Abstract—The contribution of the no-take marine reserve at Apo Island, Philippines, to local fishery yield through "spillover" (net export of adult fish) was estimated. Spatial patterns of fishing effort, yield, and catch rates around Apo Island were documented daily in 2003–2004. Catch rates were higher near the reserve (by a factor of 1.1 to 2.0), but fishing effort was often lowest there. Higher catch rates near the reserve were more likely due to spillover than to low fishing intensity. Lower fishing effort near the reserve may have been due to 1) weather patterns, 2) traditional importance of other fishing grounds, 3) high variability in catch rates, 4) lower market value of target species, and 5) social pressures. The yield taken near the reserve was only 10% of the total yield, but the actual spillover contribution was probably much less than this. This study is one of the few to estimate the spillover contribution to overall yield and to document the responses of fishermen to spillover.

How much does the fishery at Apo Island benefit from spillover of adult fish from the adjacent marine reserve?

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No-take marine reserves (areas closed to fishing) are now often established with an objective of sustaining or enhancing fisheries (Gell and Roberts, 2003). Reserves could achieve such objectives by eventually becoming net exporters of adult biomass, defined as "spillover," and by providing net larval export, known as the "recruitment effect" (Russ, 2002). Fisheries will probably benefit from spillover in a minor way only. Theoretical studies have indicated that potential fishery yield (yield per recruit) from spillover would be insignificant, if any yield at all, except when stock abundance outside reserves is very low due to high fishing mortality (Polacheck, 1990; Russ et al., 1992; DeMartini, 1993). Thus, potential gains from spillover are predicted to be only moderate. There seems to be general agreement that the more important fishery enhancement effect of reserves would be due to net larval export (Carr and Reed, 1993; Russ, 2002). However, the establishment of reserves, particularly in developing countries, requires strong support from local stakeholders, especially fishermen (Russ and Alcala, 1996; Galal et al., 2002). There is a concern that, in some cases, support for reserves may be difficult to obtain on the pretext of enhanced fisheries through increased recruitment (Russ and Alcala, 1996). Net larval export may seem less convincing to fishermen because of the broad spatial scale (tens to hundreds of kilo-

meters) at which it will probably occur (Russ and Alcala, 1996; Russ, 2002). Yields from spillover, although probably small, may play a critical role in convincing fishermen to support establishment and maintenance of reserves (Russ and Alcala, 1996). For some fishermen, adult fish "spilling-over" from reserves, especially in the case of larger fish, will appear to be a more direct and tangible benefit than larvae recruiting to fishing grounds from distant reserves. Thus, spillover may have a substantial positive psychological effect on the attitudes of fishermen toward reserves.

However, few empirical studies have quantified the effects of spillover on fishery yields, nor the responses of fishermen to spillover, perhaps because some advocates of reserves are sometimes overly optimistic about the potential benefits of spillover. Two studies in one location in Kenya showed that after several years of reserve protection, spillover was not enough to compensate for reduction of total yield due to the creation of a large no-take reserve (McClanahan and Kaunda-Arara, 1996; McClanahan and Mangi, 2000). The reserve, Mombasa Marine Park, took away 50–60% (~6–8 km^2) of the total fishing area. In this case the reserve probably occupied too large an area to supplement total fishery yield substantially (McClanahan and Mangi, 2000). However, in other countries, no-take reserves as large as Mombasa

Marine Park are rare. In the Philippines, for example, reserves that are created with fishery enhancement as a major goal are typically small (<1 km^2 of reef area) and occupy ≤25% of the available local fishing area (Alino et al., 2002). To date, only two studies of Philippine reserves, Sumilon and Apo (~25% and ~10% respectively of fishing area are no-take reserves), have shown persuasively that spillover yield may affect total fishery yield (Alcala and Russ, 1990; Russ et al., 2004, Alcala et al., 2005). In both cases, however, the magnitude of actual spillover yield was unclear (Russ et al., 2004, Alcala et al., 2005). On the other hand, two studies, one in St. Lucia (Roberts et al., 2001) and one in Egypt (Galal et al., 2002), demonstrated that catch rates of fishermen increased several years after the creation of networks of reserves. It was argued in these studies that the reserves increased total fishery yield because catch rates improved but fishing effort remained constant. However, these studies provided no information on total fishery yield, precluding estimation of the magnitude of spillover benefits. More empirical studies are needed to provide assessment of potential spillover effects on adjacent fisheries.

Besides available fishing area, the total fishery yield for a given location will be determined by fishing intensity (Hilborn and Walters, 1992). In addition, theoretical studies indicate that spillover yield will be a function of reserve size, fishing mortality rate, and demographic parameters of target species, particularly movement rates (Polacheck, 1990; Russ et al. 1992; DeMartini, 1993). However, the actual contribution of spillover to total yield will be determined by fishing intensity adjacent to reserves. Indeed it has been suggested that the "first" sign of spillover is the sight of fishermen fishing close to reserve boundaries (Gell and Roberts, 2003). This phenomenon would occur presumably in response to higher catch rates near than far from reserves. Spillover is predicted to produce a pattern of higher abundance of target species outside but close to reserve boundaries, but lower abundance farther away (Rakitin and Kramer, 1996; Kramer and Chapman, 1999). Decreasing catch rates (an index of abundance) away from reserve boundaries have been demonstrated by experimental trap fishing outside one reserve in Barbados and one reserve in Kenya (Rakitin and Kramer, 1996; McClanahan and Mangi, 2000). Also, monitoring studies of reserves in Kenya and the Philippines have shown that catch rates of fishermen were higher closer to reserve boundaries than farther away (McClanahan and Kaunda-Arara, 1996; McClanahan and Mangi, 2000; Russ et al., 2003, 2004). In New Zealand, large catches of lobsters were found to be more common closer to Leigh Marine Reserve than farther away (Kelly et al., 2002). However, it is less clear if fishermen tend to concentrate more effort adjacent to reserves when spillover may be present. Some studies suggest that fishermen may do so (McClanahan and Kaunda-Arara, 1996; McClanahan and Mangi, 2000), whereas other studies indicate that fishermen do not (Russ et al., 2003; Wilcox and Pomeroy, 2003). Some of the evidence for fishermen preferentially fishing near reserves is anecdotal (Gell and Roberts[1]). Nevertheless, it is important to stress that intense fishing near the reserve may have the effect of eventually reducing catch rates there (McClanahan and Mangi, 2000).

Fishing effort may not necessarily track the spatial distribution of fish abundance. Fishermen may not favor fishing adjacent to reserves even if catch rates there are higher. Catch rates alone may not explain the spatial distribution of fishing effort, because decisions by fishermen on where to fish are usually aimed at making a profit. Hence, decisions may be influenced by fishing costs, such as fuel or time used traveling to fishing areas (Hilborn and Walters, 1992). These costs will be related to the distance of fishing grounds from home ports or residences of fishermen (e.g., Wilcox and Pomeroy, 2003). If such costs are negligible, then fishing effort may reflect the spatial pattern of catch rates, provided that fishermen have ample information on the latter. However, this situation may be unlikely if fishermen keep information about productive areas to themselves. Furthermore, the strategies of fishermen may become highly complex in fisheries that employ a variety of fishing gears and target a multitude of species (Hilborn and Walters, 1992). This is likely to be particularly true of coral reef fisheries in developing countries (Munro, 1996). Spatial distribution of fishing effort in such fisheries may also depend upon the differential value of target species. In addition, other factors that are unrelated to income may also influence the spatial pattern of fishing effort. These include weather conditions and social factors, such as local traditions or agreements among stakeholders and managers (Wilcox and Pomeroy, 2003). Consideration of the behavior of fishermen in relation to reserves may help determine if reserves are achieving their goal of improving fishery yields through spillover. Successful use of reserves to enhance fisheries would require a case by case understanding of the spatial structure of impacted fisheries, ecosystems, and human communities (Hilborn et al., 2004).

The objective of this study was to estimate the upper limit of the spillover contribution of the no-take reserve at Apo Island, Philippines to the local fishery yield. The reserve at Apo Island has been protected for over 20 years (since 1982), and there is evidence to suggest that spillover is present (Russ and Alcala, 1996; Russ et al., 2003, 2004; Alcala et al., 2005). However, previous studies indicate that access by fishermen to productive areas far from the reserve during favorable weather influences the local fishery yield considerably (White and Savina, 1987; Bellwood, 1988). In the present study, daily fishing effort and yield were documented for eight months covering two monsoonal seasons. Spatial and temporal patterns of fishing effort, yield (biomass and value), and catch rates were examined among fishing

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[1] Gell, F., and C. M. Roberts. 2002. Unpubl. report. The fishery effects of marine reserves and fishery closures, 89 p. WWF-US, 1250 24th Street. NW, Washington D.C. 20037.

grounds around Apo island and within a few hundred meters of reserve boundaries.

Materials and methods

Study site

Apo Island (9°4′N, 123°17′E) is located in the central Philippines, about 7 km southeast of the large island of Negros (Fig. 1). It is a small volcanic island with a fringing reef area of 1.06 km² to the 60-m isobath (0.54 km² to the 20-m isobath). The island is inhabited by a community of about 700 permanent residents. The traditional source of income for the community is fisheries. At present, about 100 residents are full-time or part-time fishermen who use hook and line, gill nets, spear guns, and fish traps, and target at least 60 species of reef fishes, nonreef fishes, and some invertebrates. The majority of local fishermen sell their catch to resident fish buyers on Apo Island. Fish buyers, in turn, bring the catch to Negros to sell in Malatapay town or Dumaguete City.

In 1982, a ~450 m long no-take reserve (sanctuary) was established informally by the local community on the southeastern side of Apo Island (Fig. 1). This reserve occupies approximately 10% of the fringing reef area to the 60-m isobath (about 13% to the 20-m isobath). The local community has effectively enforced protection of the no-take reserve since 1982 (Russ and Alcala, 1999). In 1985–86, the community formally approved a marine management plan that incorporated the no-take reserve (Russ and Alcala, 1999; White et al., 2002). The management plan also prohibited destructive fishing methods (e.g., dynamite fishing and muro-ami drive-net fishing) and spear fishing with SCUBA. Compliance by local fishermen and visitors with these regulations has been generally good. Development of local tourism enterprises has been encouraged by the Marine Management Plan. In the early to mid-1990s, two small resorts that could accommodate recreational SCUBA divers were established on Apo Island. Recently, the local community implemented collection of fees for diving in the no-take reserve and at dive sites around the island.

Apo Island is influenced by a northerly mainstream current that is present for most of the year (Fig. 1). This current presumably carries the food supporting planktivorous fishes (e.g., Acanthuridae and Caesionidae) that are abundant on the northern side of the island. Predatory fishes such as Carangidae are also common in this area. Apo Island is exposed to both the NE and SW monsoons (Fig. 1). Local fishermen tend to fish the northern side of the island during the SW monsoon (June to September) and interim calm months (April, May, and October; Bellwood, 1988). However, fishing intensity on the northern side of the island may be reduced during the NE monsoon (November to March; Bellwood, 1988).
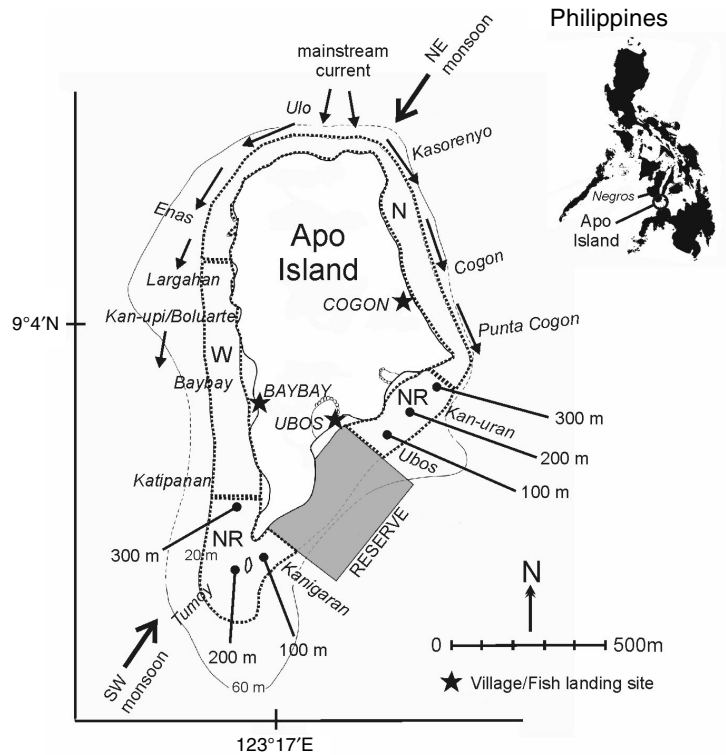

Figure 1

Apo Island, central Philippines, showing the no-take reserve (shaded). Names of fishing grounds around the island are italicized. Fishing grounds were grouped into "northern fishing grounds" (N), "western fishing grounds" (W), and "fishing grounds near Apo Reserve" (NR). The reef area of each of the fishing grounds is outlined (0–20 m isobath). Within the fishing grounds near Apo Reserve, the approximate positions of marker buoys used to indicate distance from either the northern or southern boundary of the reserve are shown. The major fish landing sites were at Baybay, Ubos, and Cogon villages (stars). Large arrows indicate the direction of the monsoons. Smaller arrows indicate direction of the mainstream current.

Data collection

The catches of fishermen residing at Apo Island were recorded daily from 22 July 2003 to 29 February 2004. Records were kept by three fish buyers, one buyer at each of the three major fish landing sites (the houses of the fish buyers) on the island, in Baybay, Ubos, and Cogon villages (Fig. 1). The fish buyers recorded the local names and weights of each species or family of fish that contributed to the catch sold by each fisherman. Catches were weighed on market scales accurate to 0.1 kg. The value of the catch sold by fishermen was estimated by multiplying the weight of each species by its average market price per kilogram in 2003, in Philippine Pesos (PHP). In addition, a resident research assistant (A. Candido) and one of the fish buyers (M. Aldeon) collected information from fishermen at each of the three villages through interviews every few days or weekly. The following information was gathered from fishermen:

fishing grounds visited, names and number of fishers, date and times when fishing started and finished, fishing gear used, and composition and weights of catches (verified from records of fish buyers). Interviewers were able to determine precisely where fishing was conducted because the names and locations of fishing grounds around Apo Island are common knowledge to local people (Fig. 1). However, if fishing was done near Apo Reserve (e.g., at Katipanan, Tumoy, Kanigaran, Ubos, and Kan-uran; Fig. 1), fishermen were also asked to estimate how far away they were from the boundaries of the reserve. Color-coded marker buoys, which fishermen could locate and identify easily while fishing, indicated approximate distances from reserve boundaries. These buoys were moored permanently at 100 m (blue), 200 m (red), and 300 m (yellow) from each of the northern and southern boundaries of Apo Reserve (Fig.1). The buoys were installed with the aid of a GPS receiver and fishermen were informed about them one week before the study started.

Data were collected from 80 full-time and part-time resident fishermen (Baybay–16, Ubos–47, Cogon–17). This group comprised 70–80% of all fishermen at Apo Island. The information in the present study probably reflects accurately the actual patterns of fishing effort and yield of the local market-oriented fishery. The majority of fishermen at Apo Island sell their catch to fish buyers at each of the three fish landing sites monitored (Maypa et al., 2002). The fish buyers usually purchased their fish from a group of "loyal" fishermen. Also, most fishermen live close to the houses of the fish buyers (landing sites). Thus, interviewers were able to collect data from fishermen regularly. Fishing effort and yield data were not adjusted to account for all resident fishermen (i.e., any fishermen not included in interviews).

However, data were not obtained from the following: 1) catch sold to part-time fish buyers on the island, 2) catch sold directly to the main island of Negros, 3) fishermen visiting from Negros, 4) catch sold dried, and 5) catch brought directly to homes for consumption. Items 1–4 are probably minor contributors to the total marketed yield. Maypa et al. (2002) surveyed the same fish landing sites monitored in the present study and estimated that only 10% of the total marketed yield (presumably from items 1–4) did not pass through the three major fish landing sites. On the other hand, yield from subsistence fishing (item 5) may be comparable in quantity to the marketed yield (White and Savina, 1987), but lower in monetary value. It is unlikely, however, that data on fishing effort collected in this study would differ much from data on subsistence fishing. It seemed common that fishermen went to sea to catch fish both to sell and keep for personal consumption.

Data analysis

Targeted species were classified into five groups according to Bellwood (1988): reef-associated species (Carangidae and Sphyraenidae), reef planktivores (Acanthuridae, Caesionidae, and Pomacentridae), reef species (mainly Lutjanidae, Lethrinidae, Scaridae, Serranidae, Kyphosidae, and octopus), open water species (Belonidae, Elopidae, and Scombridae), and off-reef species (Lutjanidae). Fishing grounds were classified into three groups: the northern fishing grounds (Enas, Ulo, Kasorenyo, Cogon, Punta Cogon), the western fishing grounds (Largahan, Kan-upi/Boluarte, Baybay, Katipanan), and the fishing grounds near Apo Reserve (Tumoy, Kanigaran, Ubos, Kan-uran) (Fig.1). Data were included in the third group if fishing was done ≤300 m from reserve boundaries. These three fishing grounds had roughly similar surface areas to the 20-m isobath (northern fishing grounds, 17.3 ha; western fishing grounds, 14.3 ha; fishing grounds near Apo Reserve, 18.9 ha). It was assumed that most fishing was done within or just outside the reef area enclosed by the 0- and 20-m isobaths (Fig. 1). In addition, data for the fishing grounds near Apo Reserve were classified into the following categories of distance from reserve boundaries: 0–100 m, 100–200 m, and 200–300 m.

Interviews allowed collection of fishing effort data even when fishermen returned from trips without catching anything (i.e., fishermen who used hook and line, gill nets, and spear guns). On average, about 20% of total fishing trips (or 23% of total fishing effort in person hours) returned with no catches. This figure varied considerably according to fishing gear (hook and line: 48%, gill net: 3%, spear gun: 7%) and months. However, fishing effort data for trips with zero catch were collected only beginning in September. Hence, the recorded fishing effort (in person hours) in July and August was adjusted by adding a correction factor in order to account for fishing trips with no catches. Correction factors were calculated from the equation

$$EC = \left[ER \times (EZ/ET) \right] / \left[1 - (EZ/ET) \right], \qquad (1)$$

where EC and ER = the correction factor (expressed in person hours) and recorded monthly fishing effort, respectively, for July or August; and

EZ and ET = the total fishing effort with zero catch and the total fishing effort, respectively, in September.

Values for September were used because this month is within the same season as July and August (SW monsoon). Correction factors were calculated per gear (hook and line, gill net, and spear gun) and per group of fishing grounds. However, prior to adjustment, the recorded monthly fishing effort for July was multiplied by three to obtain an estimate for a 30-day period. The yield for July was also multiplied by three to obtain a 30-day yield estimate. Catch per unit of effort (CPUE, in kg/person per hour for each month was calculated by taking the average CPUE of all individual fishing trips made in a given month. Monthly CPUE was calculated per gear, per group of fishing grounds, and per distance from reserve boundaries (0–100, 100–200, and 200–300 m). July and August CPUE were adjusted

to account for fishing trips with zero catch, by adding correction factors (expressed in number of fishing trips) calculated by using Equation 1. Hence, correction factors were the number of fishing trips with zero CPUE. Income per unit of effort (IPUE) was used as an indicator of economic value among fishing grounds. This was calculated in the same manner as CPUE, expressed in PHP/person per hour. IPUE for July and August were adjusted in the same manner as CPUE.

ANOVA was used to determine how fishing effort for each of the three principal gear (hook and line, gill net, and spear gun [fish traps were rarely used]) varied according to seasons (SW monsoon and interim period vs. NE monsoon) and fishing grounds (northern, western, and near Apo Reserve). ANOVA was also used to determine how CPUE or IPUE varied according to fishing grounds and the three principal fishing gear and how CPUE varied according to distance from reserve boundaries (0–100, 100–200, 200–300, and >300 m) and the three principal fishing gears. Monthly estimates of each variate of interest were used as replicates in each ANOVA. Variates were transformed (log [x+1] or square root [x+1]) to satisfy ANOVA assumptions. Tukey's test (Zar, 1999) was used in all *post hoc* analyses.

Two sets of indicators of relative economic value were used besides IPUE. The first was the frequency of capturing high-value species, and the frequency of landing a high yield of such species, expressed in number of fishing trips. This was summarized per species group and per fishing ground. High-value species were those with the highest, or the first and second highest, price per kg within species groups. Determination of a "high yield" within high-value species depended upon the average sizes of individuals within species groups, and whether species were usually landed as individuals or as groups. The following were considered high yield for high-value species: reef associated species (Carangidae, 3 spp.), ≥7.0 kg; reef planktivores (Caesionidae, 2 spp.), ≥3.0 kg; reef species (Serranidae, 3 spp., Lutjanidae, 7 spp., Lethrinidae, 2 spp.), ≥2.0 kg; open water species (Scombridae, 2 spp.), ≥7.0 kg; off-reef species (Lutjanidae, 1 sp.), ≥2.0 kg. The second indicator of economic value was the probability of capturing high-value species, and the probability of landing a high yield of such species, calculated on the basis of one fishing trip. This was calculated by dividing the frequencies (the first set of indicators) by the total number of fishing trips that used appropriate fishing gear to capture high-value species. Probabilities were calculated per species group and per fishing ground. Yield from traps were excluded in this analysis.

Results

Seasonal patterns of fishing effort and catch composition among fishing grounds

Hook-and-line fishing   The majority of hook-and-line effort (73–98%) was made on the northern fishing

grounds from July to December (Fig. 2A). However, during this period, hook-and-line fishing on the northern fishing grounds declined steadily (from 2302 to 50 person hours/month). It remained at low levels from January to February (35–173 person hours/month). Hook-and-line effort on the northern fishing grounds averaged 1015 ±342 (SE) person hours/month. The total hook-and-line yield from this area was 3549 kg (Table 1), dominated by reef-associated species (57%, mainly Carangidae) and reef planktivores (24%, mainly *Naso* spp.). Hook-and-line effort on the western fishing grounds was much lower, averaging 56 ±22 person hours/month (Fig. 2A). However, in January and February, hook-and-line effort on the western fishing grounds increased slightly (52–93 person hours/month). During this period, 38–62% of the total hook and line effort was made on the western fishing grounds, targeting an off-reef species (*Aphareus furca* (Lacepede) [Lutjanidae]). The total hook-and-line yield from the western fishing grounds was only 202 kg (Table 1), dominated by off-reef species (37%). Hook-and-line effort on the fishing grounds near Apo Reserve was the lowest among fishing grounds, averaging 33 ±9 person hours/month (Fig. 2A). It did not exhibit distinct seasonal patterns. The total hook-and-line yield near the reserve was only 166 kg (Table 1), dominated by reef species (38%, mainly octopus).

Hook-and-line effort (square root [x+1] transformed) differed significantly between seasons (ANOVA, $F_{1,18}=$ 13.14, P=0.002) and among fishing grounds (ANOVA, $F_{2,18}=$ 35.08, P<0.001). The season by fishing ground interaction was significant (ANOVA, $F_{2,18}$=16.34, P<0.001). During the SW monsoon and interim period (July to October), hook-and-line effort on the northern fishing grounds was significantly higher than on the western fishing grounds (Tukey's test, $q_{3,18}$=12.45, P<0.001) and on the fishing grounds near Apo Reserve (Tukey's test, $q_{3,18}$=11.84, P<0.001). During the NE monsoon (November to February), hook-and-line effort did not differ significantly among fishing grounds. Hook- and-line effort on the northern fishing grounds was significantly higher during the SW monsoon and interim period (July to October) than during the NE monsoon (November to February) (Tukey's test, $q_{2,18}$=9.48, P<0.001). No significant differences in hook-and-line effort between seasons were found on the western fishing grounds and on the fishing grounds near Apo Reserve.

Gillnet fishing   Gillnet fishing occurred mostly on the northern fishing grounds (194–466 person hours/month) from July to October (Fig. 2B). Gillnet effort on the northern fishing grounds averaged 268 ±44 person hours/month. The total gillnet yield from this area was 724 kg (Table 1), dominated by reef planktivores (76%, mainly Caesionidae). Beginning in November, gillnet effort shifted from the northern to the western fishing grounds. Gillnet effort on the western fishing grounds increased dramatically from zero in July, to 545 person hours/month in November (Fig. 2B). From November to February, the western fishing grounds accounted for 36–63% of the total gillnet effort. Gillnet effort on
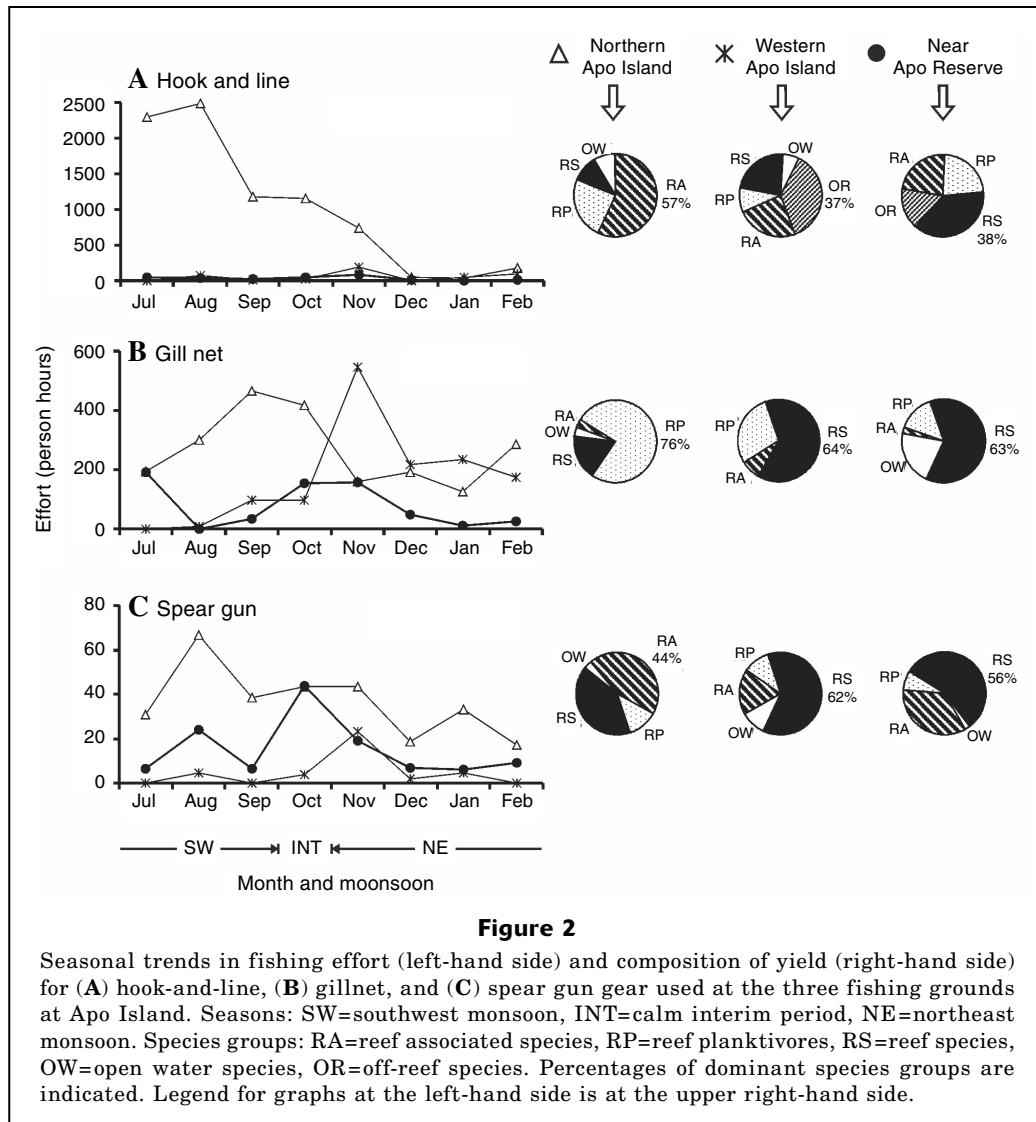
Figure 2

Seasonal trends in fishing effort (left-hand side) and composition of yield (right-hand side) for (**A**) hook-and-line, (**B**) gillnet, and (**C**) spear gun gear used at the three fishing grounds at Apo Island. Seasons: SW=southwest monsoon, INT=calm interim period, NE=northeast monsoon. Species groups: RA=reef associated species, RP=reef planktivores, RS=reef species, OW=open water species, OR=off-reef species. Percentages of dominant species groups are indicated. Legend for graphs at the left-hand side is at the upper right-hand side.

the western fishing grounds averaged 172 ±62 person hours/month. The total gillnet yield from this area was 493 kg (Table 1), dominated by reef species (64%, mainly Scaridae). Gillnet effort near Apo Reserve was much lower compared to other fishing grounds, averaging 78 ±27 person hours/month only. However, gillnet effort was relatively high near the reserve in July, October, and November (193, 155, and 157 person hours/month, respectively) (Fig. 2B). The total gillnet yield near the reserve was 318 kg (Table 1), dominated by reef species (63%, mainly Scaridae).

Gillnet effort did not differ significantly with seasons (ANOVA, $F_{1,18}$=0.18, P=0.68), but differed significantly among fishing grounds (ANOVA, $F_{2,18}$=6.72, P=0.007). The season by fishing ground interaction was significant (ANOVA, $F_{2,18}$=7.66, P=0.004). During the SW monsoon or interim period (July to October), gillnet effort on the northern fishing grounds was significantly higher than on the western fishing grounds (Tukey's test,

$q_{3,18}$=5.68, P<0.005) and on the fishing grounds near Apo Reserve (Tukey's test, $q_{3,18}$=4.81, P<0.01) but did not differ between the latter two fishing grounds. During the NE monsoon (November to February), gillnet effort did not differ between the western and northern fishing grounds, but gillnet effort on the western fishing grounds was significantly higher than near Apo Reserve ($q_{3,18}$=4.47, P<0.025). Gillnet effort on the northern fishing grounds was higher during the SW monsoon and interim period than during the NE monsoon (Tukey's test, $q_{2,18}$=2.96, P=~0.05 [$q_{0.05, 2,18}$=2.97]). Conversely, gillnet effort on the western fishing grounds was significantly higher during the NE monsoon than during the SW monsoon and interim period (Tukey's test, $q_{2,18}$= 4.67, P<0.005). Gillnet effort near Apo Reserve did not differ significantly between seasons.

Spear gun fishing   Spear fishing occurred mainly on the northern fishing grounds (Fig. 2C). However, spear

Table 1

Summary of recorded fishing effort, yield, and income of the fishery at Apo Island from 22 July 2003 to 29 February 2004. Contributions of the three fishing grounds (see Fig. 1) are shown. PHP = Philippine peso.

	Hook and line	Gill net	Spear gun	Fish trap	Overall
Total fishing effort (person hours)	8840	4141	452	129[1]	13,443[2]
Percent contribution					
Northern Apo Island	91.9	51.8	63.3	100	78.6
Western Apo Island	5.0	33.1	8.4	0	13.8
Near Apo Reserve	3.1	15.1	28.3	0	7.6
Total yield (kg)	3917	1535	406	32[3]	5890[3]
Percent contribution					
Northern Apo Island	90.6	47.2	66.2	100	77.7
Western Apo Island	5.2	32.1	4.8	0	12.1
Near Apo Reserve	4.2	20.7	29.0	0	10.2
Total income (PHP)	242,026	68,028	23,509	1371[3]	334,934[3]
Percent contribution					
Northern Apo Island	90.4	49.7	67.6	100	80.6
Western Apo Island	5.5	31.6	4.2	0	10.7
Near Apo Reserve	4.1	18.7	28.2	0	8.7

[1] Fishing effort in trap days = number of traps × number of days traps were left on the reef.
[2] Excludes fish trap effort.
[3] Trap yield in July not adjusted to 30-day period.

gun effort in this area declined from August to February (67 to 17 person hours/month, respectively). Spear gun effort on the northern fishing grounds averaged 36 ±6 person hours/month. The total spear gun yield from the northern fishing grounds was 269 kg (Table 1), dominated by reef-associated species (44%, Carangidae). Spear gun effort on the western fishing grounds was much lower, averaging only 5 ±3 person hours/month. It was highest in November (23 person hours/month) (Fig. 2C). The total spear gun yield from the western fishing grounds was only 19 kg (Table 1), dominated by reef species (62%, mainly Scaridae and octopus). Spear gun effort near the boundary of Apo Reserve was also rather low but was higher on average than on the western fishing grounds (mean 15 ±5 person hours/month). It peaked in October (44 person hours/month) (Fig. 2C). The total recorded spear gun yield near the reserve was 118 kg (Table 1), dominated by reef species (56%, mainly Scaridae and octopus).

Spear gun effort did not differ significantly between seasons (ANOVA, $F_{1,18}$=2.12, P=0.16) but differed significantly among fishing grounds (ANOVA, $F_{2,18}$=14.26, P<0.001). The season by fishing ground interaction was not significant (ANOVA, $F_{2,18}$=1.77, P=0.20). Spear gun effort on the northern fishing grounds was significantly higher than on the western fishing grounds (Tukey's test, $q_{3,18}$=7.41, P< 0.001) and the fishing grounds near Apo Reserve (Tukey's test, $q_{3,18}$=4.96, P<0.01). Spear gun effort, however, did not differ significantly between the fishing grounds near Apo Reserve and the western fishing grounds of Apo Island.

Trap fishing Bamboo fish traps were used on the northern fishing grounds only, and only in July (SW monsoon). The total trap effort was 126 trap days (4 fish traps set for 14 days, 7 for 10 days) with a total yield of 32 kg (Table 1). The yield was dominated by reef planktivores (85% Acanthuridae and Caesionidae).

Contributions of fishing gears and fishing grounds to overall fishing effort, yield, and income

Among the three principal fishing gear, most fishing effort was spent with hook and line, followed by gill nets, then with spear guns (Table 1). Hook-and-line fishing, therefore, contributed the greatest yield and highest income, accounting for 66% of the total yield and 72% of the total income recorded. Bamboo fish traps contributed the least yield and income (Table 1). All types of fishing occurred mainly on the northern fishing grounds. The northern fishing grounds accounted for 92%, 52%, 63%, and 100% of the total effort for hook-and-line gear, gill nets, spear guns, and fish traps, respectively. Accordingly, the northern fishing grounds accounted for the vast majority of total yield and total income for all types of fishing gears (Table 1).

On the other hand, fishing effort was often lowest on the fishing grounds near Apo Reserve (Table 1). The fishing grounds near the reserve accounted for only 3% and 15% of the total effort spent on hook-and-line and gillnet fishing, respectively. These fishing grounds contributed only 4% to the total yield and total income from hook and line fishing, and only 21% to the total

yield and 19% to the total income from gill-net fishing. Only 28% of the total spear gun effort was made near Apo Reserve. However, the overall spear gun effort near the reserve was about three times higher than that on the western fishing grounds. The fishing grounds near the reserve contributed about six times the yield and seven times the income of spear fishing on the western fishing grounds (Table 1).

Among species groups, the highest yield recorded was for reef-associated species, followed by reef planktivores, and then reef species (Table 2). Open water and off-reef species were minor contributors to overall yield. Reef-associated species together with reef planktivores accounted for 69% of the overall yield. The northern fishing grounds contributed ≥80% of the total yield of reef-associated species, reef planktivores, and open water species (Table 2). Much of the total yield of reef species (47%) was also taken from the northern fishing grounds. The western fishing grounds contributed 68% of the total yield of off-reef species but accounted for little of the yield for other species groups (Table 2). The fishing grounds near Apo Reserve often accounted for the smallest contribution to yield for all species groups. However, about a quarter of the total recorded yield of reef species were taken near the reserve.

Spatial patterns of CPUE and IPUE among fishing grounds

Mean hook-and-line, gillnet, and spear gun CPUE were highest in the fishing grounds near Apo Reserve (Fig. 3). CPUE near the reserve was higher than on the northern fishing grounds by a factor of 1.5, 1.4 and 1.4 for hook-and-line, gillnet, and spear fishing, respectively. CPUE near the reserve was higher than on the western fishing grounds by a factor of 1.6, 1.1 and 2.0 for hook-and-line, gillnet, and spear fishing, respectively. However, ANOVA indicated that CPUE (log $[x+1]$ transformed) did not differ significantly among the three groups of fishing grounds ($F_{2,57}=1.87$, $P=0.16$), but differed significantly among fishing gear ($F_{2,57}=9.26$, $P<0.001$).

The trends in mean IPUE reflected closely those of CPUE (Fig. 3). Mean IPUE near the reserve was higher than on the northern fishing grounds by a factor of 1.4, 1.2, and 1.4 for hook-and-line, gillnet and spear fishing, respectively. It was higher than on the western fishing grounds by a factor of 1.6, 1.1 and 2.2 for hook-and-line, gillnet, and spear fishing, respectively. However, ANOVA indicated that IPUE (log $[x+1]$ transformed) did not differ significantly among the three groups of fishing grounds ($F_{2,57}=0.49$, $P=0.62$), but
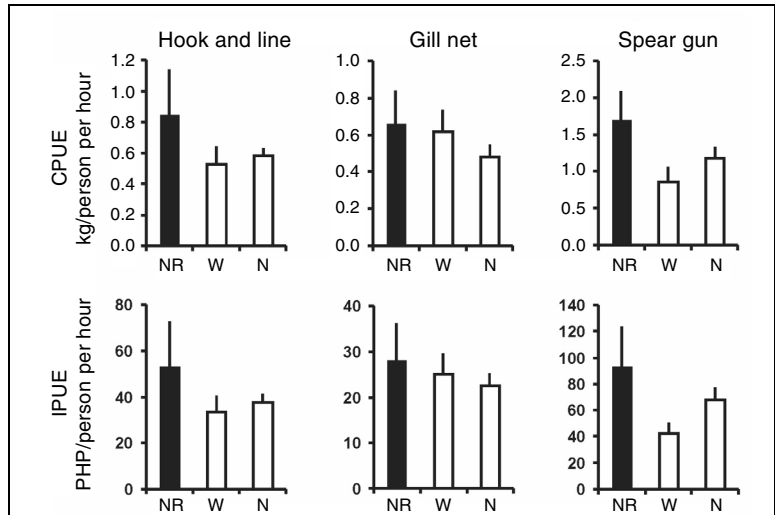

Figure 3

Mean catch per unit of effort (CPUE) and income per unit of effort (IPUE) for hook-and-line, gillnet and spear at the three fishing grounds at Apo Island. NR=near Apo Reserve, W=western Apo Island, N=northern Apo Island (see Fig. 1). Error bars are 1 standard error. PHP=Philippine peso.

Table 2

Composition of total recorded yield of the fishery at Apo Island from 22 July 2003 to 29 February 2004. Contributions of the three fishing grounds (see Fig. 1) are shown. Species groups: RA=reef-associated species, RP=reef planktivores, RS=reef species, OW=open water species, OR=off-reef species. Yield in July adjusted to 30-day period for each species group. Table excludes 16 kg of unidentifiable catch.

	RA	RP	RS	OW	OR
Total yield (kg)	2333	1772	1305	418	111
Percent contribution					
Northern Apo Island	92.4	85.6	46.7	80.0	7.9
Western Apo Island	3.9	9.1	28.4	3.6	67.5
Near Apo Reserve	3.7	5.2	24.9	16.4	24.6

differed significantly among fishing gear ($F_{2,57}=6.77$, $P=0.002$).

Monthly mean hook-and-line, gillnet, and spear gun CPUE and IPUE near Apo Reserve were more variable than in the other fishing grounds (Fig. 4, A–C). For example, the monthly hook-and-line CPUE near Apo Reserve changed from >1.5 to <1.0 to >2.0 and to <1.5 kg/person per hour from July to October. However, from November to February, it remained at <0.5 kg/person per hour, but was zero in January (Fig. 4A). Monthly hook-and-line IPUE near Apo Reserve varied accordingly. It changed from >100 to <50 to >150 and to <100 PHP/person per hour from July to October, but was less than 30 PHP/person per hour from November to February and was zero in January. In contrast, the monthly

hook- and-line CPUE and IPUE on the northern and western fishing grounds of Apo Island exhibited little variability (Fig. 4A). For most of the period between July and February, the monthly hook-and-line CPUE on the

northern fishing grounds remained between 0.5 to 0.8 kg/person per hour, whereas IPUE remained between 30 to 50 PHP/person per hour. Monthly CPUE for the western fishing grounds remained mostly between 0.2 to 1.0 kg/person per hour, whereas monthly IPUE remained mostly between 15 to 60 PHP/person per hour.

Fishing grounds near Apo Reserve often had the lowest minimum monthly CPUE and IPUE for all fishing gears, except for spear gun, which had the lowest minimum monthly CPUE and IPUE on the western fishing grounds (Table 3). However, fishing grounds near Apo Reserve always had the highest maximum monthly CPUE and IPUE for all fishing gears (Table 3, Fig. 5). Maximum monthly CPUE near the reserve was higher by a factor of 1.2 to 3.0, depending on the fishing gear and fishing ground (Fig. 5). Maximum monthly IPUE near the reserve was higher by a factor of 1.6 to 4.3, depending on the fishing gear and fishing ground. On the other hand, the highest minimum monthly CPUE and IPUE for all fishing gears were most often found only on the northern fishing grounds of Apo Island (Table 3).

Spatial patterns of high-value catches among fishing grounds

Capturing high-value species and landing a high yield of such species were often more frequent on the northern fishing grounds (Table 4). For example, 133 captures of high-value reef-associated species (Carangidae—*Caranx ignobilis* (Forsskål), *Caranx melampygus* (Cuvier), and *Carangoides* sp.) were made on the northern fishing grounds. In 46 of these captures, the yield was ≥7.0 kg or 525 PHP. Six of the fishes cap-

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Table 3

Range of monthly mean catch per unit of effort (CPUE) and income per unit of effort (IPUE) for hook-and-line, gillnet, and spear gun gear at the fishing grounds at Apo Island (see Fig. 1). Lowest minimum and highest maximum average values are marked by the symbol †. Highest minimum values are marked by ‡. PHP = Philippine peso.

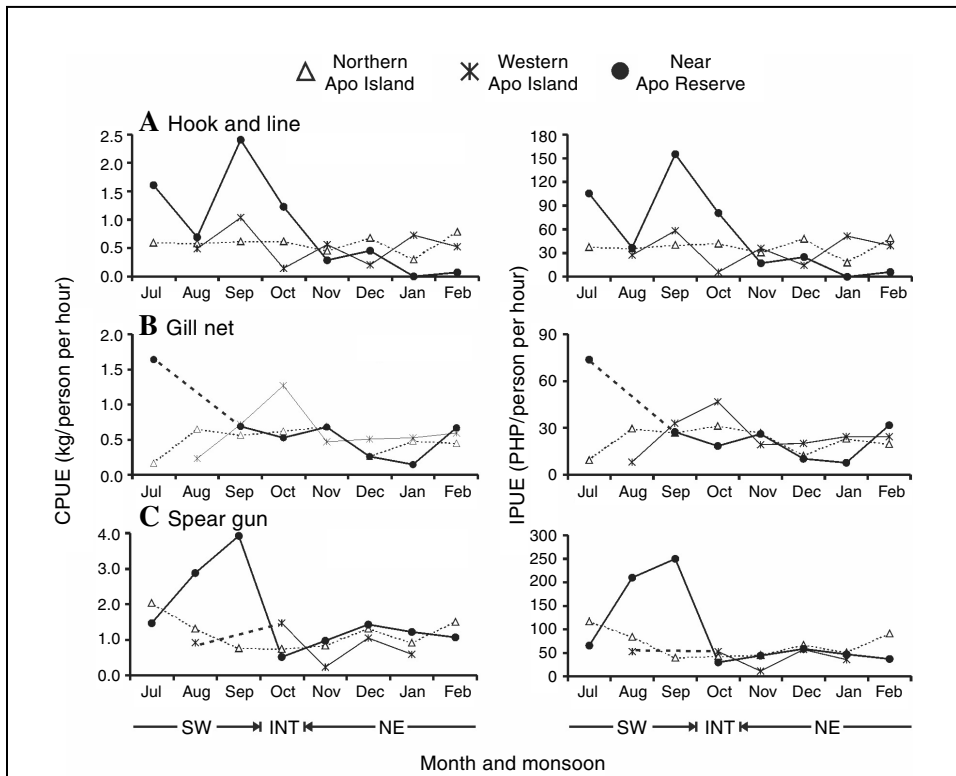|	Hook and line	Gill net	Spear gun
CPUE (kg/person per hour)			
Northern Apo Island	0.3‡–0.8	0.2‡–0.7	0.7‡–2.0
Western Apo Island	0.1–1.0	0.2‡–1.3	0.2†–1.5
Near Apo Reserve	0.0†–2.4†	0.1†–1.6†	0.5–3.9†
IPUE (PHP/person per hour)			
Northern Apo Island	18.4‡–49.00	9.6‡–31.30	40.30‡–117.60
Western Apo Island	6.20–58.40	8.20–46.40	11.90†–57.80
Near Apo Reserve	0†–154.90†	7.80†–73.70†	30.50–249.90†

Figure 4

Monthly mean catch per unit of effort (CPUE) and income per unit of effort (IPUE) for (**A**) hook-and-line, (**B**) gill-net, and (**C**) spear at the three fishing grounds at Apo Island. Seasons: SW=southwest monsoon, INT=calm interim period, NE=northeast monsoon. PHP=Philippine peso.
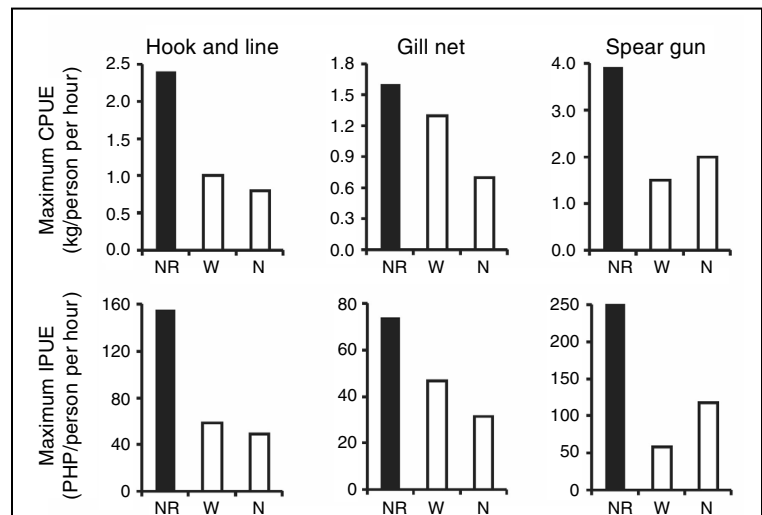
Table 4

Frequency and probability of capturing or landing a high yield of high-value species within each species group for each of the three fishing grounds at Apo Island (see Fig. 1). Upper values: frequency (number of fishing trips) and probability (in parentheses) of capturing high-value species. Lower values: frequency (number of fishing trips) and probability (in parentheses) of landing a high yield of high-value species. Highest frequencies are marked with the symbol †. Highest probabilities are marked with the symbol ‡. Price per kg and prices of what were considered "high yield" are given in Philippine pesos (PHP).

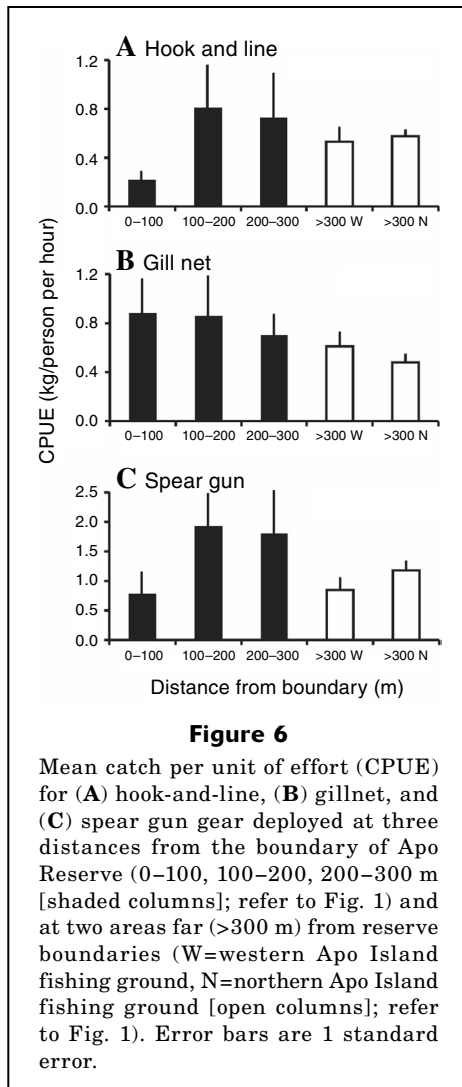| Species groups, families	Northern Apo Island		Western Apo Island		Near Apo Reserve	
Reef-associated species (Carangidae)						
75 PHP/kg	133†	(0.07)‡	9	(0.03)	8	(0.05)
≥7.0 kg or PHP 525	46†	(0.03)‡	1	(0.004)	4	(0.02)
Reef planktivores (Caesionidae)						
55 PHP/kg	123†	(0.07)‡	17	(0.06)	9	(0.05)
≥3.0 kg or PHP 165	36†	(0.03)‡	4	(0.02)	0	(0)
Reef species (Serranidae, Lutjanidae, Lethrinidae)						
70–75 PHP/kg	57†	(0.03)	15	(0.06)	12	(0.07)‡
≥2.0 kg or PHP 150	31†	(0.02)	10	(0.04)	9	(0.05)‡
Open water species (Scombridae)						
75–90 PHP/kg	5†	(0.003)	1	(0.01)‡	0	(0)
≥7.0 kg or PHP 525	3†	(0.002)‡	0	(0)	0	(0)
Off-reef species (Lutjanidae)						
75 PHP/kg	4	(0.003)	29†	(0.23)‡	3	(0.04)
≥2.0 kg or PHP 150	2	(0.001)	13†	(0.10)‡	2	(0.03)

tured weighed ≥15 kg (equivalent to a value of ≥1125 PHP). The largest was a 31.9-kg *C. ignobilis* valued at 2393 PHP, which was also the biggest fish caught during our study. In contrast, only eight captures of high-value reef-associated species were made near Apo Reserve. In only four of these captures were the yields ≥7.0 kg or 525 PHP. Only one of the fishes captured near the reserve weighed >15 kg. This was a 20.2-kg *C. ignobilis* valued at 1515 PHP.

Capturing high-value species and landing a high yield of such species often had the greatest probability of occurring on the northern fishing grounds (Table 4). For example, the probability of capturing high-value reef-associated species from the northern fishing grounds was 0.07. Landing a high yield of such species from this area had a probability of 0.03. In contrast, the probability of capturing high-value reef-associated species near Apo Reserve was 0.05. Landing a high yield of such species near the reserve had a probability of 0.02. However, the probability of capturing high-value reef species (Serranidae—*Cephalopholis, Epinephelus, Variola* spp.; Lutjanidae—*Aprion, Lutjanus, Macolor, Symphorichthys, Symphorus* spp.; and Lethrinidae—*Lethrinus* spp.) was greatest near Apo Reserve (Table 4). The probability of landing a high yield of such species (≥2.0 kg or 150 PHP) was also greatest near the

Figure 5

Maximum monthly mean catch per unit of effort (CPUE) and income per unit of effort (IPUE) for hook-and-line, gill-net, and spear gun gear used at the three fishing grounds at Apo Island. NR=near Apo Reserve, W=western Apo Island, N=northern Apo Island (see Fig. 1). Error bars are 1 standard error. PHP=Philippine peso.

reserve, despite the higher frequency of capturing high-value reef species, or landing a high yield of such species, on the northern fishing grounds than near Apo Reserve (Table 4).

Figure 6

Mean catch per unit of effort (CPUE) for (**A**) hook-and-line, (**B**) gillnet, and (**C**) spear gun gear deployed at three distances from the boundary of Apo Reserve (0–100, 100–200, 200–300 m [shaded columns]; refer to Fig. 1) and at two areas far (>300 m) from reserve boundaries (W=western Apo Island fishing ground, N=northern Apo Island fishing ground [open columns]; refer to Fig. 1). Error bars are 1 standard error.

Spatial patterns of CPUE near reserve boundaries

Spatial patterns of CPUE away from reserve boundaries differed for hook-and-line, gillnet, and spear gun gear (Fig. 6). Gillnet CPUE exhibited a pattern of decrease from 0–100 to 200–300 m from the reserve boundaries (from 0.88 to 0.70 kg/person per hour; Fig. 6B). Gillnet CPUE further decreased >300 m from reserve boundaries (western and northern fishing grounds). In contrast, hook-and-line and spear gun CPUE was lowest near (0–100 m) reserve boundaries, but much higher at distances of 100–300 m from the boundaries (Fig. 6, A and C). Hook-and-line and spear gun CPUEs at 100–300 m from reserve boundaries were higher than farther away (>300 m) from the boundaries (western and northern fishing grounds). However, hook-and-line and spear gun CPUEs were highest at 100–200 m from reserve boundaries (Fig. 6, A and C). An ANOVA with data for 0–300 m indicated only that CPUE did not differ significantly with distance from reserve boundaries ($F_{2,39}=0.73$, $P=0.49$) or with fishing gear ($F_{2,39}=2.52$,

Table 5

Frequency of fishing trips for each of the three distances from the boundaries of Apo Reserve (see Fig. 1), for each of hook and line, gill net, and spear gun. Fishing trips were made between 22 July 2003 and 29 February 2004.

	Number of times fished		
	Hook and line	Gill net	Spear gun
Distance from reserve boundaries			
0–100 m	2	3	4
100–200 m	43	24	33
200–300 m	25	28	7

$P=0.09$). However, an ANOVA with data for 0–300 and >300 m indicated that CPUE (log [$x+1$] transformed) did not differ significantly with distance from reserve boundaries ($F_{4,76}=1.19$, $P=0.32$) but differed significantly among fishing gear ($F_{2,76}=7.28$, $P=0.001$).

Contrasting patterns were also found in fishing effort (frequency of fishing trips) at different distances from the boundaries of Apo Reserve (Table 5). Hook-and-line and spear fishing occurred most frequently at intermediate distances from reserve boundaries, but gillnet fishing occurred most frequently at the farthest distances. However, all types of fishing occurred very infrequently within 100 m of reserve boundaries (Table 5).

Discussion

Results indicate that the maximum possible contribution of spillover from the no-take reserve to the overall yield and income of the fishery at Apo Island is small. If one assumes that the spillover of coral reef fishes is most likely to operate on spatial scales of hundreds of meters (Russ, 2002), and, thus, would be unlikely to affect fishery yields on the western and northern fishing grounds, the maximum possible contribution would be 10% of the total fishery yield, but the real value is probably much less than this. We assumed that the eight months sampled in 2003–2004 are representative of the general spatial pattern of fishing at Apo Island. Furthermore, we assumed that the spatial pattern of fishing during the four months not sampled (March to June) remains consistent with the general pattern of fishing. It can be estimated from the present study that the total fishery yield at Apo Island in 2003–2004, excluding the yield consumed locally, was around 10.4 tons/km^2 per year (to the 60-m isobath). Thus, spillover from Apo Reserve would have contributed very much less than 1.0 ton/km^2 per year in 2003–2004.

Fishing effort was often lowest on the fishing grounds near the reserve. The fishery at Apo Island is primarily hook and line, targeting reef-associated species (Carangidae), and to a lesser extent reef planktivores (*Naso*

spp.) (Alcala and Luchavez, 1981; White and Savina, 1987; Bellwood, 1988; Maypa et al., 2002; present study). Ninety-two percent of total hook-and-line effort was made on the northern fishing grounds of the island. Gill nets, spear guns, and fish traps were not used as much as hook-and-line; however, fishing with these gear was also carried out mostly on the northern fishing grounds, contributing to a yield of reef-associated species and reef planktivores. Fishing near Apo Reserve contributed mainly to catch of reef species (Scaridae and octopus), which are a less important species group for the local fishery. The fishery depended heavily on access to the northern fishing grounds during the SW monsoon and calm interim period (Bellwood, 1988; present study). Results clearly showed that fishing effort on the northern fishing grounds was considerably lower during the NE monsoon, especially for hook-and-line gear and gill nets. However, fishing effort did not shift to the fishing grounds near Apo Reserve during the NE monsoon. Gillnet fishing seemed to transfer instead to the western fishing grounds, targeting reef species (Scaridae). To a much lesser degree, hook-and-line fishing also transferred to the western fishing grounds, targeting high-value off-reef species (*Aphareus furca* [Lutjanidae]). The northern fishing grounds alone accounted for 78% of overall yield and 81% of overall income recorded in our study (Table 1). In contrast, fishing grounds near Apo Reserve accounted for only 10% of overall yield and 9% of overall income (Table 1). However, it is highly unlikely that spillover from Apo Reserve supplied the entire yield taken from fishing grounds near the reserve. That is, the yield near the reserve was probably not composed totally of migrants from the reserve. Therefore, the actual spillover contribution of Apo Reserve would be much less than 10% to the overall yield and income generated by the fishery.

However, CPUE of fishermen was highest on the fishing grounds near Apo Reserve. This pattern may have resulted from 1) spillover from the reserve or 2) lower fishing intensity near the reserve, resulting in higher abundance of fish and, thus, higher CPUE. There is far more empirical evidence supporting the spillover hypothesis than the lower fishing intensity hypothesis. Considerable evidence exists that some supplement for the fishery near the reserve has developed over time. Firstly, monitoring of Apo Reserve since 1983 has shown that fish populations inside the reserve have increased in abundance, some having tripled in density or biomass over the last two decades (Russ and Alcala, 1996, 1998, 2003; Russ et al., 2003, 2004; Alcala et al., 2005). Secondly, long-term monitoring indicates that the reserve began to export adult fish to a site open to fishing after ~8 years of reserve protection (Russ and Alcala, 1996; Russ et al., 2003, 2004). Thirdly, catch rates of some species (Acanthuridae) were found to be higher near the reserve than elsewhere around Apo Island after two decades of reserve protection (Russ et al., 2003, 2004). Fourthly, recent studies indicate that patterns of decreasing abundance of some targeted species are present across the northern boundary of the reserve (Abesamis et al., 2005). Lastly, a recent study indicates that density-dependence may be driving net emigration of adult fish (*Naso vlamingii* (Valenciennes)) from the reserve (Abesamis and Russ, 2005). On the other hand, no direct evidence is available to show that fishing effort near Apo Reserve has remained low over the last two decades. However, the fishing grounds near the reserve may be partially exposed to the SW and NE monsoons (Alcala and Luchavez, 1981). During the SW monsoon, the fishing grounds adjacent to the southern end of the reserve may become rough, but those adjacent to the northern end are usually calm (Fig. 1). The pattern is reversed during the NE monsoon. Thus, fishing effort near the reserve may be reduced for nine months of the year (June to September, November to March) because only the area close to one side of the reserve may be fished, depending on the monsoon. The role of the monsoons in limiting fishing effort near the reserve cannot be ruled out entirely.

If spillover has increased CPUE near the reserve, as long-term evidence seems to indicate, then why have local fishermen not responded noticeably to the improvement in catch rates? Weather may be important in limiting fishing effort near the reserve, but it cannot explain the low fishing intensity in this area during the calm interim months. Results show that hook-and-line and gillnet effort on the fishing grounds near the reserve in October were still considerably lower than on the northern fishing grounds (Fig. 2, A and B). Anecdotal information also indicates that most fishermen still prefer to fish the northern fishing grounds even during April and May (Pascobello[2]). This information is consistent with the findings of previous studies (White and Savina, 1987; Bellwood, 1988; Maypa et al., 2002), which indicate that the general pattern of fishing effort at Apo Island has not changed much since creation of the reserve in 1982. Furthermore, a reasonable amount of fishing area (8–11 ha) near the reserve is still available to fishermen during either monsoon. Given the higher catch rates, fishermen could still concentrate effort near the reserve, one side of the reserve at a time, depending on the monsoon. Higher costs (time and energy spent to paddle a small boat [*banca*]) are certainly not preventing fishermen from fishing adjacent to the reserve. The majority of fishermen (80%) reside near the reserve, in Baybay and Ubos villages (Fig. 1) and therefore for most fishermen the costs of fishing the northern side of Apo Island may actually be higher. It is also unlikely that fishermen are not aware of higher catch rates near the reserve. Fishermen can probably obtain good information about catch rates from the experiences of fellow fishermen, or from word-of-mouth, because the community is relatively small and tightly knit. Many fishermen are members of the same family (including cousins and uncles) or are friends with each other. Income rates *per se* can also be ruled out as an

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[2] Pascobello, M. 2002. Personal commun. Apo Island resident and village chairman. Apo Island, Dauin Municipality, Negros Oriental, Philippines, 6217.

important influence on the spatial pattern of effort because results indicated that IPUE for all gears was also highest on the fishing grounds near the reserve. However, one cannot discount that the northern side of Apo Island may be regarded by the local community as their main traditional fishing ground. This area has probably been fished for decades, providing the income for families generation after generation.

Other characteristics of the CPUE and IPUE data may also provide a partial explanation. CPUE and IPUE were more variable on the fishing grounds near Apo Reserve (Fig. 4). In fact, the fishing grounds near the reserve often had both the highest and lowest CPUE and IPUE per month for all types of fishing gears (Table 3, Fig. 5). The only exception was for spear gun, which had the lowest CPUE and IPUE on the western fishing grounds (Table 3). These findings may indicate that near the reserve, fishermen could obtain very high average monthly catch rates and income rates. However, they may also indicate that near the reserve, fishermen (using hooks and lines and gill nets) could obtain very low average monthly catch rates and income rates. Monthly CPUE and IPUE were least variable on the northern fishing grounds (Fig. 4). In addition, the highest minimum average monthly CPUE and IPUE were always found in this area (Table 3). Therefore, a plausible explanation for the spatial pattern of fishing effort at the island scale is that fishermen probably tend to avoid fishing near Apo Reserve in order to make their monthly incomes more stable and avoid occasional very low catch rates. Fishermen may prefer the northern fishing grounds even if catch rates in this area are not as high as near the reserve because they are assured of obtaining higher minimum yields and a more stable income. This strategy may be a form of financial "risk aversion" (Hilborn and Walters, 1992). It is further postulated that such a risk aversion strategy could explain why total spear gun effort was higher on the fishing grounds near Apo Reserve than on the western fishing grounds (Tables 1 and 3). Also, a risk aversion strategy may partly explain why fishing with gill nets and hook and line transferred to the western fishing grounds instead of near the reserve during the NE monsoon (Fig. 2B, Table 3).

Other factors may also influence the decision by fishermen to concentrate effort on the northern side of Apo Island. For example, the largest and most valuable fish recorded in this study, a 31.9-kg *Caranx ignobilis* worth almost PHP 2400, was captured from the northern fishing grounds. A high-priced catch such as this one may have a tremendous psychological impact on local fishermen. Anecdotal information seems to indicate that the income from such a yield may be enough to provide for 80% of the daily expenses of one family for one month at Apo Island (Pascobello-Rhodes[3]). In com-

parison, the largest and most valuable fish caught near Apo Reserve, also *C. ignobilis*, was only two-thirds the weight (20.2 kg) and value (PHP 1515) of the largest fish caught from the northern fishing grounds. This fish was the only one caught near the reserve with a value greater than PHP 1000. Local fishermen probably consider fish of this size more common on the northern fishing grounds. During this study, five individuals of *C. ignobilis* (range: 15.0–19.0 kg) that were captured from the northern fishing grounds had weights similar to the largest fish caught near the reserve. Therefore, the biggest psychological impact on fishermen may not be due to spillover from the reserve.

A perception by local fishermen that the northern fishing grounds are productive areas for high-value species may not only have a psychological basis. Results indicate that the probability of capturing high-value reef-associated species (Carangidae) and the probability of landing a high yield of such species were highest on the northern fishing grounds (Table 4). The same was true for high-value reef planktivores (Caesionidae) (Table 4). The probability of landing a high yield of high-value open water species (Scombridae) was also greatest on the northern fishing grounds (Table 4). Assuming that fishermen prefer to target high-value species, these findings indicate that fishermen have better chances of making higher incomes from the northern fishing grounds than from other areas. The better prospect of making a higher income probably influences the decision by fishermen to concentrate effort on the northern side of Apo Island whenever it is accessible. Similarly, some fishermen probably shift to the western fishing grounds during the NE monsoon (the "off-season") because of better chances of gaining higher incomes by targeting high-value off-reef species (*A. furca* [Lutjanidae]) (Table 4).

However, the results indicated that the probability of capturing high-value reef species (Serranidae, Lutjanidae, and Lethrinidae), or landing a high yield of such species, was greatest on the fishing grounds near Apo Reserve (Table 4). Fishing intensity for high-value reef species, on the other hand, appears to be greatest on the northern fishing grounds, because capturing or landing a high yield of high-value reef species was most frequent there (Table 4). Thus, it seemed that most fishermen avoided fishing for high-value reef species near Apo Reserve despite better chances of making high incomes from high-value reef species. One plausible explanation for avoiding the fishing grounds hear the reserve is that fishermen would still prefer to fish the northern fishing grounds because they can target the high-value species that come in larger sizes (Carangidae and Scombridae) or greater numbers (Caesionidae) and at the same time occasionally capture high-value reef-species. The high-value reef species (Serranidae, Lutjanidae, Lethrinidae) are unsatisfactory alternatives for fishermen because they come in smaller sizes (compared to Carangidae and Scombridae) or in smaller numbers (compared to Caesionidae), and therefore would fetch a lower price.

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[3] Pascobello-Rhodes, L. 2003. Personal commun. Apo Island resident. Apo Island, Dauin Municipality, Negros Oriental, Philippines, 6217.

On the other hand, the highest maximum monthly CPUE and IPUE were invariably found near Apo Reserve (Fig. 5, Table 3). This result is consistent with the occasional spillover of bigger fish from the reserve. Such an effect may have a positive influence on the attitudes of fishermen toward reserves (Russ and Alcala, 1996). However, in the case of the artisanal fishery at Apo Island, any psychological impact of large catches near the reserve on fishermen is probably attenuated by the importance of the northern fishing grounds. In other fisheries, however, occasional spillover of large adults may be important. Recreational "trophy" fisheries, for example, may benefit directly from such an effect of no-take reserves (Bohnsack, 1998; Johnson et al., 1999; Roberts et al., 2001). In New Zealand, Kelly et al. (2002) showed that lobster catch rates (kg/trap haul) were similar close to and far from Leigh Marine Reserve, although catches around the reserve consisted of fewer individuals. The lobsters caught near the reserve were bigger. Furthermore, the amount of money made per trap haul close to the reserve was similar to sites far from the reserve.

The findings at the scale of a few hundred meters from the boundary of the reserve provide little evidence to indicate that spillover from Apo Reserve is present. In fact, the most informative result at this spatial scale was that fishermen seemed to avoid fishing very close to the reserve (i.e., within 100 m from the boundaries) (Table 5). Furthermore, catch rates seemed to be lowest closest to reserve boundaries for hook-and-line and spear fishing (Fig. 6, A and C). However, gillnet fishing seemed to have a pattern of decreasing catch rate away from reserve boundaries (Fig. 6B). Gear selectivity interacting with the spatial distribution of target species may explain the differences in spatial patterns of CPUE among the three gears. Gillnet fishing is probably less selective than hook-and-line and spear fishing.

The pattern of fishing effort found very near to the reserve can be interpreted in two ways. Firstly, local fishermen may be well aware of the distribution of catch rates near Apo Reserve, and they adjust their fishing effort accordingly. This interpretation is supported to some degree by the correspondence between the pattern of CPUE and the pattern of fishing effort for hook-and-line and spear gun gear. Both CPUE and fishing effort for these gear were highest at intermediate distances (100–200 m), but lower at the closest (0–100 m) and farthest distances (200–300 m) from the reserve (Fig. 6, A and C, Table 5). Fishermen may know from experience that hook-and-line and spear gun catch rates are low nearest the reserve (0–100 m), hence they tend to avoid fishing in this area. Experimental fishing with hooks and line, but specifically targeting *N. vlamingii*, supports the contention that hook-and-line CPUE is low very close to the boundary of Apo Reserve (Abesamis and Russ, 2005). Hook-and-line CPUE for *N. vlamingii* was higher at intermediate distances (150–200 m) than at the closest (50–100 m) and farthest (250–300 m) distances from the reserve (Abesamis and Russ, 2005). Although movement of fish from Apo Reserve to sites

at intermediate distances (100–200 m) from the reserve has never been demonstrated directly, research in the last two decades has shown that fish populations (Acanthuridae, Carangidae, Serranidae, Lutjanidae, and Lethrinidae) have increased outside but close to the southern boundary of the reserve (about 200–250 m from that boundary) after about eight years of reserve protection (Russ and Alcala, 1996; Russ et al. 2003, 2004). This increase in populations may indicate that the present spatial distribution of hook-and-line and spear gun effort at the local scale may reflect the response of a small number of fishermen to spillover from the reserve.

Secondly, local fishermen may avoid fishing very close to the boundaries of Apo Reserve in order to prevent being accused of poaching inside the reserve. The inconsistent result of a higher catch rate but lower fishing effort nearest the reserve for gillnet fishing supports this idea (Fig. 6B, Table 5). Furthermore, there may be tremendous motivation for resident fishermen not to be implicated in poaching inside the reserve. The ultimate reason for this probably lies in the smallness of the community at Apo Island. Almost everyone has known each other for most of their lives. The no-take reserve was established by the community for their own benefit (Russ and Alcala, 1999). It has been guarded and maintained by community members, many of them fishermen themselves, for most of the two decades of its existence (Russ and Alcala, 1999). It has an important role in tourism on the island, from which the local community has benefited considerably in many ways (Alcala, 1998; Russ and Alcala, 1999). It is the principal factor that has made Apo Island a nationally and internationally recognised model for successful, community-based resource management (Alcala, 1998; Russ and Alcala 1999). Many residents are probably aware of most, if not all, of these achievements. For these reasons, it is clearly against the best interests of a resident fisherman, and his family, to be labeled by fellow community members as a threat to the security of their reserve.

In conclusion, this study has shown that spillover yield from the no-take reserve at Apo Island probably contributes much less than 10% of the overall yield to the local fishery. Fishing effort was often lowest near the reserve, despite higher catch rates there. The finding of low fishing intensity near reserve boundaries despite indications of spillover contrasts with most empirical evidence collected so far (e.g., Gell and Roberts, 2003) and recent theoretical studies (e.g., Salomon et al., 2002) indicate that spillover will increase fishing effort near reserve boundaries. Fishing effort adjacent to the reserve appears to be limited by 1) weather determined by the monsoons, 2) the traditional importance of the northern fishing grounds, 3) high variability of catch rates and income rates, 4) lower value of target species found near the reserve, and 5) social pressures related to the history of community management of the reserve. However, the present study has no information on how fishing effort, yield, and catch rates near the reserve have changed over the past 20 years since

reserve establishment. Despite the Apo Island fishery being one of the best studied coral reef fisheries in the world (Alcala and Luchavez, 1981; White and Savina, 1987; Bellwood, 1988; Maypa et al., 2002; Russ et al, 2004; Alcala et al., 2005), the present study is the first to quantify detailed spatial variations in fishing effort, catch, and CPUE at Apo Island. Furthermore, it is not clear if spillover yield to the local fishery has reached its full potential or not. Long-term fishery monitoring is required to answer these questions. Although the reserve probably provides limited direct benefits to the local fishery through spillover, its indirect benefits to the community at Apo Island are considerable. The reserve became the foundation for a program of fishery conservation for the whole island, which eliminated unsustainable fishing practices such as dynamite fishing and muro-ami drive-net fishing. It played a critical role in enhancing tourism activities on the island, which had a tremendous positive effect on the standard of living of the local community (Russ and Alcala, 1999; White et al., 2002). These indirect effects of reserve establishment are arguably as important as the direct benefits of reserves to developing areas of the world. It remains to be seen whether successful reserves such as Apo Reserve have broader-scale direct benefits to fisheries through net larval export.

Acknowledgments

Literature cited

Abesamis, R. A., and G. R. Russ.
 2005. Density-dependent spillover from a marine reserve: long-term evidence. Ecol. Appl. 15:1798–1812.
Abesamis, R. A., G. R. Russ, and A.C. Alcala.
 2005. Gradients of abundance of fish across no-take marine reserve boundaries: evidence from Philippine coral reefs. Aquatic Conserv. Mar. Freshw. Ecosyst. 15.
Alcala, A. C.
 1998. Community-based coastal resource management in the Philippines: a case study. Ocean Coast. Manag. 38:179–186.
Alcala, A. C., and T. Luchavez.
 1981. Fish yield of the coral reef surrounding Apo Island, Negros Oriental, Central Visayas, Philippines. Proc. 4th Int. Coral Reef Symp. 1:70–73.

Alcala, A. C., and G. R. Russ.
 1990. A direct test of the effects of protective management on abundance and yield of tropical marine resources. J. Cons. Int. Explor. Mer 47:40–47.
Alcala, A. C., G. R. Russ, A. P. Maypa, and H. P. Calumpong.
 2005. A long-term, spatially replicated, experimental test of the effect of marine reserves on local fish yields. Can. J. Fish. Aquat. Sci. 62:98–108.
Alino, P. M., N. E. Palomar, H. O. Arceo, and A. T. Uychiaoco.
 2002. Challenges and opportunities for marine protected area (MPA) management in the Philippines. Proc. 9th Int. Coral Reef Symp. 2:635–640.
Bellwood, D. R.
 1988. Seasonal changes in the size and composition of the fish yield from the reef around Apo Island, central Philippines, with notes on methods of yield estimation. J. Fish Biol. 32:881–893.
Bohnsack, J. A.
 1998. Application of marine reserves to reef fisheries management. Aust. J. Ecol. 23:98–304.
Carr, M. H., and D. C. Reed.
 1993. Conceptual issues relevant to marine harvest refuges: examples from temperate reef fishes. Can. J. Fish. Aquat. Sci. 50:2019–2028.
DeMartini, E. E.
 1993. Modelling the potential of fishery reserves for managing Pacific coral reef fishes. Fish. Bull. 91: 414–427.
Galal, N., R. F. G. Ormond, and O. Hassan.
 2002. Effect of a network of no-take reserves in increasing catch per unit effort and stocks of exploited reef fish at Nabq, South Sinai, Egypt. Mar. Freshw. Res. 53:199–205.
Gell, F., and C. M. Roberts.
 2003. Benefits beyond boundaries: the fishery effects of marine reserves. Trends Ecol. Evol. 18: 448–455
Hilborn, R., K. Stokes, J. J. Maguire, T. Smith, L. W. Botsford, M. Mangel, J. Oresanz, A. Parma, J. Rice, J. Bell, K. L. Cochrane, S. Garcia, S. J. Hall, G. P. Kirkwood, K. Sainsbury, G. Steffanson, and C. Walters.
 2004. When can marine reserves improve fisheries management? Ocean Coast. Manag. 47: 197–205.
Hilborn, R., and C. J. Walters.
 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty, 570 p. Chapman and Hall, New York, NY.
Johnson, D. R., N. A. Funicelli, and J. A. Bohnsack.
 1999. Effectiveness of an existing estuarine no-take fish sanctuary within the Kennedy Space Center, Florida. N. Am. J. Fish. Manag. 19:436–453.
Kelly, S., D. Scott, and A. B MacDiarmid.
 2002. The value of a spillover fishery for spiny lobsters around a marine reserve in Northern New Zealand. Coast. Manag. 30:153–166.
Kramer, D. L., and M. R. Chapman.
 1999. Implications of fish home range size and relocation for marine reserve function. Environ. Biol. Fishes 55:65–79.
Maypa, A. P., G. R. Russ, A. C. Alcala, and H. P. Calumpong.
 2002. Long-term trends in yield and catch of the coral reef fishery at Apo Island, central Philippines. Mar. Freshw. Res. 53:207–213.
McClanahan, T. R., and B. Kaunda-Arara.
 1996. Fishery recovery in a coral-reef marine park and its effect on the adjacent fishery. Conserv. Biol. 10:1187–1199.

McClanahan, T. R., and S. Mangi.
2000. Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. Ecol. Appl. 10:1792–1805.
Munro, J. L.
1996. The scope of tropical fisheries and their management. *In* Reef fisheries (N. V. C. Polunin and C. M. Roberts, eds.), p. 1–12. Chapman and Hall, London.
Polacheck, T.
1990. Year around closed areas as a management tool. Nat. Resour. Model. 4:327–354.
Rakitin, A. and D. L. Kramer.
1996. Effect of a marine reserve on the distribution of coral reef fishes in Barbados. Mar. Ecol. Prog. Ser. 131:97–113
Roberts, C. M., J. A. Bohnsack, F. Gell, J. P. Hawkins, and R. Goodridge.
2001. Effects of marine reserves on adjacent fisheries. Science 294:1920–1923.
Russ, G. R.
2002. Yet another review of marine reserves as reef fishery management tools. *In* Coral reef fishes: dynamics and diversity in a complex ecosystem (P. F. Sale, ed.), p. 421–443. Academic Press Inc, San Diego, CA.
Russ, G. R., and A. C. Alcala.
1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, Central Philippines. Mar. Ecol. Prog. Ser. 132:1–9.
1998. Natural fishing experiments in marine reserves 1983–1993: community and trophic responses. Coral Reefs 17:383–397.
1999. Management histories of Sumilon and Apo Marine Reserves, Philippines, and their influence on national marine resource policy. Coral Reefs 18:307–319.
2003. Marine reserves: rates and patterns of recovery

and decline of predatory fish, 1983–2000. Ecol. Appl. 13:1553–1565.
Russ, G. R., A. C. Alcala, and A. S. Cabanban.
1992. Marine reserves and fisheries management on coral reefs with preliminary modelling of the effects on yield per recruit. Proc. 7th Int. Coral Reef Symp., Guam 2:978–985.
Russ, G. R., A. C. Alcala, and A. P. Maypa.
2003. Spillover from marine reserves: the case of *Naso vlamingii* at Apo Island, the Philippines. Mar. Ecol. Prog. Ser. 264:15–20.
Russ, G. R., A. C. Alcala, A. P. Maypa, H. P. Calumpong, and A.T. White.
2004. Marine reserve benefits local fisheries. Ecol. Appl. 14:597–606.
Salomon, A. K., N. P. Waller, C. McIlhagga, R. L. Yung, and C. Walters.
2002. Modelling the trophic effects of marine protected area zoning policies: a case study. Aquat. Ecol. 36:85–95.
White A. T., and G. C. Savina.
1987. Reef fish yield and nonreef catch of Apo Island, Negros, Philippines. Asian Mar. Biol. 4:67–76.
White, A. T., C. A. Courtney, and A. Salamanca.
2002. Experience with marine protected area planning and management in the Philippines. Coast. Manag. 30:1–26.
Wilcox, C., and C. Pomeroy.
2003. Do commercial fishers aggregate around marine reserves? Evidence from Big Creek Marine Ecological Reserve, Central California. N. Am. J. Fish. Manag. 23:241–250.
Zar, J. H.
1999. Biostatistical analysis, 4th ed., 663 p. Prentice-Hall, Inc., Upper Saddle River, NJ.