of patrols drove compliance within the KRA MFMA. However, to effectively deter illegal activities, enforcement systems need to create economic disincentives that exceed the economic benefits of rule-breaking (Akella & Cannon, 2004). In the case of the KRA MFMA, the limitations of the current enforcement system identified in our study (as follows) likely prevent generation of a sufficient disincentive. This was also the view of 18% of respondents who felt that insufficient enforcement deterrence explained the existence of illegal behaviours.

Lack of knowledge of the MFMA regulations and lack of demarcation were cited as the second most common driver of illegal fishing. Adequate and widespread understanding of the rules is a prerequisite for compliance, although communication-based interventions can also be effective when rules are not understood (Leisher *et al.*, 2012). Although awareness-raising meetings were conducted before and after the MFMA's designation with the local CFIs and communities, these have been less frequent in villages lacking a CFI or difficult to access. Additionally, since the meetings only involved local fishers, they would not have influenced the awareness of outsiders.

Legitimacy of the MFMA rules was by far the most commonly reported driver of compliance in the KRA MFMA. This has been shown to be an important prerequisite for compliance in fisheries elsewhere (Hønneland, 2000; Raakjær Nielsen & Mathiesen, 2003; Viteri & Chávez, 2007) and can be strengthened through the involvement of local communities in formation and enforcement of regulations (Jentoft *et al.*, 1998; Pollnac *et al.*, 2001). In the KRA, the extensive consultations with the CFIs during MFMA planning and the adoption of a co-management approach after its declaration likely led to high levels of perceived legitimacy and presumably high compliance among local fishers.

Social factors have been found to influence compliance in protected areas (e.g., Eggert & Ellegard, 2003; St. John *et al.*, 2014). Norms in the sense of typical actions, attitudes and expectations on the behaviour and attitude of others can significantly influence individual decisions (Axelrod, 1986). Morals, understood as "internalised norms" according to "perceptions of what is right or wrong" can similarly affect individual behaviour (Hoffman, 1977; Raakjær Nielsen & Mathiesen, 2003). In our study, morals and norms were only occasionally cited as drivers of compliance. For example, few respondents believed that social pressure or concern for future generations motivated fishers to follow the rules. However, one-fifth of respondents felt that social factors

were also the cause of illegal behaviour, particularly the perception that rule-breaking was common among many other fishers (i.e., social norms). The prevalence of compliance and non-compliance perceived among peers can influence individual decision-making and encourage compliance as well as non-compliance with conservation rules (Cialdini *et al.*, 1990; Bergseth & Roscher, 2018). In other words, as non-compliance becomes more prevalent, its social acceptability may increase. Conversely, increases in compliance with the rules could lead to further increases of the same through the influence of social norms.

It should be noted that our study did not assess the perceptions of outsiders who were reported by local residents as frequently engaging in illegal activity. We therefore recommend additional key informant interviews or social surveys with outsiders to complement the findings of our work. Given the drivers of compliance and non-compliance perceived by locals, we also believe that illegal behaviours must be addressed through a combination of improved awareness of the rules, clear demarcation of fishing-restricted areas, sustained participation of local communities in MFMA management and effective law enforcement. Although enforcement alone is unlikely to be successful, it is crucial to address commercial-scale illegal activities (Akella & Cannon, 2004) and illegal fishing by outsiders who are difficult to reach in campaigns aimed at increasing awareness and perceived legitimacy of the rules. Moreover, an effective enforcement system could offer fast results by counteracting the economic incentives of illegal fishing while allowing time for other strategies to come into effect (Arias, 2015).

Spatial and temporal distributions of non-compliance and enforcement effort

The effectiveness of enforcement depends on the probability of detection, severity of penalties and chances of prosecution and conviction (Akella & Cannon, 2004). While the latter rely more on legal and political jurisdictions that can be difficult to influence, the probability of detection is mainly technical and site-specific (Arias *et al.*, 2016) and thus more easily managed at the protected area level. This can be improved through greater or more efficient effort. However, patrol effort is often constrained by the associated costs (e.g., McCook *et al.*, 2010) and the limited resources and personnel available in marine protected areas such as the KRA MFMA. Therefore, efforts to increase the efficiency of patrols by better targeting these in space and time must be prioritised.

Identifying the spatial distribution of illegal activities is crucial to target limited enforcement resources to the areas most severely affected. Patrol records are an

attractive information source in this regard, being cheap and readily available (Keane *et al.*, 2011). We used patrol records collected since MFMA designation to calculate the number of infractions per patrol and mapped these to identify hotspots that patrols should target. However, some hotspots were located in rarely patrolled areas and therefore might have been erroneously identified due to biases associated with small sample sizes. Moreover, hotspots of illegal fishing may have been overlooked in unpatrolled areas.

The reliability of patrol data can be severely limited when patrol effort is not uniformly distributed (Keane *et al.*, 2011). As the distribution of patrols in the KRA MFMA is highly uneven, with most effort undertaken near villages with operational patrol teams and some areas rarely or never visited, we incorporated the perceptions of local stakeholders—a source of information increasingly recognised by conservation managers (Treves *et al.*, 2006)—in analysis. Assuming that areas that experience greater illegal fishing would be reported by more people, we mapped the perceived distribution of illegal fishing (Fig. 4A) and detected several hotspots, some of which roughly coincided with areas detected by patrols as experiencing high non-compliance (Fig. 4B). However, some incongruencies were apparent between maps based on perception and patrol data. For example, perception data indicated that moderate levels of illegal fishing occur in areas never visited by patrols and therefore not detected by the latter (Fig. 4A vs. Fig. 5B). Additionally, some areas identified as non-compliance hotspots in patrol data were not apparent in perception data. For example, whereas all villages appeared to frequently experience illegal fishing, IDPP values surrounding these were generally low according to patrol data. It is to be expected that areas better known or more visible to respondents such as the vicinity of villages would be reported more frequently than areas rarely visited. This is demonstrated by the perceived low prevalence of illegal fishing in the southern and less accessible part of the MFMA which is remote from the main villages (Fig. 4A). In addition, perceptions may be biased towards conspicuous infractions or those that are known to be illegal (e.g., trawling) by more people. Because perception data are based on personal experiences and second-hand stories from acquaintances (Treves *et al.*, 2006), they must also be interpreted with caution.

We also used local perceptions and participatory mapping to assess the predictability of patrols. These revealed that when an area is patrolled more often, more people become aware of this (Figs 5A & 5B). It consequently follows that if patrol distributions become known to local fishers, these could adjust their activi-

ties to avoid highly patrolled areas. However, areas not patrolled in the previous year but patrolled prior to that were also reported as highly patrolled by respondents, suggesting that creation of a deterrence effect may not require continuous patrols.

The temporal distribution of patrols also requires careful planning because fishing may be undertaken at certain times of day to evade detection. Our data indicates that most local respondents believe that illegal fishing mainly occurs at night-time. This could be to evade detection under the cover of darkness or be due to the limited presence of law enforcement teams at this time, or both (Islam *et al.*, 2017). At present however, we cannot determine if the timing of legal fishing differs from illegal fishing. New approaches are being explored to address the limited capacity and infrastructure for fisheries monitoring and management in Cambodia, which will hopefully improve understanding of fishing trends, legal and illegal. Several factors currently prevent night patrols in the KRA MFMA. These include a lack of appropriate equipment and the rare availability of the Royal Navy to ensure the security of local rangers. Our patrol data indicates that just over 5% of patrols included some effort at night and that 85% of patrol hours occurred during the day. Although our data on night patrols were insufficient to draw firm conclusions, it nonetheless suggests that a high percentage of illegal fishing occurs at night. As a consequence, we believe that an increase in the number of night patrols would improve the efficiency and effectiveness of law enforcement in the KRA MFMA. For this to occur however, measures would be required to improve the capacity and ensure the safety of CFI patrol teams.

Overall, our study demonstrates that the effectiveness of law enforcement in the KRA MFMA is limited by a lack of resources and uneven patrol effort. We consequently recommend periodic assessment of patrol records complemented by information from key informants to monitor the distribution of illegal activity and target patrol effort to the greatest effect. Because local communities quickly learn where patrols are undertaken, we also recommend reducing their predictability and maximising patrol areas to prevent displacement of illegal activity to unpatrolled areas. This would also improve the quality of patrol records. Patrols of additional areas may not need to be intensive, as our results suggest that areas frequently visited in the past are still perceived to be highly patrolled by many people.

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Appendix 1 Categories for responses on perceived drivers of compliance (+) and non-compliance (-)

Category	+/-	Response
Economic/livelihood	+	They are afraid [illegal fishing] will impact tourism.” “[Complying with the rules] will lead to increases in income and jobs.” “They do not need to do illegal fishing because their income has diversified and is obtained through various sectors.” “They cannot afford illegal gear.”
	-	“There are more or more profitable resources in restricted areas.” “Illegal gear is more efficient than legal gear.” “Fishing legally is not profitable.” “The prices of fish are high and want to maximise catch to maximise benefits.” “They want the personal (economic) benefit.” “There is a higher demand for fish.” “They receive pressure from their bosses.” “They are poor and have no alternative.”
Sanctions & deterrence	+	“They are scared of being caught by the patrols.”
	-	“There is a low probability of being caught/being punished.” “They are not scared of patrols because they have the support of powerful men.”
Legitimacy of rules	+	“They support and accept the rules.”
	-	

Appendix 1 Continued

Category	+/-	Response
Norms and morals	+	“Other people comply with the rules.”
		“Illegal fishing is not accepted by the community.”
		“They want to protect resources for the coming generations.”
	-	“The resources will not end.”
		“It is their way of living, and they do not care.”
Knowledge of the rules	+	“They do whatever they want, they do not care, they are thieves.”
	-	“Other fishers do not follow the rules.”
		“They did not participate in the information meetings.”
		“They do not know the rules.”