Reference Area as a Factor Affecting Potential Yield Estimates of Coral Reef Fishes

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Abstract

A compilation of 48 estimates of Caribbean and Pacific coral reef fish catches, ranging from 0.1 to 23.7 $t \cdot km^{-2} \cdot year^{-1}$, obtained from coral reef areas ranging from 0.1 to nearly $4 \cdot 10^5$ km^2, are used to show that observed catches, and hence potential yield estimates, depend strongly on the reference area. The implications for coral reef fisheries assessments are discussed.

Introduction

Coral reefs are regarded as one of the most highly productive types of ecosystem in the world; they have high rates of gross primary productivity (Odum and Odum 1955; Grigg et al. 1984; Polovina 1984; Kinsey 1985), a reason why they are potentially capable of sustaining highly productive fisheries (Marten and Polovina 1982). Smith (1978) estimated the global fisheries potential of coral reefs to be six million tonnes per year. However, Longhurst and Pauly (1987) mentioned that the yield in 1983 was 0.48 million tonnes, a value well short of this potential.

Refined estimates of potential yields of coral reef fisheries are important in many ways. For example, they can be used as a basis for the rational development of a fishery, with the aim of ensuring that the now-familiar problem of fleet over-capacity does not occur. Accurate and precise description of the limits of production from wild stocks could also act as a catalyst for the development of alternative sources of animal protein, such as aquaculture. Projections of potential yield are also critically important in determining the feasibility of fisheries development projects. For example, it has been noted that the failure of large-scale fisheries development projects in the Caribbean region can be linked to overly-optimistic estimates of potential yield (Goodwin 1987).

Yields from coral reefs have been studied repeatedly (Stevenson and Marshall 1974; Marshall 1980, 1985; Marten and Polovina 1982; Munro 1983; Russ 1984; Munro and Williams 1985; Russ 1991). However, early reviews emphasized results from the Caribbean, with yields ranging from 0.4 to 5.14 $t \cdot km^{-2} \cdot year^{-1}$ obtained from large areas interspersed with coral (e.g., 55,000 km^{-2} in Cuba; Buesa Mas 1964). Recent reviews, on the other hand, included more data from the Pacific and small areas covered entirely by coral reefs, with yields of up to 36.9 $t \cdot year^{-1}$ (e.g., 5.4 km^{-2} in America Samoa; Hill 1978).

The present study examines the relationship between reef yield and study area further.

Material and Methods

All estimates of coral reef fish yields available to the authors were compiled into a single table (Table 1) along with the areas to which they refer—generally the area fished. The (fishing) depths were added where it was stated or could be inferred.

These yield values were then plotted against the reference areas, using means wherever there were several yield estimates for any given area. No adjustment was made for some areas being under- or overfished, and thus some of our figures may be underestimates.

Results and Discussion

The first conclusion emerging from Table 1 is that there is a clear inverse relationship between yields and reference areas; this is confirmed by Fig. 1, although the plot does not meet all the assumptions of linear regression.

The second conclusion suggested by the data in Table 1 is that the relationship between yield and depth may not be as strong as suggested in previous studies, although this may be due to the scarcity and heterogeneity of the available depth records.

Marten and Polovina (1982) mentioned that reef fisheries generally operate in patchworks of coral reef and sandy bottom; thus, the yield per unit area of a given reef should depend upon the size of the area and the percentage of that area covered by coral. Similarly, Munro (1984) suggested that the maximum yield per unit of area should be obtained by selectively harvesting reef fish from comparatively small areas of live coral only (see also Munro 1978). The data presented here confirm these two views. Also, we note that the inverse relationship between size of area

Table 1. Estimates of fish yields and related statistics from various coral line areas.

Study location	Study area (km^2)	Depth (m)	Reef fish yield ($t \cdot km^{-2} \cdot year^{-1}$)	Author(s)
Caribbean				
Bahamas	116,549.0	-	2.4	Gulland (1971)
Bahamas	116,549.0	-	1.4	Higgs (1983)
Bermuda	1,035.0	-	0.4	Bardach and Menzel (1957)
Cuba	55,000.0	-	0.5	Buesa Mas (1964)
Dominican Republic	-	-	2.5	WECAFC (1983)
Jamaica	2,860.0	-	2.0	Munro (1969)
Jamaica	2,860.0	-	4.1	Munro and Thompson (1973)
Jamaica Shelf	4,170.0	-	2.2	Haughton (1988)
Jamaica/Belize	2,515.0	-	1.9	Koslow et al. (1994)
Puerto Rico	2,300.0	-	0.8	Juhl and Suarez-Caabro (1972)
Puerto Rico + USVI	7,504.0	-	3.3	Juhl (1973)
St. Kitts/Nevis	708.0	-	2.1	Olsen (1984)
Pacific				
American Samoa	5.4	-	8.0	Hill (1978)
American Samoa	3.3	8	18.3	Wass (1982)
American Samoa	3.3	-	20.0	Munro (1984)
Apo Island, Philippines	1.5	60	11.4	Alcala and Luchavez (1981)
Apo Island, Philippines	0.7	20	22.1	Savina and White (1986)
Apo Island, Philippines	1.1	60	24.9	Bellwood (1988)
Cape Bolinao, Philippines	11.0	-	4.4	Acosta and Recksiek (1989)
Davies Reef, Australia	0.0	-	18.5	Polunin and Klumpp (in press)
Fiji	-	-	4.4	Bayliss-Smith (unpubl.)
Hulao-hulao reef, Philippines	0.5	15	5.2	Alcala and Gomez (1985)
Ifaluk	6.0	-	5.0	Douglas (1969)
Ifaluk	6.0	-	5.1	Stevenson and Marshall (1974)
"IndoPacific region"	358,572.0	-	5.0	Ardill (1983)
Kapingamaringi	67.0	-	0.7	Stevenson and Marshall (1974)
Kora and Labeka, Fiji	8.0	-	5.0	Stevenson and Marshall (1974)
Lamotrek	0.5	-	0.5	Stevenson and Marshall (1974)
Lamotrek Atoll	-	-	0.4	Alkire (1965)
Mauritius	350.0	-	4.7	Wheeler and Ommanney (1953)
Moorea, French Polynesia	0.001	1.5	23.0	Galzin (1987)
Ontong Java	122.0	-	0.6	Stevenson and Marshall (1974)
Pamilacan Island, Philippines	1.8	20	10.7	Savina and White (1986)
Port Moresby, NG	-	-	5	Lock (1986)
Raroia	0.1	-	0.1	Stevenson and Marshall (1974)
Selinog Island, Philippines	1.3	30	5.9	Alcala and Gomez (1985)
Sumilon Island, Philippines	0.5	40	36.9	Alcala and Russ (1990)
Sumilon Island, Philippines	0.5	40	9.7	Alcala (1981)
Sumilon Island, Philippines	0.5	40	14.0	Alcala (1981)
Sumilon Island, Philippines	0.5	40	15.0	Alcala (1981)
Sumilon Island, Philippines	0.5	40	23.7	Alcala (1981)
Sumilon Island, Philippines	0.5	40	19.9	Alcala (1981)
Sumilon Island, Philippines	0.5	40	19.9	Alcala and Russ (1990)
Tarawa Atoll	-	-	4.4	Marriott, cited in Munro (1984)
Tigak Islands, Papua NG	208.0	30	0.42	Wright and Richards (1985)
Upolu Island, Western Samoa	300.0	40	11.4	Russ (1991)

fished and fish yield can account for differences in potential yield between the Caribbean and Pacific. As might be seen from Fig. 1, many of the studies which included large areas fished were from the Caribbean. Conversely, a large proportion of studies in the Pacific dealt with small reef-specific study areas.

Comparisons of fish yields between groups of coral reefs (e.g., Pacific *vs* Caribbean) generally do not take into account the characteristics of the resource systems that are compared (physiography, depth, coral cover, fishing area, etc.). However, these very studies suggest that potential yields of coral reef fishes depend on such characteristics. Thus, the fish yield of any given reef is a function of the amount of fishing effort at that reef. Any increases in effort from relatively low levels will, at first, result in substantial increases in the harvest (Munro 1983). Also, estimated yields per area depend on the perception of the investigator as to the maximum depth at which true reef fishes occur (Bellwood 1988; Russ 1991). This is related to the question of whether a given group of fish is truly reef associated or not, which also can have a substantial effect on estimated reef yields (Bellwood 1988; Russ 1991). Gross physiographic features can substantially affect yields of fish from coral reefs. Marshall (1985), for example, mentioned that very high yields are limited to localities where the ratio of coral reef area to adjacent shallows is in the order of 1:1 or greater. Finally, and perhaps most importantly, yields will depend on the trophic level and sizes of the fish exploited by the fishery.

It is interesting to note that the higher yield of reef fishes came from small-scale fisheries which take a wide size range of fishes (e.g., Apo Island, Philippines; in Bellwood 1988). The great variation in yields seen in Table 1 and Fig. 1 may be due in part to different size and trophic levels being included in catches.

Generalizations concerning reef fish yields are thus difficult. Coral reef ecosystems and their fisheries yields tend to be more different among themselves than was previously anticipated. Here we have identified only one of the factors associated with the variability of coral reef fish yields, but it is clear that there must be others. These

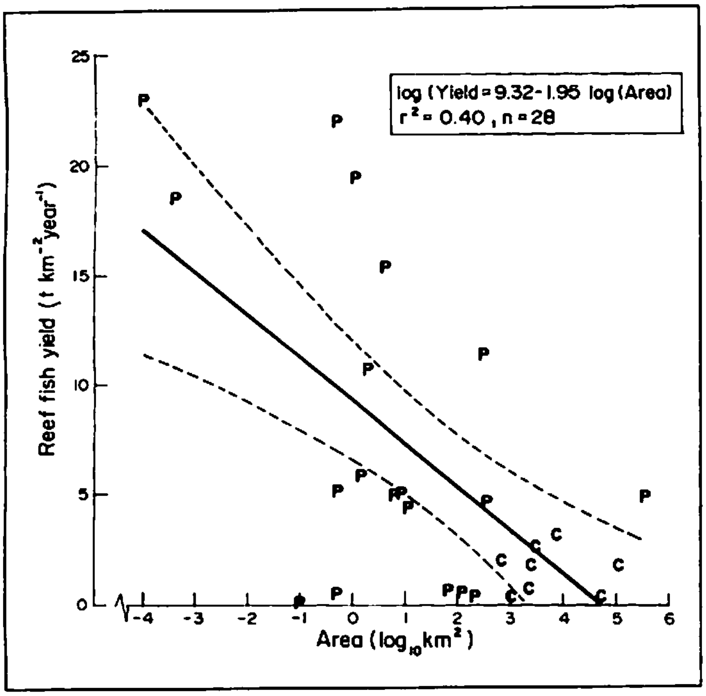

Fig. 1. ***Double logarithmic plot illustrating the strong relationship between the yield estimates (Y) in Table 1 and the size of the corresponding study area in the (Indo)Pacific (P) or Caribbean (C). This plot is presented for illustrative purposes only, as the data appear to violate the assumption of equal variance, with the Ps being more variable than the Cs.***

associated factors may be ecological (coral cover, primary productivity, fish sizes, etc.) and technical (accessibility of the reef area for small-scale fisheries, history of the fishery, etc). They offer a wide area for future research.

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Length-Weight Relationship of Threadfin Bream (*Nemipterus bipunctatus*) in the Gulf of Manaar, India

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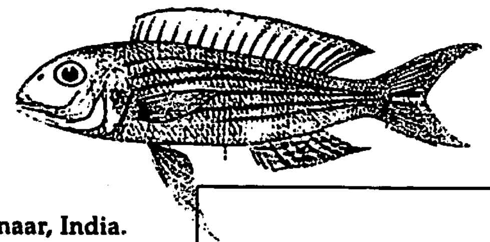

Fig. 1. *Delagoa threadfin bream* **(Nemipterus bipunctatus)**, *earlier known as* **N. delagoae** *(see Russel 1990).*

Nemipterus bipunctatus (Fig. 1) is the predominant species among the nemipterids, which contribute 3.6% of the total fish catch landed by small trawlers (up to 14 m) off Tuticorin (lat. 8°.48'N., long. 78°.9'E) in the Gulf of Manaar, India.

While studying the biochemical composition of *N. bipunctatus*, the author sampled 156 specimens of this species, ranging from 9 to 25 cm in total length and weighing 22-350 g. From these a length-weight relationship was estimated, of the form $W = aL^b$, using the logarithmic transformation log W = log a + b log l, where a and b are constants estimated by linear regression of the log-transformed variates. This regression takes the form

$$\text{Log } W = -3.9296 + 2.6713 \log L \quad ...1)$$

(Fig. 2), corresponding to

$$W = 0.001176\ L^{2.671} \quad ...2)$$

which may be used to convert length-frequency data to catch-at-length data.

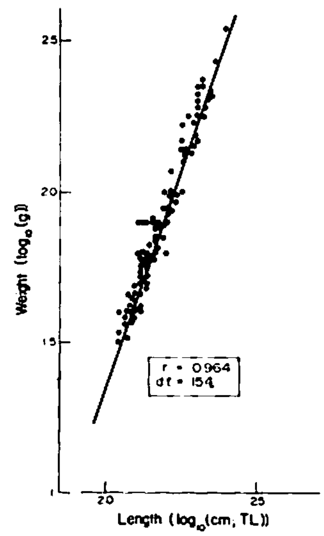

Fig. 2. *Linearized form of length-weight relationship for* **Nemipterus bipunctatus** *caught in the Gulf of Manaar, Tamil Nadu, India.*

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