The effect of intensive line fishing on the virgin biomass of a tropical deepwater snapper, the crimson jobfish (*Pristipomoides filamentosus*)

Edwin M. Grandcourt
Marine Environmental Research Centre
Environmental Research and Wildlife Development Agency
Corniche Road
P.O. Box 45553
Abu Dhabi, United Arab Emirates
E-mail address: egrandcourt@erwda.gov.ae

Abstract—An intensive commercial hook-and-line fishing operation targeted the demersal fisheries resources at Saya de Malha Bank in the Southwest Indian Ocean. Fishing was conducted with 12 dories that were equipped with echo sounders and electric fishing reels and supported by a refrigerated mothership. Over a 13-day period in the 55–130 m depth range, a total of 74.3 metric tons (t) of fish were caught, of which the crimson jobfish (*Pristipomoides filamentosus*) represented 80%. Catch rates decreased with time and could not be attributed to changes in location, climatic conditions, fishing depth, fishing method, or bait type. The initial virgin biomass of *P. filamentosus* available to a line fishery at the North Western promontory of Saya de Malha Bank was estimated at 72.6 t through application of the Leslie model to daily catch and effort data. Biomass densities of 2364 kg/km^2 and 1206 kg/km were obtained by applying the initial biomass estimates to the surface area and to the length of the dropoff that was fished. The potential sustainable yield prior to exploitation was estimated at 567 kg/km^2 per year. The quantity of *P. filamentosus* caught by the mothership-dory fishing operation represented 82% of the initial biomass available to a hook-and-line fishery, equivalent to more that three times the estimated maximum sustainable yield. The results of the study are important to fisheries managers because they demonstrate that intensive line fishing operations have the potential to rapidly deplete demersal fisheries resources.

Manuscript accepted 23 October 2002.
Manuscript received 9 January 2003 at NMFS Scientific Publications Office.
Fish. Bull. 101:305–311 (2003).

The crimson jobfish, *Pristipomoides filamentosus* (Valenciennes, 1830), occurs throughout the tropical Indo-Pacific from the Red Sea in the west to Hawaii in the east and has a latitudinal distribution in the western Pacific ranging from southern Japan to New Caledonia (Randall et al., 1997). It is discontinuously distributed in the western Indian Ocean and has been recorded from Madagascar, Réunion, the east coast of Africa, the west coast of India, and the Chagos archipelago (Allen, 1985), and tends to aggregate in shoals in upcurrent localities and near underwater promontories and headlands (Ralston et al., 1986). The habitat occupied is characterized by deep waters from 90 to 360 m over rocky bottoms, along the edge of the continental shelf, and around isolated oceanic islands and banks (Randall et al., 1997).

Juveniles inhabit flat, featureless shallow banks and sediment bottoms close to sources of drainage, moving into deeper waters as they mature (Haight et al., 1993a; Parrish et al., 1997). Nevertheless, for adult fish there has been no correlation found between size and depth (Ralston and Williams, 1988).

Studies from Hawaii showed that *P. filamentosus* is primarily a zooplanktivore, although fish, crustaceans, and mollusks also feature in the diet (Ralston et al., 1986; Haight et al., 1993b). Reproductive studies of *P. filamentosus* in the Seychelles suggest that spawning is protracted and peaks between February and April, and in November (Mees, 1993). The size at which 50% of females reach sexual maturity (Lm_{50}) on banks in the South West Indian Ocean is approximately 52 cm fork length (Mees, 1993).

Pristipomoides filamentosus is a commercially important tropical snapper that is caught with handlines, electric fishing reels, and deepwater gill nets (Hardman-Mountford et al., 1996). Because lutjanid species are favored for consumption or sale, they are commonly targeted by fishermen (Munro, 1983; Koslow et al., 1988) and their aggressive nature and relatively large size makes them more vulnerable to fishing gears (Munro and Williams, 1985). Furthermore, low rates of growth, recruitment, and natural mortality, combined with a prolongation in the attainment of sexual maturity, make lutjanids particularly vulnerable to overfishing (Russ, 1991). Owing to the steeply shelving substratum over which *P. filamentosus* is found, the stock density for this fish has been estimated to be 10 times greater than that of other lutjanids in adjacent shelf areas (Mees, 1993). The concentration of the stock in a narrow depth band makes targeting easy and consequently the potential for overfishing is great (Mees, 1993).

Intensive fishing, over a period that is sufficiently short to permit the assumption that a population is closed, can produce data suitable for estimating the initial population size (e.g. Mees, 1993; Polovina, 1986). Where a population is exploited for the first time, knowing the initial biomass is often useful in determining whether overexploitation has occurred during the development of the fishery (Hilborn and Walters, 1992). The practicality of using daily catch-and-effort data from commercial

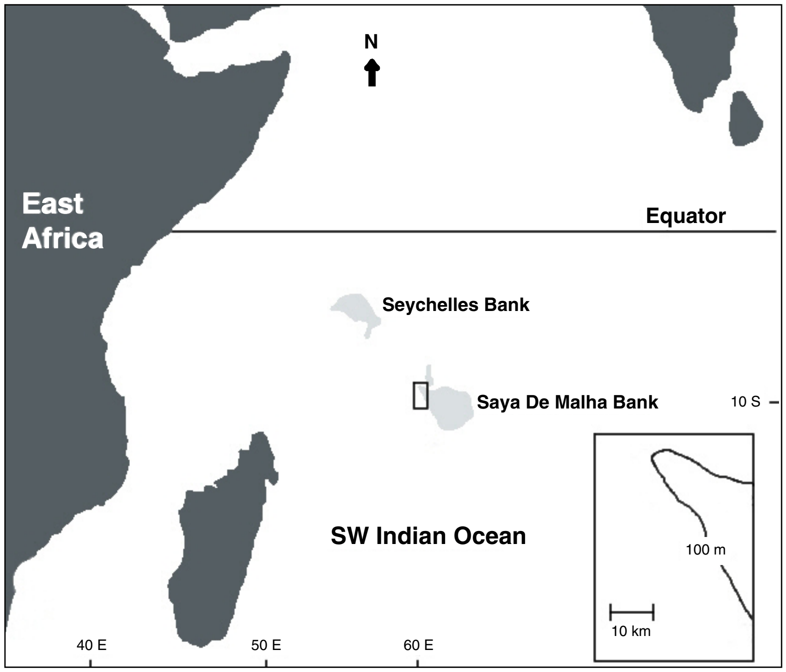

Figure 1
The position of Saya de Malha Bank in the SW Indian Ocean and the location of the hook-and-line fishing ground for demersal fishes (see small rectangular box in map and enlarged inset).

fishing operations may be limited because of confounding effects from changes in target species, fishing depth, and other factors that would normally be controlled within the experimental design of a research cruise. Despite these constraints, valuable management information may be obtained from commercial fisheries data at a much lower cost in cases where these factors have remained constant or have not influenced catch rates of the target species (e.g. Mees, 1996a).

An intensive line fishing operation, consisting of a refrigerated cargo mothership and 12 catcher boats (dories), targeted *P. filamentosus* on the dropoff at Saya de Malha Bank in the southwest Indian Ocean during March 1993. The operation had previously fished at locations in the Seychelles archipelago and had been shown to rapidly deplete reef fisheries resources (Mees[1]).

The mode of operation was characteristic of a "hit and run" fishery, where fishing would be conducted at a location until catch rates dropped to a level where it was not longer viable to continue. Daily catch and effort data are used in the present study to determine the effect of intensive line fishing on the initial virgin biomass of *P. filamentosus* at Saya de Malha Bank in the southwest Indian Ocean.

[1] Mees, C. C. 1992. *Pecheur Breton*: an analysis of data relating to a mothership dory fishing operation in Seychelles waters from March 1991–June 1992. Seychelles Fishing Authority Technical Report (SFA/R&D/023), 38 p. Seychelles Fishing Authority, Government of Seychelles, P.O. Box 449, Victoria, Mahé, Seychelles.

Materials and methods

Study area

Saya de Malha Bank is located on the Mascarene Plateau in the southwest Indian Ocean (Fig. 1). The bank consists of three plateau areas, the periphery of which ranges in depth from 15 to 200 m. The specific study area was 60.2 km of the dropoff in the 55–130 m depth range between latitude 9°53′S, longitude 59°45′E and latitude 94°3′S, longitude 59°50′E. The area corresponds to the grounds fished by the mothership-dory fishing operation over a 13-day period.

The region has a tropical humid climate modified by the NW monsoon from December to March and the SE trade winds from May until October. Intermonsoon periods of light, variable winds and frequent calms occur during April and November when equatorial troughs affect the region (Walsh, 1984).

Data collection

During March 1993, 12 fiber glass dories equipped with echo sounders and electric fishing reels were deployed at Saya de Malha Bank from an 88-m refrigerated cargo ship. Fishing was conducted during the day and catches were landed to the mothership each evening. A daily log of the activities of individual catcher boats per fishing trip was maintained, which included the total weight by species, fishing trip duration, fishing method, bait type, depth range fished, number of men, and the number of lines used. In addition, the weather condition and current strength were recorded on a subjective scale from 1 (good) to 5 (poor).

Data analysis

Daily catch and effort data were analyzed by fishing trip duration, depth, gear type, bait type, and climatic conditions to determine the effect on catch rates. The catchability coefficient (q) of the Leslie constant catchability model (Leslie and Davis, 1939) and intercept parameter (a) were determined by using least squares linear regression, where "q" is the value of the regression coefficient. The adjusted cumulative catch (x)—the cumulative catch to interval i plus one half of the catch during interval i—was used as the independent variable; this adjustment proposed by Chapman (1961) compensates for the decline in catchability during each time interval (King, 1995). The daily catch per unit of effort was used as the dependent variable. Data from the first day of fishing were excluded from the analyses because *P. filamentosus* was not being fully targeted. The Leslie constant catchability model was used to derive an estimate of the initial population biomass of *P. filamentosus* accessible to a line fishery within the study area. Polovina (1986) described the Leslie model as the catch per unit of effort during a time interval (t), and because ($CPUE_{(t)}$) is defined as the product of catchability (q) and the mean population biomass present during the period t ($B_{(t)}$), the model can be expressed as

$$CPUE_{(t)} = qB_{(t)}. \quad (1)$$

Suppose that up to the beginning of period t, $K_{(t)}$ fish have been caught and removed. If the period t is relatively short, the population of fish closed or isolated, and the fishing pressure heavy enough so that it can be assumed that mortality from other factors is negligible, then $B_{(t)}$ can be expressed as

$$B_{(t)} = B_{(0)} - K_{(t)} .$$

Where $B_{(0)}$ is the initial population biomass at the beginning of the experiment (t=0), inserting this expression for $B_{(t)}$ in Equation 1 produces the Leslie constant catchability model:

$$CPUE_{(t)} = qB_{(0)} - qK_{(t)}.$$

For the initial population biomass estimate, bootstrapping was used to determine 95% confidence intervals. 100 runs were made. Daily estimates of the remaining biomass size were calculated by subtracting the cumulative catch from the initial biomass estimate i.e: $B_{(t)} = B_{(0)} - K_{(t)}$, where $B_{(t)}$ is the biomass present at the beginning of time (t); $B_{(0)}$ is the initial virgin biomass prior to fishing at $t = 0$; and $K_{(t)}$ is the cumulative catch to the beginning of time period (t).

The length of the 100-m contour, mean width of the 55–130 m depth band, and surface area of the fishing ground were determined from chart data. Stock density was calculated by applying the initial biomass estimate to the length and surface area of the grounds fished. The annual maximum sustainable yield (MSY) was determined by using the results of Mees (1993), where the MSY was estimated as 24% of the initial virgin biomass of *P. filamentosus* on the edge of the Seychelles Bank, situated 400 km north west of the study site. Potential yield estimates were calculated per km and km^2 on a yearly and daily basis by applying the maximum sustainable yield as a proportion to the respective biomass densities.

Table 1

Species composition of the catch from the dropoff at Saya de Malha Bank.

Species	Weight (kg)	Proportion of total (%)
Aprion virescens	784	1.1
Carangoides gymnostethus	171	0.2
Carangoides sp.	147	0.2
Coryphaena hippurus	44	0.1
Epinephelus chlorostigma	1846	2.5
Epinephelus morrhua	1847	2.5
Epinephelus multinotatus	5337	7.2
Epinephelus sp.	432	0.6
Gymnosarda unicolor	128	0.2
Lethrinus olivaceus	6	0.0
Lutjanus sp.	118	0.2
Lethrinus sp.	116	0.2
Pristipomoides filamentosus	59,522	80.1
Seriola rivoliana	3646	4.9
Thunnus albacares	57	0.1
Variola louti	83	0.1

Results

A total of 173 dory fishing trips with a mean trip length of 7.7 hours were made over a period of 13 days. There were two fishermen in each of the 12 dories; all used electric fishing reels, the hooks of which were baited with skipjack tuna (*Katsuwonus pelamis*). The mean catch rate for all species was 28.5 kg/man hour, equivalent to 429.4 kg per dory trip. The crimson jobfish represented 80.1% of the total catch of 74.3 t. The Serranidae were the second most abundant family, and of this family *Epinephelus multinotatus* formed 7.2%, *Epinephelus chlorostigma* 2.5%, and *Epinephelus morrhua* 2.5% of the total catch from the dropoff at Saya de Malha Bank (Table 1). The mean depth fished was 88.8 m and ranged from 55 m to 130 m. The length of the 100-m contour was 60.2 km, mean width of the 55–130 m depth band was 510 m, and the surface area of the grounds fished was 30.7 km^2.

There was an overall reduction of the catch rate over the 13-day period (Fig. 2 and Table 2). This could not be

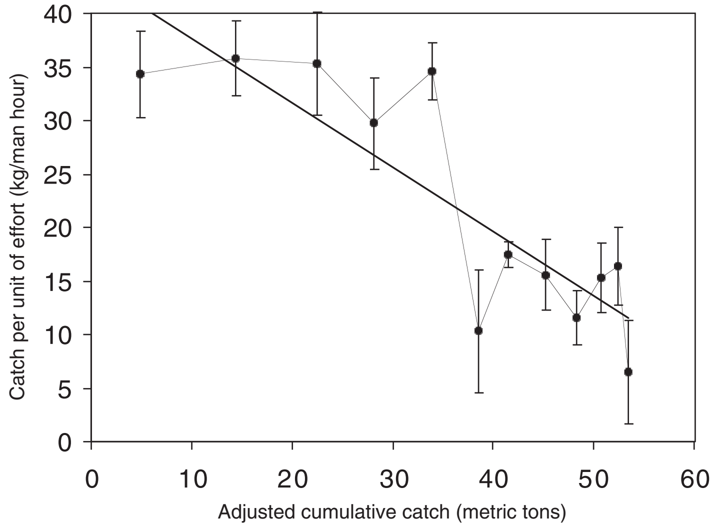

Figure 2

The relationship between mean daily catch per unit of effort (±SE) and the adjusted cumulative catch for *Pristipomoides filamentosus* on the dropoff at Saya de Malha Bank. Straight line shows the Leslie plot; $CPUE_{(t)} = q(B_{(0)} - K_{(t)})$, fitted by least squares linear regression (r^2=0.729).

Table 2

Daily effort, catch, catch per unit of effort, cumulative catch, and adjusted cumulative catch for the deepwater snapper *Pristipomoides filamentosus* at Saya de Malha Bank.

Day	Effort (man/hours)	Catch (kg)	Catch per unit of effort (kg/man hour)	Cumulative catch (kg)	Adjusted cumulative catch (kg)
1	264.6	5623	21.3	0	2812
2	286.4	9817	34.3	5623	10,532
3	253.4	9077	35.8	15,440	19,979
4	202.8	7158	35.3	24,517	28,096
5	143	4252	29.7	31,675	33,801
6	207.2	7163	34.6	35,927	39,509
7	199.4	2061	10.3	43,090	44,121
8	223.4	3899	17.5	45,151	47,101
9	233.6	3634	15.6	49,050	50,867
10	221	2554	11.6	52,684	53,961
11	151.6	2318	15.3	55,238	56,397
12	57.4	939	16.4	57,556	58,026
13	158.2	1027	6.5	58,495	59,009

attributed to changes in fishing method, bait type, or current strength, all of which remained constant. In addition, weather condition, depth fished, and trip duration did not have a significant effect on the catch rate (P>0.05).

The reduction in the daily catch per unit of effort with increasing cumulative catch was significant (P<0.05, 12 df, F=9.729). The results of the regression analysis, with the adjusted cumulative catch as the independent variable and the daily catch per unit of effort as the dependent variable was

$$y = 43.633 + 0.0006x \qquad (r^2=0.729).$$

Application of the Leslie model with the catchability coefficient (q) = 0.0006 (±0.0001 SE) and intercept parameter (a)

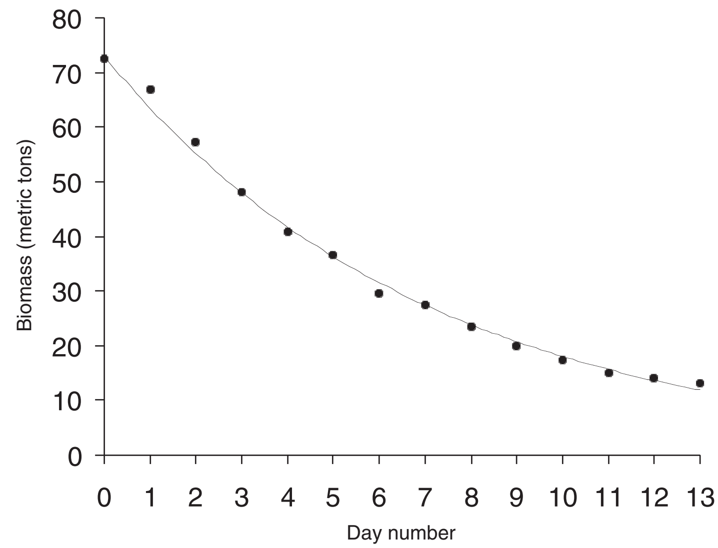

Figure 3

Reduction in the biomass of *Pristipomoides filamentosus* over the fishing period at Saya de Malha Bank. Line shows the exponential model; $y = 72.972\ e^{-1397x}$ fitted to the data (r^2=0.994).

of 43.633 (±4.538 SE) kg/man hour gave an initial biomass estimate of 72,582 kg for *P. filamentosus* accessible to a line fishery at the study site. Bootstrapped upper and lower 95% confidence limits for the initial biomass estimate were 62,750 and 91,376 kg, respectively. Analysis of the daily estimates showed that there was an exponential decrease in remaining biomass over the fishing period (Fig. 3). The biomass densities, potential yield estimates, and respective 95% confidence intervals are given in Table 3.

Mees (1993) derived a maximum sustainable yield estimate of 24% for the virgin biomass of *P. filamentosus* on the edge of the Seychelles Bank using the method of Beddington and Cooke (1983).

Applying this proportion to the initial biomass for *P. filamentosus* on the north western promontory of Saya de Malha Bank gives an annual maximum sustainable yield estimate of 17.4 t. The quantity of *P. filamentosus* caught by the mothership-dory fishing operation represented 82% of the initial virgin biomass available to a hook-and-line fishery. The amount removed was equivalent to more than three times the estimated annual maximum sustainable yield.

Table 3

Initial biomass density and the potential yield prior to exploitation for *Pristipomoides filamentosus* at Saya de Malha Bank.

	Estimate	95% CI
Biomass density (kg/km^2)	2364	2044–2976
Biomass density (kg/km)	1206	1042–1518
Potential yield (kg/km^2 per day)	1.6	1.3–2.0
Potential yield (kg/km^2 per year)	567	490–714
Potential yield (kg/km per day)	0.8	0.7–1.0
Potential yield (kg/km per year)	289	250–364

Discussion

The fisheries resources of Saya de Malha Bank have been exploited by Mauritian mothership-dory fishing operations since the late 1960s.

However, the fisheries operate only to a maximum depth of 50 m, and a single species (*Lethrinus mahsena*) constitutes 80–90% of the catch (Mees[2]). The exploitation of *P. filamentosus* had not occurred prior to the present study because of the belief that the fish were ciguatoxic (Samboo and Mauree, 1987), and consequently the population remained in a virgin state.

The Leslie constant catchability model assumes that the population is completely closed, i.e. there is no recruitment, growth, natural mortality, immigration or emigration during the time frame of the data to which it is applied. Natural mortality, recruitment, and growth can be assumed to

[2] Mees, C. C. 1996. Management of multi-species tropical fisheries, 193 p. Marine Resources Assessment Group Ltd., 47 Princes Gate, London SW7 2QA, UK.

be negligible over the fishing period. However, the initial population biomass, stock density, and potential yield could have been overestimated if there was immigration into the study area from adjacent habitats. Although the study site is characteristic of the habitat in which *P. filamentosus* aggregates (Ralston et al., 1986), the data relate to the peak spawning period of this species on the nearby Seychelles Bank. If there was an inward flux of fish to a spawning site during the time that fishing was conducted, the biomass would have been overestimated. Conversely, it would have been underestimated if there was emigration out of the area. Because of the short time frame over which fishing took place, it is assumed in the present study that the population was closed and any such flux was insubstantial.

Inconstant catchability is perhaps the greatest potential source of error in applying methods of estimation based on secular change in catch per unit of effort (Ricker, 1975). The Leslie model assumes that catchability (q) is constant over the fishing period. However, it is often found that the first few units of effort cause a rapid depletion of more vulnerable, faster, and more aggressive fish, and an accompanying rapid change in catch per unit of effort or other abundance indices. After this initial removal, the remaining fish have effectively lower q values, so that q declines progressively as depletion proceeds. There may even be a large pool of fish with $q = 0$ for some reason, and this pool will not be sampled by the depletion process. Thus, the general effect of varying catchability among individuals is that the estimate of q is biased upwards (and consequently the initial biomass estimate is biased downwards), so that underestimates of biomass in the order of 30% to 50% are not unlikely (Hilborn and Walters, 1992). The use of an adjusted cumulative catch is intended to compensate for the decline in catchability during each time interval (Chapman, 1961). Nonetheless, as suggested by Cowx (1983), estimates should be treated with care.

In commercial fishing operations, fishermen may maintain their catch rates as abundance drops by targeting the remaining high concentrations of fish. As a result, catchability can be underestimated and the initial stock size overestimated. The data used in the present study showed a relatively constant catch rate for the first six days of fishing, followed by a dramatic reduction for the remaining seven days. This pattern may be result of an overall shift in location of the fishing units. However, because the individual dories were not equipped with position-fixing equipment, there were no data collected on the precise location of individual catches. Furthermore, the phenomena could equally have been caused by a change in the behavioral characteristics of the fish. A sudden drop in water temperature, caused by localized upwelling or an increase in planktonic prey abundance (or by both), could have contributed to the decline in catch per unit of effort. The patterns observed in the data suggest that they do not conform well to the assumptions of a depletion model and therefore limit the integrity of the biomass estimates. Position-fixing capability on each of the dories and an independent means of determining behavioral characteristics, such as an underwater video system, would have helped to elucidate the cause of the irregular decline in catch per unit of effort.

A problem with the use of depletion estimators in the case of multispecies applications is that the catchability of each of the component species may not remain constant in relation to each other over the period that fishing is conducted. Interactions between species, such as the competition for baits, can alter catchability, e.g. Rothschild (1967). An increase in the catchability of a subordinate species may occur as a result of the removal of a more competitive species, as shown to be the case with the deepwater snappers *Pristipomoides auricilla* and *Pristipomoides zonatus* (Polovina, 1986). *Pristipomoides filamentosus* comprised 80.1% of the total catch from the fishing grounds on Saya de Malha Bank. Of the remaining species in the catch, there was none that was considered abundant enough to bias the catchability estimate through species interactions, such as competition for bait.

Polovina (1986) showed that after over half of the initial biomass of the deepwater snapper *Pristipomoides zonatus* had been removed, there was very little change in size composition with cumulative catch. Despite this finding, size-specific behavior has been considered to affect catchability and could be a potential source of error in the estimate of "q" determined in the present study. Given the need for studies of the effects of fishing on commercially important tropical species (Russ, 1991) and recent developments in aging *Pristipomoides filamentosus* (Hardman-Mountford et al., 1996), future studies should examine the implications of intensive line fishing on the age structure of snapper populations.

The major reproductive peak for *P. filamentosus* on the edge of the Seychelles Bank, 400 km to the northwest of Saya de Malha Bank, was found to occur between February and April (Mees, 1993). If the reproductive peak for the stock at Saya de Malha Bank occurred at the same time, then the catcher boats may have been targeting spawning aggregations. If this was the case, the population biomass and subsequently stock density at the study site would be lower during periods of the year when there is a reduction in spawning activity. Furthermore, *P. filamentosus* tends to aggregate in shoals in upcurrent localities and near underwater headlands and promontories (Ralston et al., 1986). In addition to being the possible behavior of spawning aggregations, this behavioral characteristic explains why *P. filamentosus* comprised 80.1% of the total catch of what is basically a multispecies fishery.

Errors may have occurred in the calculation of the width of the 55–130 m depth band. If the gradient of the seabed in this depth range was steeper than that estimated, the biomass density would be greater and *vice versa*. A bathymetric survey would have improved the precision of the surface area calculations and biomass density estimates.

Nevertheless, the biomass density obtained in the present study (2364 kg/km^2) is of the right order compared to that of Mees (1993), where the mean initial biomass density of *P. filamentosus* on three banks in the Seychelles was 2987 kg/km^2 for populations that had not previously been exploited. Likewise, the estimated potential yield of 567 kg/km^2 per year derived in the present study compared well to the maximum sustainable yield of 717 kg/km^2 per year (Mees, 1993) for *P. filamentosus* in the Seychelles. The proportion (82%) of the initial biomass of *P. filamentosus* removed is not dissimilar to that estimated by Polovina (1986) for *P. zonatus* (68%) in the Mariana Archipelago over the same number of fishing days.

The results of this study are relevant to fisheries managers because they demonstrate that although intensive line fishing operations are efficient at harvesting offshore demersal fisheries resources, they have the potential to heavily overexploit populations in a short time frame.

Acknowledgments

I thank Kerlson Gonzales for enduring the difficult living conditions aboard the mothership during the trip to Saya de Malha Bank and for the high quality of data collected, Cecile Botsoie for entering the log book information into the database, Chris Mees for instruction in the use of the programme PBRETON used in the analysis of the daily catch records, and Francis Marsac for providing constructive comments and discussion.

Literature cited

Allen, G. R.
1985. FAO species catalogue. Vol. 6: Snappers of the world: an annotated and illustrated catalogue of Lutjanid species known to date. FAO Fish Synopses 125, 208 p. FAO, Rome.

Beddington, J. R., and J. G. Cooke.
1983. The potential yield of fish stocks. FAO Fisheries Technical Paper 242, 47 p. FAO, Rome.

Chapman, D. G.
1961. Statistical problems in dynamics of exploited fisheries populations. Proc. Berkeley Symp. Math. Stat. Probab. 4: 153–168.

Cowx, I. G.
1983. Review of the methods for estimating fish population size from survey removal data. Fish. Manag. 14:67–82.

Haight, W. R., D. R. Kobayashi and K. E. Kawamoto.
1993a. Biology and management of deepwater snappers of the Hawaiian archipelago. Mar. Fish. Rev. 55(2):17–24.

Hardman-Mountford, N. J., N. V. C. Polunin and D. B. Boulle.
1996. Can the age of tropical species be determined by otolith measurement? A study using *Pristipomoides filamentosus* (Pisces: Lutjanidae) from the Mahé Plateau, Seychelles. NAGA. The ICLARM Quarterly 20(2):27–31.

Haight, W. R., J. D. Parrish and T. A. Hayes.
1993b. Feeding ecology of deepwater lutjanid snappers at Penguin Bank, Hawaii. Trans. Am. Fish. Soc. 122: 328–347.

Hilborn, R., and C. J. Walters.
1992. Quantitative fisheries stock assessment. Choice, dynamics and uncertainty, 570 p. Chapman and Hall, New York, NY.

King, M.
1995. Fisheries biology, assessment and management, 341 p. Fishing News Books, Blackwell Science, Oxford.

Koslow, J. A., F. Hanley, and R. Wicklund.
1988. Effects of fishing on reef fish communities at Pedro Bank and Port Royal Cays, Jamaica. Mar. Ecol. Prog. Ser. 43:201–212.

Leslie, P. H., and D. H. S. Davis.
1939. An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8:94–113.

Mees, C. C.
1993. Population biology and stock assessment of *Pristipomoides filamentosus* on the Mahé Plateau, Seychelles. J. Fish Biol. 43:695–708.
1996. Demersal fish stock assessment in Seychelles: An analysis of a mothership/catcher boat fishery. *In* Biology, fisheries and culture of tropical groupers and snappers (F. Arreguín-Sánchez, J. L. Munro, M. C. Balgos, and D. Pauly, eds.), 449 p. ICLARM Conf. Proc. 48.

Munro, J. L.
1983. Epilogue: progress in coral reef fisheries research, 1973–1982. *In* Caribbean reef fishery resources, vol 7, p. 249–265. International Centre for Living Aquatic Resources Management, Manila, Philippines.

Munro, J. L., and D. M. Williams.
1985. Assessment and management of coral reef fisheries: biological, environmental and socio-economic aspects. Proc. Int. Coral Reef Cong., 5th. 4:545–581.

Parrish, F. A., E. E. DeMartini, and D. M. Ellis.
1997. Nursery habitat in relation to production of juvenile pink snapper, *Pristipomoides filamentosus*, in the Hawaiian archipelago. Fish. Bull. 95:137–148.

Polovina, J. R.
1986. A variable catchability version of the Leslie model with application to an intensive fishing experiment on a multispecies stock. Fish. Bull. 84(2):423–428.

Randall, J. E. G. R. Allen, and R. C. Steene.
1997. Fishes of the Great Barrier Reef and Coral Sea, 557 p. Univ. Hawaii Press, Honolulu, HI.

Ralston, S., R. M. Gooding, and G. M. Ludwig.
1986. An ecological survey and comparison of bottom fish resources assessments (submersible versus handline fishing) at Johnston atoll. Fish. Bull. 84:141–155.

Ralston, S., and H. A. Williams.
1988. Depth distributions, growth and mortality of deep slope fishes from the Marianas archipelago. U.S. Dep. Commer., NOAA Tech. Memo. SWFC113, 47 p.

Ricker, W. E.
1975. Computation and interpretation of biological statistics for fish populations. Fish. Res. Board Can. Bull. 191, 382 p.

Rothschild, B. J.
1967. Competition for gear in a multiple-species fishery. J. Cons. 31:102–110.

Russ, G. R.
1991. Coral reef fisheries: effects and yields. *In* The ecology of fishes on coral reefs (P. F. Sale, ed.), p. 601–635. Academic Press, London.

Samboo, C. R., and D. Mauree.
1987. Summary of fisheries and resources information for Mauritius. *In* Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean (M. J. Sanders, P. Sparre and S. C. Venema, eds.), p. 62–79. FAO/UNDP: RAF/79/065/WP/41/88/E. Food and Agricultural Organization of the United Nations, Viale delle Terme di Caracalla 00100, Rome.

Walsh, R. P. D.
1984. Climate of the Seychelles. *In* Biogeography and ecology of the Seychelles Islands (D. R. Stoddard, ed.), p. 39–62. DR W. Junk Publishers, The Hague.