

Seasonality and historic trends in the reef fisheries of Pulau Banggi, Sabah, Malaysia

L. S. L. Teh · D. Zeller · A. Cabanban ·
L. C. L. Teh · U. Rashid Sumaila

Received: 13 June 2006 / Accepted: 13 November 2006 / Published online: 22 February 2007
© Springer-Verlag 2007

Abstract The reef fisheries of Pulau (meaning “island” in Malay) Banggi, Sabah are not managed, and lack baseline fisheries data despite forming part of a proposed marine park. Thus, a combination of qualitative and quantitative approaches was applied to obtain a baseline picture about the past and present state of the fisheries. Fish landings were monitored, and fisher interviews conducted to investigate seasonal effects and historical changes in Banggi’s reef fisheries. Monsoon winds were a major driver of seasonal differences in catch quantities for the hook and line, but not the gillnet fishery. Spatial distribution of fishing effort and target species also differed by season. Fishers consistently indicated that Banggi’s fisheries were declining, with a suggested three to four times decrease in catch rates over the last 20 years. Interestingly, it appeared that substantial decreases began in the year

2000. The responses of fishers to seasonal changes, and the resultant implications for management are discussed. Importantly, the need for immediate management policies to prevent further declines and to maintain sustainable reef fisheries is stressed.

Keywords Reef fisheries · Pulau Banggi · Sabah · Small-scale fisheries · Seasonality · Malaysia

Introduction

Tropical reef fisheries are multispecies and dynamic, and are often characterized by distinct seasonality with regard to catch rates, spatial distribution of effort, target species, and fishing methods. These spatial and temporal patterns of catches and effort are influenced by a range of biophysical, ecological, and economic factors (Van Oostenbrugge et al. 2001; Wiyono et al. 2006).

The reef fisheries of Pulau Banggi, Sabah, Malaysia, which are not actively managed or monitored, require information about seasonality and historical trends for assessing the fisheries’ status, and for making decisions to support their sustainable management. A one million hectare Marine Park (Tun Mustapha Marine Park) has been proposed for northern Sabah, which includes Pulau Banggi. Thus, baseline information on past and current use patterns of the area and the status of its marine resources are required.

Understanding the effects of seasonal changes on catch rates and fishing effort is valuable for evaluating alternative management policies. It also sheds light on the drivers behind observed fishing practices and fisher behaviour (e.g. Pet Soede et al. 2001; Salas et al. 2004). Insights derived from examining the spatial and tem-

Communicated by Biology Editor M.I. McCormick.

Electronic supplementary material The online version of this article (doi:10.1007/s00338-006-0182-x) contains supplementary material, which is available to authorized users.

L. S. L. Teh (✉) · D. Zeller · U. R. Sumaila
Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, Canada V6T 1Z4
e-mail: l.teh@fisheries.ubc.ca

A. Cabanban
WWF Malaysia, 6th Fl, CPS Tower,
No.1, Jalan Centre Point, 88000 Kota Kinabalu,
Sabah, Malaysia

L. C. L. Teh
Institute for Resources, Environment and Sustainability,
University of British Columbia, 2202 Main Mall,
Vancouver, Canada V6T 1Z4

poral trends of Banggi's reef fisheries may help in the development of locally relevant fisheries policies.

In many small-scale tropical fisheries, time-series catch statistics are not available, thus requiring the use of unconventional methods and information to establish such trends (e.g. Sadovy and Cheung 2003; Zeller et al. 2006). This applies to Banggi's reef fisheries, which are not recorded in the official statistics for the Kudat region, of which Banggi is a sub-district. Being aware of historical trends in a fishery is particularly pertinent in Southeast Asia, where heavy fishing in recent decades has led to often substantial catch declines (McManus 1997; Burke et al. 2002).

In this study, reef fisheries refer to the capture of both demersal reef fish, as well as reef-associated and coastal pelagic species such as scombrids and carangids. A detailed description of Banggi's reef fisheries can be found in Teh et al. (2005) and Teh (2006). Briefly, the reef fisheries of Banggi are small-scale, artisanal, and open access with little regulation. Fishing is done with manually operated gears, with hook and line and gillnets being the two most important fishing gears. Hook and line consists of a single handline with one baited hook. Alternatively, a series of eight to ten small hooks with cloth lures are used either for trolling or jigging for pelagic fish such as mackerel and ox-eye scads. Gillnet fishers use monofilament nets approximately 150–200 m in length, and 1.5 m in height. Net mesh sizes vary from 6.4 to 12.7 cm.

Less frequently used fishing methods include traps, jigs, spears and spear guns, reef gleaning (manually harvesting shell fish or invertebrates in shallow water or on dry reef flats during low tide), as well as illegal methods such as explosives and cyanide. The majority of local fishers use wooden skiffs powered by modified 7–8 hp water pump engines. A small number of fishers operate fibreglass boats with outboard engines that are provided as part of a poverty alleviation scheme administered by the Sabah Fisheries Development and Fishers Corporation ("Ko-Nelayan"). There are approximately 130 boats in southern Banggi (R. Jumin, personal communication)

The major fishing ground is the Maliangin area, which covers approximately 17 km² (Fig. 1). It is the primary fishing area for hook and line fishers, and is considered a "traditional fishing zone" where commercial fleets such as trawlers and purse seiners are prohibited from fishing.¹ It is characterized by shallow reefs 3–5 m in depth near shore, and deeper patch reefs

of 15–30 m depth further offshore. Fishing areas are highly gear specific. Hook and line fishers aggregate around south-west Maliangin to fish over patch reefs, while gillnet fishers fish over more dispersed, sandy bottom habitat locations (Fig. 1).

Sabah's climate is characterized by the Asian southwest (SW, March–September) and northeast (NE, November–March) monsoons. Fishing seasons are largely determined by the severity of monsoon winds. The peak fishing season occurs during the calm period at the beginning of the SW monsoon, between March and May/June. This is followed by the low fishing season which coincides with the windiest months of the SW monsoon from June until September, when inclement weather prevents regular fishing activity. Strong NE winds during the beginning of the year (NE monsoon) cause another low fishing period.

The objectives of the present study were to (1) understand seasonal patterns of catches, species composition, and effort distribution for Banggi's reef fisheries; (2) investigate historical trends in the fisheries; and (3) explore the implications of (1) and (2) for management of the island's reef fisheries. Seasonal variation in catches, effort, and species composition of the island's artisanal reef fisheries were first quantified, based on fishery surveys carried out in two different seasons in 2004 and 2005. Information from interviews with fishers was then utilized to establish a trend of the historic change in catch rates and effort. These findings provided important baseline information about the current state of Banggi's fisheries, and are directly applicable to management planning for the proposed Tun Mustapha Marine Park.

Materials and methods

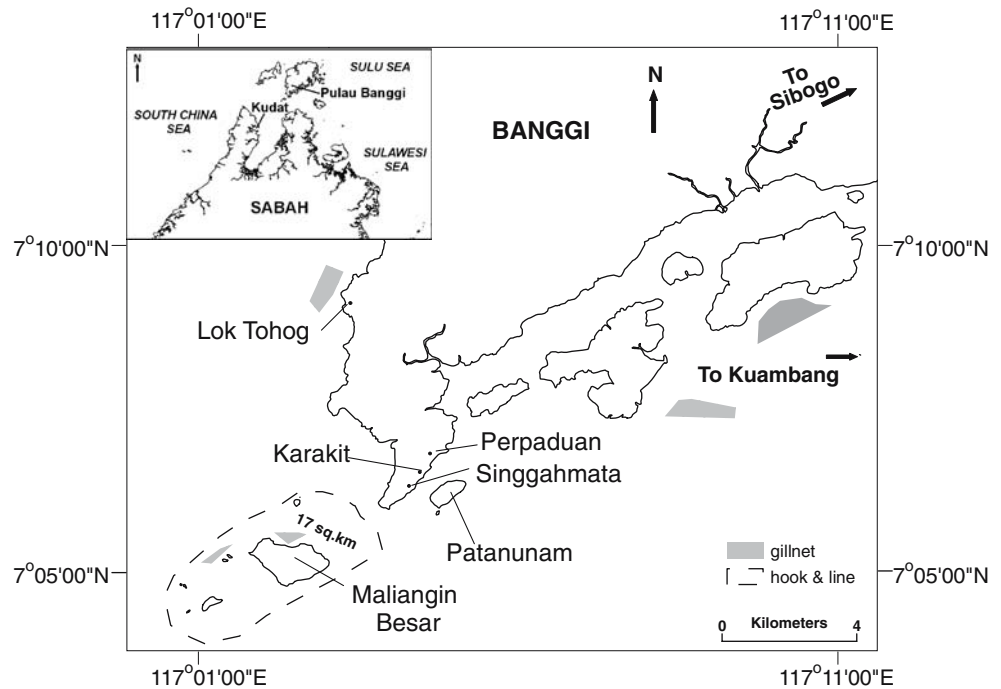
Study site

Pulau Banggi (7°14'N, 117°10'E), with a total area of 700 km², is situated off the northern tip of Sabah, East Malaysia (Anon 2003a). The nearest mainland town is Kudat, approximately 30 km across the Banggi Channel (Fig. 1). This study focused on southern Banggi, where Karakit is the administrative centre, and together with Singgahmata and Perpaduan, comprises the main population and socio-economic centre of southern Banggi.

The key fishing ground is the Maliangin area (Fig. 1), which is one of the four main fishing areas in Banggi, the others being Kuambang and Sibogo in the east, and Balambangan in the west. These other fishing grounds are approximately 1 h boat rides from south-

¹ The Malaysia Fisheries Comprehensive Licensing Policy designates the area within five nautical miles of the shoreline as a traditional fishing zone.

Fig. 1 Map of southern Banggi showing villages and the Maliangin fishing ground, with distribution of fishing effort by gear and fishery type. The *inset* map shows Sabah state with Pulau Banggi off the northern coast



ern Banggi, and the decision to fish these fishing grounds is influenced by local fishing conditions, and the availability and cost of fuel and ice.

The population of Banggi was estimated as 16,000 in 2005, with an annual population growth rate of 4% (Anon 2005). There were approximately 1,100 inhabitants in the vicinity of the study site (Teh et al. 2005). Banggi remains relatively undeveloped, and coastal households are below the Sabah poverty line (Anon 2003b). Fishing, a key source of livelihood, accounts for about 70% of the island's economic activity (Anon 2003b). There are thought to be 1,195 fishers on the island of Banggi (Kudat Fisheries Department unpublished data); the number of fishers in the villages of south Banggi who frequented the Maliangin fishing grounds was estimated to be between 130 and 140 (Teh 2006).

Data collection

Primary data was collected during two periods: June–August 2004 (SW monsoon), and during the normally calm period of March–April 2005 (Fig. 2). These primary data periods were supplemented with receipt data from local fish traders for November 2004–February 2005 (gillnet fishery), and mid April–May (gillnet and hook and line fisheries). Winds were unusually strong in 2005, and recorded catch data are thought to underestimate normal peak season levels. As such, our catch estimates are likely to be conservative.

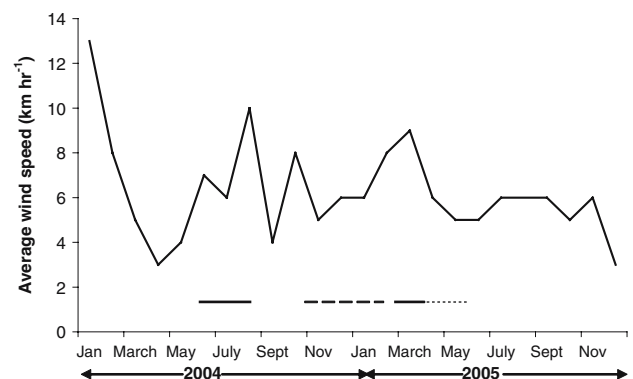


Fig. 2 Monthly average wind speeds for 2004 and 2005. *Solid lines* indicate sampling periods when catch and interview data were collected. *Dashed line* indicates receipt data collected for the gillnet fishery in 2004/2005, and *dotted line* indicates receipt data collected for the gillnet and hook and line fisheries in 2005

Fishery data

Fishery data were collected for the hook and line and the gillnet fisheries, which accounted for the majority of fish captured for sale in Banggi. These recorded artisanal catches did not include the subsistence catches, i.e., the amount of fish fishers kept for self consumption. As such, recorded catch data did not represent total catch. Methods used included fishing ground surveys and monitoring catch landings. Surveys of the Maliangin fishing grounds were conducted, weather permitting, three times a week between 0730

and 1100 hours, a period when there was a high probability of catching fish. Fishers were randomly stopped and the following information was recorded: (a) gear type; (b) quantity of fish caught (weight was estimated by the researchers' boat handler, who was also an experienced fisher); (c) number of hours fished; and (d) species caught.

Fish landings during the first sampling period (2004) were recorded at the two main fish buyers' sites at Karakit and Singgahmata in June–July and August 2004. This data collection period corresponded with the low fishing season, and was considered representative for that period. Gillnet fishers landed their catch at the Karakit site between 2030 and 2300 hours, and this site was continuously monitored so that all catches that were landed were recorded. Hook and line catches were landed more sporadically at the Singgahmata site. Therefore, sampling at this site was more opportunistic. The majority of sampled hook and line catches during 2004 was recorded during the fishing ground surveys.

During the second sampling season (2005), catch landings were recorded in March–April 2005 at the two main fish buyers' sites in identical manner to the first season. In addition, receipts covering parts of November 2004 to February 2005 (corresponding to NE monsoon), and mid April–May 2005 (typically the peak season) were supplied by the Karakit fish trader, while receipts covering mid April–May 2005 were supplied by the Singgahmata fish trader. In total, data covering three and four periods were available for the hook and line and gillnet fisheries, respectively. Owing to the possibility that peak season catches for both these fisheries might have occurred during the mid April to May sampling period, receipts from this period were treated as a separate data set from those recorded on site from March–April. It should be noted that the sampling frequency for all data collection periods was not the same.

Interviews

Interviews lasting between 15 and 60 min were conducted by the senior author and Lydia Teh (LT) in villages where fishers were known to frequent the Maliangin fishing ground. In 2004, semi-structured interviews were carried out with 20 fishers, 2 fish traders, and 3 village leaders in the villages of Karakit, Perpaduan, Singgahmata, Maliangin Besar, and Lok Tohog (Fig. 1). Interviews were also conducted with two fisheries officers in the Sabah Department of Fisheries. In addition, a participative approach (Reason 1994), in which the senior author and LT joined in

fishing and reef gleaning activities, was undertaken to better understand local fishing practices. During 2005, 30 additional interviews were conducted with fishers in the villages of Perpaduan, Maliangin Besar, Kobong, Lumais, and Patanunam (Fig. 1). Altogether, the number of interviews in 2004 and 2005 represented roughly 30 to 40% of the total fisher population in these villages.

Prepared questions pertaining to catch, effort, target species, historical trends, fish consumption, and perceptions on the future of fishing in Banggi were asked in Malay by the senior author without the need of a translator (see Electronic Supplementary Material). Fishers were given breadth in answering the questions; consequently, not all interviews followed exactly the same format, and the number of respondents varied for each question. Fishers were chosen opportunistically, by going house to house and interviewing any fisher who was willing to speak to the researchers. No refusals were encountered. Additional information was gathered through informal interviews conducted whenever the opportunity arose.

Estimation of total annual catch

Total annual catch for the island of Banggi was estimated based on two fundamental assumptions: (1) recorded catch landings and fishing effort in southern Banggi was representative and applicable to the whole island; and (2) total fisheries yield consisted of artisanal and subsistence catches. Artisanal yield was estimated based on the commercial component of the hook and line and gillnet fisheries, while other gears such as spear and trap had insufficient data on which to base an estimate. Subsistence catch was estimated based on the information obtained from targeted interview questions.

Total seasonal artisanal catches per fisher for each gear was calculated by multiplying the mean recorded daily catch (excluding catch retained for self-consumption, see subsistence estimates below) in each sampling period by the average number of fishing days and duration of the season (i.e. total seasonal catch per fisher = mean catch per day \times average number of fishing days per week \times number of weeks in season). Seasonal catches were summed to produce total annual catch estimate per fisher. Minimum and maximum bounds for the catch estimate were based on 95% confidence intervals.

Owing to the limited temporal coverage of our data, seasonal catches were calculated by expanding the number of weeks in each sampling period to a fishing season. For the gillnet fishery, each of the four data

periods (one receipt and one catch/interview each in 2004 and 2005, Fig. 2) was expanded to 13 weeks for a total of 52 weeks. For the hook and line fishery, the three data periods (one receipt in 2005 and one catch/interview each in 2004 and 2005, Fig. 2) were adjusted as follows: The 8-week period from June to August 2004 was extended to 13 weeks to represent the low fishing season. The sampling period March to mid April 2005 was adjusted to 26 weeks to represent the inter-monsoon season. Finally, the mid April to May 2005 period was adjusted to 13 weeks to represent the peak fishing season.

Annual artisanal catch per fisher was multiplied by the estimated number of fishers in Banggi to obtain the estimate of island-wide annual artisanal fish catch. The total number of fishers for the whole island was conservatively estimated at 978, based on the average of two separate estimates: (a) 1,195 fishers recorded by the Kudat Fisheries Department (Sabah Department of Fisheries Kudat Branch, unpublished data); and (b) 760 fishers derived by applying the approximate ratio of artisanal fishers per village in southern Banggi (Teh 2006) to the 19 fishing villages in Banggi. On the basis of the observed effort distribution in southern Banggi, 80% of fishers were assumed to use hook and line, with the remaining 20% using gillnet.

The subsistence catch estimate was based on the amount of fish that fishers caught for their own consumption, as described during fisher interviews. Fishers do not land this portion of their catch, and it was therefore not accounted for in the recorded catch landings. This retained amount was assumed to be the amount of fish consumed by members of fishing households. The total island-wide subsistence catch was then estimated by multiplying the amount of fish kept for personal consumption per fisher per day by the estimated number of subsistence fishers in Banggi and the estimated number of subsistence fishing days. The number of subsistence fishing days is higher than artisanal effort because fishers often only go fishing near shore during unfavourable weather to catch enough for their own needs, but not for economic gain. Likewise,

the number of subsistence fishers is also higher than artisanal fishers.

Data analysis

Only non-zero catches were used for analysis as it was not possible to record zero catches for the gillnet landings, while zero catches for the hook and line fishery were not recorded consistently. Therefore, mean daily catches reflected successful trips only, which introduced a positive bias to the analysis. Linear regression analysis between wind-strength and daily catch was conducted to determine the effect of weather. The data used were the sum of all recorded catches (for each fishery) for each sampling day, and the maximum and minimum wind speed recorded on that day. Wind data originated from the Kudat airport, which is 30 km from southern Banggi, but were considered representative.

Results

Catches

Artisanal catches

Mean catch for the hook and line fishery was 7.13 ± 0.98 (mean \pm SE) kg fisher⁻¹ day⁻¹ for June–August 2004, 11.17 ± 0.80 kg fisher⁻¹ day⁻¹ (March–April 2005), and 11.57 ± 1.29 kg fisher⁻¹ day⁻¹ (April–May 2005) (Table 1). Mean gillnet catches in 2004 were 14.79 ± 1.44 kg fisher day⁻¹ (Table 1), while available fish buyer receipts covering November 2004 to February 2005 showed that mean artisanal catch during the NE monsoon was 13.36 ± 0.84 kg fisher⁻¹ day⁻¹. During this period, many fishers also captured cuttlefish. Mean catch weight for this cuttlefish fishery was 49.83 ± 14.16 kg fisher⁻¹ day⁻¹ (Table 1). During March–April 2005, mean gillnet catch was 16.39 ± 1.09 kg fisher⁻¹ day⁻¹, and rose to 18.82 ± 3.13 kg fisher⁻¹ day⁻¹ during April–May (Table 1). The seasonal frequency distributions of catches for both hook

Table 1 Daily mean \pm SE and median catch weights (kg day⁻¹) for hook and line, gillnet, ox-eye scad and cuttlefish spear fisheries in four sampling seasons

Gear	June/Aug 2004		Nov 04–Feb 05		March/April 2005		April/May 2005	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Hook and line	7.1 ± 1.0	4.1	–	–	11.2 ± 0.8	9.0	11.6 ± 1.3	6.8
Gillnet	14.8 ± 1.4	11.5	13.4 ± 0.8	10	16.4 ± 1.1	11	18.8 ± 3.1	11
Ox-eye scad	–	–	–	–	14.1 ± 1.1	13	–	–
Cuttlefish spear	–	–	49.8 ± 14.2	35	–	–	–	–

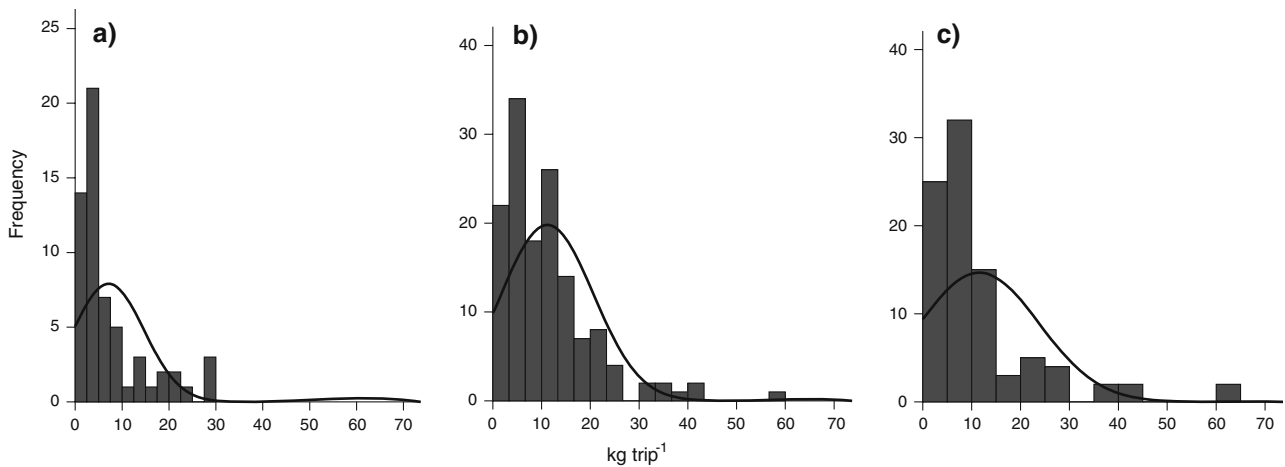
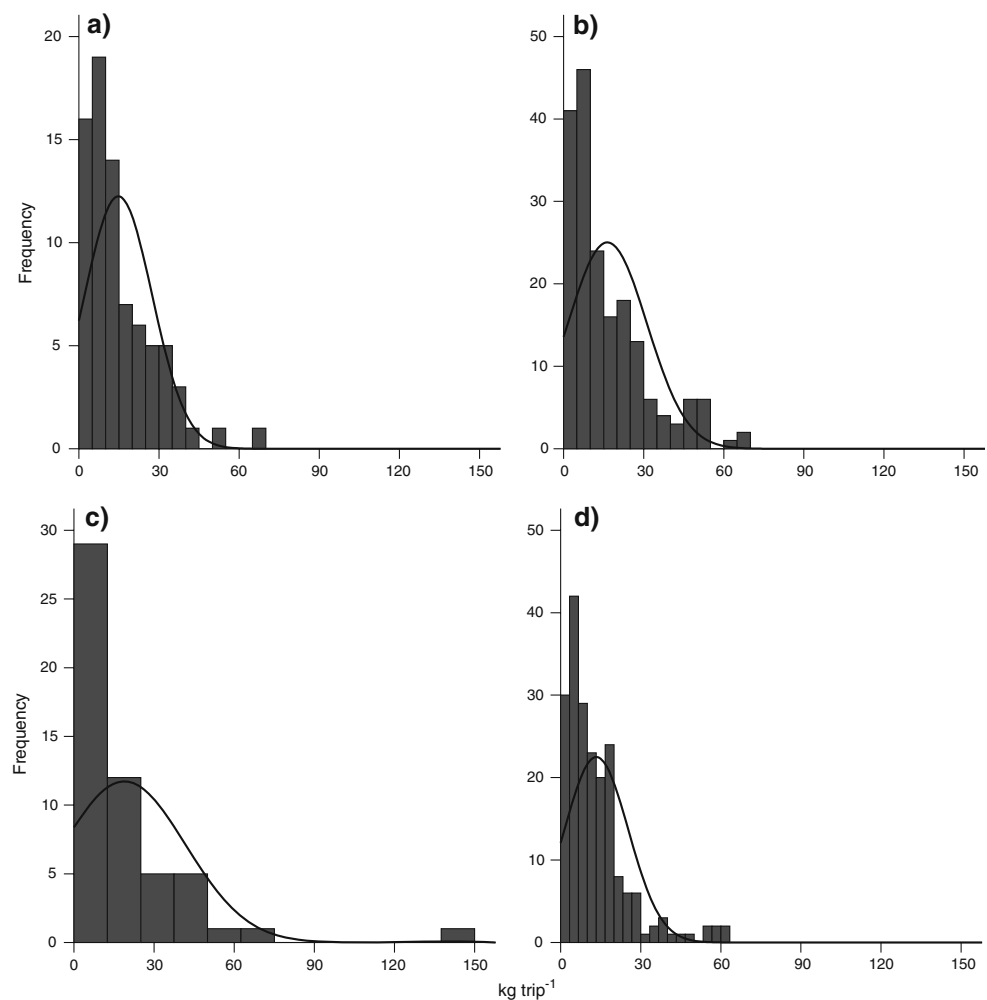


Fig. 3 Frequency distribution of recorded hook and line catches (kg trip^{-1}) for: **a** June and August 2004; **b** March–April 2005; and **c** April–May 2005

Fig. 4 Frequency distribution of recorded gillnet catches (kg trip^{-1}) for **a** June and August 2004; **b** March–April 2005; **c** April–May 2005; and **d** Nov 2004–Feb 2005



and line and gillnet fisheries are presented in Figs. 3 and 4, respectively, and are positively skewed, with a small number of big catches.

On the basis of fisher interviews and personal observation, wind speed was considered the biggest constraint on fishing activity. To our knowledge, fishing

trips were not timed to correspond to tide or current conditions. A regression of maximum and minimum wind speed on catches suggested that during March–April 2005, maximum wind speed was a significant explanatory variable for the variation in total daily fish catches landed for the hook and line fishery ($F = 4.22$, $P < 0.05$, $df = 32$). Minimum wind speed was not a significant explanatory variable. For the gillnet fishery, neither maximum nor minimum wind speeds could explain the variability in total daily fish landings. In recognition of the non-linear nature of wind speed data, non-linear regressions were also undertaken, but the best fit was provided by linear regression.

Subsistence catches

It was conservatively assumed that fish was eaten approximately 300 days a year, taking into account that fishers were prevented from even subsistence fishing for about 2 months during the most severe windy weather, and that few alternative protein sources (e.g. chicken) are available on the island. On the basis of the interview data, the average amount of catch kept by each fisher was $2.0 \pm 0.3 \text{ kg day}^{-1}$ (mean \pm SE, range 1.0–5.0). With an estimated 1,195 fishers island-wide, this suggested a potential total subsistence catch for the island ranging from 359 to 1,793 tonnes, with a mean of 717 tonnes per year (Table 2).

Table 2 Estimate of artisanal, subsistence, and total catch (tonnes per year) for the island of Banggi

	Artisanal catch (tonnes)	Subsistence catch (tonnes)	Total catch (artisanal + subsistence) (tonnes)
Mean	2,970	717	3,687
Minimum	1,677	359	2,036
Maximum	6,374	1,793	8,167

Total catches

The estimate of the potential total mean artisanal catch islandwide was 2,970 tonnes per year (range 1,677–6,374) (Table 2). Combining this with the mean subsistence catch estimate of 717 tonnes (range 359–1,793 tonnes) yields an estimated total annual catch of 3,687 tonnes (range 2,036–8,167; Table 2). Thus, subsistence catches made up around 20% of total catches.

Target species and catch composition

The coral grouper (*Plectropomus* spp.) and Spanish mackerel (*Scomberomorus commerson*) were the most important target species for hook and line fishers (Table 3). The former was caught predominantly during the SW monsoon season, whereas the latter was targeted during the NE monsoon season. Gillnet fishers primarily targeted trevallies (Carangidae, Table 3).

The catch composition for both gears displayed inter-seasonal variation. For hook and line, catch composition was recorded using frequency of occurrence during 2004, and using weight in 2005. It is acknowledged that the different measurement methods might have potentially biased our data. In 2004, demersal reef fish were the most frequently occurring group, making up 76% of a typical catch (Fig. 5a). Within this group, serranids (groupers) were the dominant family (36%), followed by lethrinids (emperors) (17%), nemipterids (breams) (10%), and lutjanids (snappers) (8%). Other families in the catch consisted of carangids (trevallies and scads) (6%) and scombrids (tunas and mackerels) (5%).

During March–April 2005, the proportion of demersal reef fish in the total catch decreased substantially, comprising only 32% of the catch (Fig. 5a). Pelagic fish, namely, yellowtail scad (*Atule mate*) and scombrids [Spanish mackerel (*Scomberomorus commerson*) and ‘other scombrids’] became more important,

Table 3 Target species and the predominant seasons/months during which they are targeted

Gear	Target species	Scientific name	Season	Months
Hook and line				
Trolling with live bait	Spanish mackerel	<i>Scomberomorus commerson</i>	NE	Oct–Feb/March
Trolling with lures	Kawakawa (Scombridae)	<i>Euthynnus affinis</i>	NE	Jan–March
Jigging with lures	Yellowtail scad	<i>Atule mate</i>	NE	Jan–March
Baited hook	Coral grouper	<i>Plectropomus</i> spp.	SW	April–Sept
Gillnet	Trevallies	Carangidae	NE and SW	Year-round
	Juvenile blacktip reef shark	<i>Carcharhinus melanopterus</i>	SW	July/August
Trap	Coral grouper	<i>Plectropomus</i> spp.	NE/SW	Jan–Sept
Spear	Cuttlefish	<i>Sepia</i> spp.	NE	Nov–Feb
Squid jig	Squid	<i>Loligo</i> spp.	SW	June–Sept
Diving/gleaning	Invertebrates		SW	–

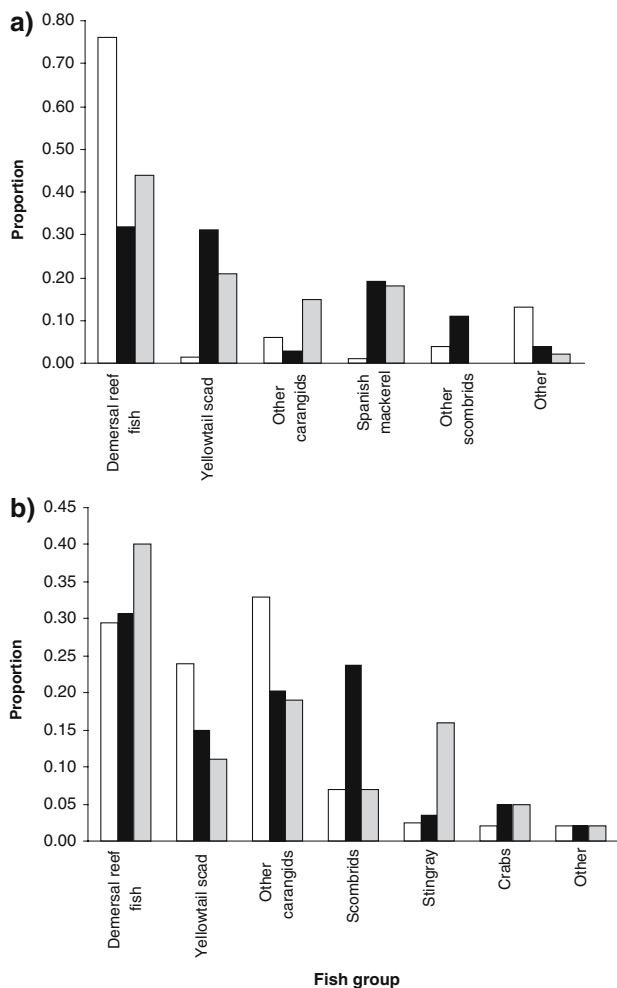


Fig. 5 Catch composition for **a** hook and line and **b** gillnet landings by major fish groups for three sampling seasons: June–August 2004 (white bar), March–April 2005 (black bar) and April–May 2005 (grey bar)

making up 31 and 30% of the catch, respectively. Spanish mackerel (19%) and kawakawa (*Euthynnus affinnis*) (11%) were responsible for the increase in scombrids. The months of March and April were considered the end of the Spanish mackerel season; thus, it is likely that this species contributed more than 19% to the catch during the peak of the Spanish mackerel season from November to January. During April–May 2005, demersal reef fish began to dominate the catch again, rising to 44% of total catch (Fig. 5a). The proportion of Spanish mackerel remained steady at 18%, while there was an increase in carangids from 3 to 15% (Fig. 5a).

Gillnet catch composition during both sampling periods was recorded by weight. Although gillnet composition was more consistent than hook and line, inter-seasonal variation still existed (Fig. 5b). Carang-

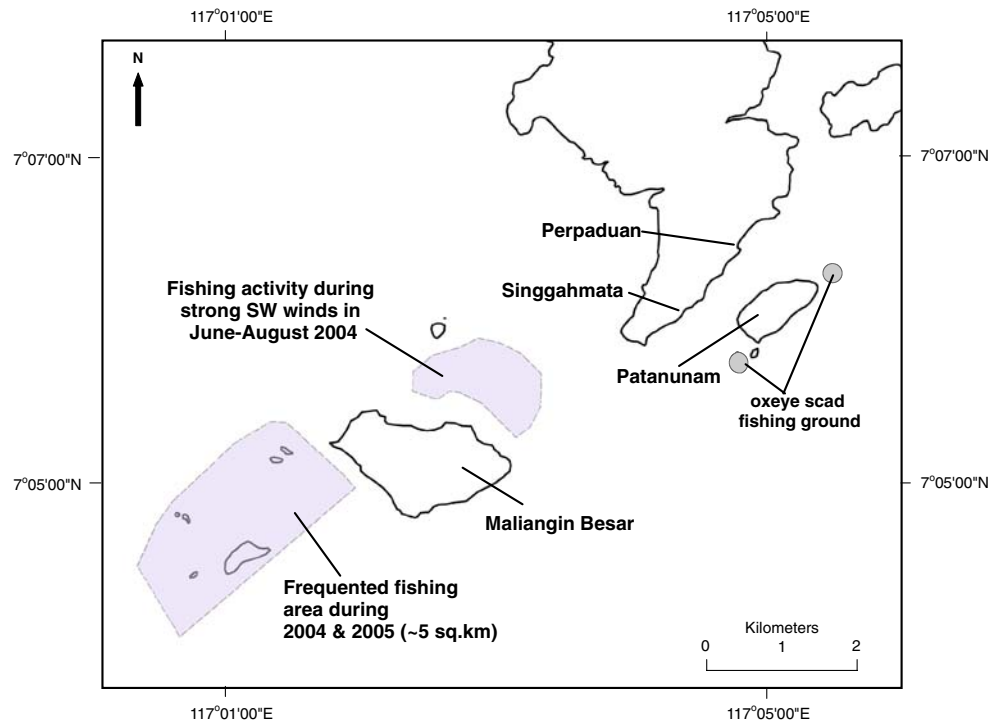
idae (i.e. ‘yellowtail scad’ and ‘other carangids’) was the dominant family in 2004, and made up 57% of the total catch. Demersal reef fish, mainly Haemulidae (sweetlips), Lethrinidae (emperors), and Lutjanidae (snappers) made up 30% of the catch. In March–April 2005, the proportion of demersal reef fish stayed approximately the same at 31%, while Carangidae decreased to 35%, and scombrids increased from 7 to 24%, caused mainly by kawakawa (Fig. 5b). The proportion of demersal reef fishes increased in April–May 2005, from 31 to 40% (Fig. 5b). One distinct difference was the abundance of stingray during April–May 2005, which increased to 16% from less than 5% in the other seasons (Fig. 5b).

Distribution of fishing effort

The highest observed effort in Maliangin occurred during calm days of the SW monsoon. An average of 11 (range 8–23) hook and line fishing boats per day were observed during fishing ground surveys in 2004. In contrast, only six fishing boats were recorded per day (range 4–12) during March–April 2005. In general, during calm weather fishers made two fishing trips a day, fishing up to 9 h daily. During windy periods they made only three to four fishing trips a week, and fished up to 6 h a day. This was usually most prevalent during the SW monsoon winds (June–September); however, this fishing effort pattern was also observed during March–April 2005 due to the unseasonably strong winds. On the nights of a new moon during windy conditions, effort was concentrated on fishing for scads (*Selaroides leptolepis* and *Selar* spp.) off the northern and southern points of Patanunam Island (Fig. 6). Interviewed fishers who fished for scad ($n = 3$) indicated that between 10 and 20 fishers engaged in this fishery, although only six to eight boats were observed in the present study by counting the number of illuminated boats from shore. However, this was likely a minimum estimate, as not all boats used lamps.

Hook and line fishers were observed fishing at more dispersed locations in 2004. Besides aggregating at the south-western side of Maliangin, they also fished at reefs on the north facing side of Maliangin Besar Island (Fig. 5). In contrast, during March–April 2005, fishers kept to a much smaller spatial scale, keeping to an actively fished area of approximately 5 km² on the south-western side of Maliangin. There were approximately 15 regular gillnet fishers operating in the southern Banggi area. While gillnet fishers may also be influenced by severe weather, gillnetting grounds are more sheltered, and gillnet fishers could make at least four to five fishing trips per week during windy periods,

Fig. 6 Map showing seasonal usage of Maliangin fishing ground by hook and line fishers



and fished daily during calm weather. During favourable weather, gillnet fishers set their nets twice a day, once in the evening from around 1800 to 2000 h and again in the early morning hours from 0400 to 0600.

Historic trends

Interviews indicated that there was a consensus among fishers (44 out of 45), regardless of what gear they used, that individual catch rates had declined from the past. When asked about the magnitude by which catch rates had decreased, 50% of fishers who answered the question mentioned a three or four times decrease in the catch rate (Table 4), with one gillnet fisher reporting the largest decrease, a 20 times reduction. Maximum daily catches were suggested to have ranged from 10 to 50 kg for hook and line in the 1980s, compared to recorded maximum catches between 4 and 30 kg in 2005. Gillnet fishers suggested they used to be able to catch up to 200 kg of fish per day, compared to a maximum of 30 kg per day now.

The majority (67%) of fishers indicated that catches started to decline from 2000 onwards (Table 4), and this was consistent among all gears. This assessment was particularly prevalent among the older fishers, with 88% of the fishers in the two oldest age groups ($n = 8$) mentioning 2000 as the period of catch decline. Overall, the next most commonly mentioned time period of decline was the 1990s (30%), followed by the 1980s. The respondents were in general not able to quantify

the number of hours they used to fish in the past, compared to the present. Instead, 70% said that it was easier to get fish in the past (Table 4). Of this group, 43% said that they used to spend less time fishing compared to the present. Both these responses suggested that individual catch rates had decreased.

Fishers had not noticed a change in the catch of fish at the broad family or group level (e.g. demersal reef fish). In regard to species-specific decline, leopard coral grouper (*Plectropomus leopardus*) was mentioned the most, followed by pelagic species such as Spanish mackerel, yellowtail scad, trevallies, and Indian mackerel (Table 4). Furthermore, catches of humphead wrasse (*Cheilinus undulatus*) and humpback grouper (*Cromileptes altivelis*) were nowadays extremely rare. Trap fishers remembered catching up to a maximum of 30 kg week⁻¹ of coral grouper in the 1980s, compared to a maximum of 10 kg week⁻¹ in 2005. The corresponding figures for hook and line fishers were a maximum of 20 kg day⁻¹ in the past (1970s) compared to a maximum of 5 kg day⁻¹ now.

Sixty-five percent of the respondents said that fish sizes had decreased from before (Table 4). Of these, 64% specified decreased sizes in coral groupers, while the rest referred to emperors, Spanish mackerel, and trevallies. Fishers said that the coral groupers they caught used to commonly weigh 1–2 kg, whereas the fish only weighed 0.1–0.8 kg now. Similarly, Spanish mackerel were also thought to have decreased substantially in size.

Table 4 Selected questions and responses to fisher interview questions

Question	Responses					No. of respondents
Have catches declined from the past?	Yes 44 (98%)	No 1 (2%)				45
How much more fish did you use to catch in the past? 2 (9%)	1–2 times 22	2–3 times	3–4 times	>4		times (14%)
When did catches start to decrease?	1980s	1990s	2000 and after			27
Was it easier to catch fish last time ?	1 (3%) Yes 7	8 (30%) No 3	18 (67%)			10
Have fish sizes changed from the past?	Yes—smaller 11(65%)	No 6 (35%)				17
Which fish species' catch has declined a lot or has become very difficult to find/catch? (15%)	Coral grouper 10 (38%)	Humphead wrase 2 (8%)	Humpback grouper 1 (4%)	Trevally 3 (12%)	All species 6 (23%)	Other ^a 4

For complete questionnaire see Electronic Supplementary Material

^a Other includes Spanish mackerel, tuna, scads, and fusiliers

Discussion

Catches

The present estimate of Banggi's total annual catches suggests that subsistence catches may make up almost 20% of total annual catches of around 3,687 tonnes. This underlines the importance of reef fisheries as a local source of protein, and subsequently, its importance to the nutrition and health of Banggi's population. It also indicates the potential extent to which Banggi's fisheries yield might be underestimated, leading to overly optimistic resource outlooks if future fisheries monitoring activities focus on recording commercially landed fish (artisanal fisheries) only. Furthermore, the average total catch estimate of 3,687 tonnes per year indicated that Banggi's fisheries were substantial within the broader spatial context of Kudat's regional traditional gear landings, which, between 1999 and 2003, were estimated to average 7,370 tonnes annually (Kudat Fisheries Statistics, Sabah Department of Fisheries). This suggests that the official statistics may underestimate true catches by a considerable margin, a pattern also observed for tropical fisheries elsewhere (Zeller et al. 2005, 2006).

The monsoon driven winds influenced fishers' ability to go fishing, leading to seasonally variable fishery yields. Seasonal weather patterns have been shown to affect the allocation of effort in other artisanal reef fisheries (e.g. Wiyono et al. 2006). Maximum wind speed was shown to be a significant explanatory variable for the variation in daily catch for the hook and

line fishery. Prevailing wind conditions were also known to influence catch and effort patterns in the commercial hook and line fishery on Australia's Great Barrier Reef (Williams et al. 1994). However, such differences were not observed for the gillnet fishery, and may be attributable to the more sheltered location of gillnet fishing grounds. Furthermore, while gillnets are passive, hook and line are active gears that require fishers to 'feel' their lines for bites, and thus windy conditions hamper their ability to do so effectively.

Variability of estimates

Recorded catch data, particularly for the hook and line fishery, showed large variation. This was due to a small number of large catches (see Fig. 3), resulting in positively skewed data. This is not atypical of other tropical fisheries, for example, Van Oostenbrugge et al. (2001) found that the coefficient of variation in catch rates for an Indonesian coastal fishery ranged between 2 and 3. As the limited number of recorded non-zero catches were excluded from analysis in the present study, the true variability in catches is likely to be even higher. However, in general, artisanal fishers minimized the occurrence of zero catches by not going fishing during unfavourable conditions. While there is considerable variance in the estimate of total annual fisheries yield (2,036–8,167 tonnes, mean of 3,687 tonnes), the total catch estimate is useful in providing a baseline estimate of the island's fisheries production. Such knowledge can aid the development of management plans for the proposed Tun Mustapha Marine Park, and highlights

the need for more comprehensive long-term monitoring on Pulau Banggi.

Effort

The shortage of alternative employment opportunities on Banggi may contribute to the total fishing effort (i.e. number of fishers) remaining fairly constant throughout the year, albeit distributed differently in time and space. Adapting to seasonal changes in the environment and resource availability enables fishers to maintain their income and protein needs (Salas and Gaertner 2004). This was apparent in Banggi, where gillnet fishers, for example, responded to poor fishing conditions in southern Banggi by travelling to more distant fishing grounds, or switching between large and small net mesh sizes depending on the severity of winds (Teh 2006). Similarly, stronger winds influenced hook and line fishers to jig for yellowtail scad and other pelagics instead of fishing for demersal fish. Suitable oceanographic conditions during the SW monsoon, combined with the economic incentives of the Live Reef Fish (LRF) trade, contributed to the high hook and line effort observed in 2004 (Teh 2006), even though this was also the windiest period of the year.

In contrast, the lower hook and line fishing effort observed during March–April 2005 reflected fishers trying to minimize economic risks. This was a transition period between the end of the Spanish mackerel season and start of the coral grouper season, and not an optimal time to obtain good catches of either species. Furthermore, winds in 2005 were unusually strong for this period; thus, many fishers were content to wait for calmer southwest winds before resuming normal activities. Consequently, fishing was mostly done near shore to meet subsistence needs only. Except for fishers from Maliangin Besar, who lived closest to the fishing ground, fishers from other southern Banggi villages diverted their effort to the ox-eye scad fishery nearer to the villages of Singgahmata and Perpaduan. Even though total fishing effort reflected anticipated changes in synchrony with different fishing seasons, it was also subject to the variability of a separate set of socio-economic factors (e.g. availability of land-based employment, or family matters, see Teh 2006).

Historic trends in catch

The decline in catch per unit effort (CPUE) of target species consistently indicated by fishers suggested that Banggi's small-scale fisheries may be in a state of decline. Within the context of Southeast Asia's intensively fished reefs, the threefold decline in catch rates

over the past two decades suggested here appeared reasonable, and less severe than those reported from comparable areas (e.g. White and Cruz-Trinidad 1998).

Another trend indicative of likely overexploitation was the spatial expansion of fishing grounds due to the lack of target fish near shore, as suggested from the interview data. This might also be attributed to degraded coral reef habitat caused by destructive fishing methods (e.g. dynamite and cyanide). Technological advances such as the introduction of air compressors and more fuel-efficient water pump engines have increased fishing efficiency. With Banggi's fisheries under no management, these developments have likely contributed to excessive fishing.

Notable about the temporal trend in southern Banggi is that compared to neighbouring countries, distinct declines appeared to have only happened relatively recently. While coastal inshore fisheries in the Philippines and Indonesia have been considered heavily overexploited since the 1970s (Pet-Soede et al. 1999; Alcala and Russ 2002), the earliest decade mentioned by Banggi fishers was the 1980s. In fact, today's daily catches for the Banggi fisheries remain higher than those recorded during the early 1990s for certain reef fisheries in the Philippines (Amar et al. 1996). Furthermore, profitability analysis of the Banggi fisheries by Teh (2006) indicated that both fisheries provide positive economic benefits to fishers. However, Banggi's high population growth rate (~4% per year) and the ongoing movement of illegal migrant fishers to Banggi are likely to increase pressure on fisheries resources, resulting in decreased economic benefits to individual fishers. This is further exacerbated by the shortage of alternative employment opportunities in Banggi.

Fishers' views on the decline in size and catch rate of *Plectropomus* spp. was consistent with a study by Daw et al. (2002) who reported a 50–90% reduction in the yields of LRF trade species in Kudat, and suggested that the stock may be biologically overfished, similar to another LRF trade species, the humphead wrasse (*Cheilinus undulatus*), throughout northern Sabah (CITES 2004²). However, aside from the valuable LRF species mentioned above, species composition of catches appeared to remain fairly constant. Moreover, there was no bycatch observed for both hook and line and gillnet fisheries. Nevertheless, the fact that Banggi's fisheries appear to have declined suggests the need for limiting or controlling fishing effort. Teh (2006) used preliminary ecosystem modelling to investigate

² Available at <http://www.cites.org/eng/cop/13/prop/E13-P33.pdf>. Accessed 15 October 2006

the effects of four fisheries management policies, including limiting and eliminating fishing effort. According to Teh (2006), the likely best option would be for the establishment of locally controlled no-take marine reserves. This option should be considered as part of the implementation of the proposed Tun Mustapha Marine Park.

Interestingly, the majority of interviewees indicated the most noticeable decreases in catch rate started to occur since 2000, with the primary reasons given being, (1) purse seine vessels from Kudat and other parts of Sabah encroaching upon the ‘traditional fishing zone’; (2) increase in the number of fishers; and (3) use of more efficient or destructive fishing techniques. The number of registered purse seine vessels in Kudat had increased from 1 in 1993 to 25 in 2001 (A. Cabanban, unpublished data), and has likely impacted the artisanal fisheries, particularly with respect to mackerel and scad. Furthermore, if these vessels were indeed operating illegally within the traditional fishing zone, this would lend credibility to the fishers’ allegations. Nevertheless, the likely substantial increase in the number of artisanal fishers (e.g. due to the high illegal immigration rate) and the use of more efficient and destructive gear is likely to have a more direct impact on the local resources.

An impediment of information derived from fisher interviews is that it is subject to time-dependent memory loss (Neis et al. 1999). However, as a large proportion of all respondents, as well as the majority of older interviewees mentioned 2000 onwards as the starting period of noticeable catch decline, it appears either that (a) the magnitude of decrease has been greatest in the last 5 years; or (b) fishers’ recent memory outweighs their long-term memory (>5 years) of ‘bad’ fishing days (e.g. catches of less than 10 kg per day).

Management implications

The proposed Tun Mustapha Marine Park (TMMP) will be a multiple use marine managed area where several small no-take marine reserves are being considered for fisheries management. In this context, the historic, spatial, and seasonal trends explored in the present study support the following insights into management planning for Banggi’s reef fisheries within the TMMP:

1. The estimated mean annual fisheries yield for Banggi (3,687 tonnes) is substantial, providing important local socio-economic benefits. However, declining catch rates and fish sizes, particularly for

the coral grouper fishery, indicate the immediate need for an effective method to control growth in fishing effort. For example, small, community-based marine reserves are a potential management tool which has been successful elsewhere (e.g. Alcala 1998). This option was discussed in Teh (2006);

2. The fairly constant overall fishing effort throughout the year reflected the importance of Banggi’s coastal reef fisheries as a source of income and subsistence, and highlighted the lack of alternative employment. Any policy that restricts fishers’ ability to fish should be complemented by alternative income schemes (e.g. Pet-Soede 2003);
3. Any consideration of potential spatial closures needs to be gear use sensitive. Since hook and line fishers mostly concentrated their effort in one location, they would be more heavily affected by spatial closures compared to gillnet fishers, with their more spatially dispersed fishing sites (e.g. Sumaila and Armstrong 2006);
4. The intrusion of commercial purse seine operations within the traditional fishing grounds should be addressed immediately, as it has the potential to negatively affect the fisheries resource and local catch rates; and
5. The present study’s findings could be enhanced by establishing long-term monitoring of catch landings and effort, including regular estimation of subsistence catches.

Acknowledgments We thank the fishers of southern Banggi for their generosity in sharing their knowledge, and the Borneo Marine Research Institute Seaweed Project for logistic support to Louise and Lydia Teh. A. Adnan Amna from the Kudat Fisheries Department provided data on traditional gear landings, and R. Jumin supplemented demographic data. D. Zeller and R. Sumaila acknowledge funding from the *Sea Around Us* Project, an initiative funded by the Pew Charitable Trusts.

References

- Alcala AC (1998) Community-based coastal resource management in the Philippines: a case study. *Ocean Coast Manage* 38:179–186
- Alcala AC, Russ GR (2002) Status of Philippine coral reef fisheries. *Asian Fish Sci* 15:177–192
- Amar EC, Cheong RMT, Cheong MVT (1996) Small-scale fisheries of coral reefs and the need for community-based resource management in Malalison Island, Philippines. *Fish Res* 25:265–277
- Anon (2003a) Profail Daerah Kecil Banggi Tahun 2003. Pejabat Daerah Kecil Banggi
- Anon (2003b) Laporan Kajian Mengenai Pengetahuan dan Pandangan Masyarakat Pulau Banggi Terhadap Penubuhan

- Taman Tun Mustapha. Institut Penyelidikan Marin Borneo, Kota Kinabalu
- Anon (2005) Profil Daerah Kecil Banggi Tahun 2005. Pejabat Daerah Kecil Banggi
- Burke L, Selig L, Spalding M (2002) Reefs at risk in Southeast Asia. WRI, Washington
- Daw T, Jeffrey L, Bin Ali MA (2002) Preliminary assessment of the live reef fish trade in the Kudat Region. WWF Malaysia, Kota Kinabalu
- McManus JW (1997) Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. *Coral Reefs* 16:S121–S127
- Neis B, Schneider DC, Felt L, Haedrich RC, Fischer J, Hutchings JA (1999) Fisheries assessment: what can be learned from interviewing resource users? *Can J Fish Aquat Sci* 56:1949–1963
- Pet-Soede L (2003) Mariculture as a sustainable livelihood strategy in support of conservation and management—a case study of Komodo National Park, Indonesia. *Aqua KE Government Documents* 2006(101):1010040
- Pet-Soede C, Machiels MAM, Stam MA, van Densen WLT (1999) Trends in an Indonesian coastal fishery based on catch and effort statistics and implications for the perception of the state of the stocks by fisheries officials. *Fish Res* 42:41–56
- Pet-Soede C, van Densen WLT, Hiddink JG, Kuyl S, Machiels MAM (2001) Can fishers allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia. *Fish Manag Ecol* 8:15–36
- Reason P (1994) Three approaches to participative inquiry. In: Denzin NK, Lincoln YS (eds) *Handbook of qualitative research*. Sage Publications, Thousand Oaks, California, pp 324–337
- Sadovy Y, Cheung WL (2003) Near extinction of a highly fecund fish: the one that nearly got away. *Fish Fish* 4:86–99
- Salas S, Gaertner D (2004) Strategies of fishers and fisheries management. *Fish Fish* 5:153–167
- Salas S, Sumaila UR, Pitcher T (2004) Short term decisions of small-scale fishers selecting alternative target species: a choice model. *Can J Fish Aquat Sci* 61:374–383
- Sumaila UR, Armstrong CW (2006) Distributional and efficiency effects of marine protected areas: a study of the Northeast Atlantic cod fishery. *Land Econ* 82:321–332
- Teh L (2006) The ecological and socio-economic sustainability of the reef fisheries of Pulau Banggi, Sabah, Malaysia. MSc thesis, University of British Columbia, p 143
- Teh L, Cabanban AS, Sumaila UR (2005) The reef fisheries of Pulau Banggi, Sabah: a preliminary profile and assessment of ecological and socio-economic sustainability. *Fish Res* 76:359–367
- Van Oostenbrugge JAE, Van Densen WLT, Machiels MAM (2001) Risk aversion in allocating fishing effort in a highly uncertain coastal fishery for pelagic fish, Moluccas, Indonesia. *Can J Fish Aquat Sci* 58:1683–1691
- White AT, Cruz-Trinidad A (1998) The values of Philippine coastal resources: why protection and management are critical. Coastal Resources Management Project, Philippines
- Williams D McB, Russ GR, Choat JH, Bellwood O (1994) Review of data on fishes of commercial and recreational fishing interest in the Great Barrier Reef. Great Barrier Reef Marine Park Authority Research Publication No 33, Townsville
- Wiyono ES, Yamada S, Tanaka E, Arimoto T, Kitakado T (2006) Dynamics of fishing gear allocation by fishers in small-scale coastal fisheries of Pelabuhanratu Bay, Indonesia. *Fisheries Manag Ecol* 13:185–195
- Zeller D, Booth S, Pauly D (2005) Reconstruction of coral reef and bottom-fisheries catches for US flag island areas in the Western Pacific, 1950 to 2002. Honolulu: Report to the Western Pacific Regional Fishery Management Council
- Zeller D, Booth S, Craig P, Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa. *Coral Reefs* 25:144–152