Field and Laboratory Observations on the Growth of some Bermuda Reef Fisheries*

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MOST TROPICAL AND SUB-TROPICAL FISHERIES have as yet not been under sufficient scrutiny to allow an estimate of the rates of fish production, or even, for that matter, of the numbers of fish present at any one time. Bermuda waters can, with some license, be called sub-tropical. Here the fishery pursued relies primarily on reef-bound species rather than on pelagic fish (Mowbray, 1947). The fishing area is relatively small and clearly defined and lends itself well to field observations. Fishery research in Bermuda might, therefore,

Contribution No. 218 from the Bermuda Biological Station.
*This work was supported jointly by a grant from the National Science Foundation and the Bermuda Government Fisheries Research Program.

attempt to estimate reef productivity in terms of fish flesh, first for its principal commercial species and eventually for all reef fishes.

The production of fish in a given area can be estimated only if the rate of growth and the rate of mortality are known (Ricker, 1946). We measured the rate of growth and we could obtain some indication of fishing mortality from the commercial landings. In the absence of any means by which to measure natural mortality and to detect a change caused by man in the stable ecosystem of the reef, we must assume that there is no overall increase in the total fish population. Whether there is a decrease, as some commercial fishermen vociferously claim, only further and more intensive studies can show.

We chose the approach of studying the growth of certain representative species, of obtaining a fairly complete picture of size and numbers of these fish by all censusing methods available, and of then attempting a best guess, or estimate, of their yearly growth.

Growth was measured by following the weight increments of marked fish in the field. At the same time individuals of one species were kept in the laboratory for short periods and weight gains upon saturation feeding were compared with the field data.

Marks do occur on the scales of many Bermuda fish, but they were not used for growth estimations since they could not be definitely ascribed to differential growth rates influenced by seasonal temperature changes.

Reef fish populations are characterized by having numerous species with relatively few individuals of any one species. This, and the decentralization of Bermuda's commercial fishery, make it difficult to obtain sufficient numbers of individuals of different size to allow analysis of growth by means of size-frequency distribution.

A shallow reef in the outer reef chain which rises vertically from the sandy lagoon of 60 feet depth to a depth of 3-5 feet on its pinnacles, and 15-20 feet in its sandholes, was selected for this study because of its representative fish fauna, its relative position to other reefs, and its accessibility (Figure 1). On its 2.47 acre (1 ha.) surface, fish traps were set, albeit at irregular intervals, for over a year. Fish were tagged with plastic streamer tags and metal jaw tags, and measured to the nearest millimeter at tagging, as well as on recaptures during the year. Fish caught and retained elsewhere allowed us to construct length-weight diagrams for the species involved. Weighing of the tagged fish themselves was dispensed with for the sake of returning them to the water as quickly as possible.

The Nassau grouper *(Epinephelus striatus)*, the red hind *(E. guttatus)* and some rockfish (gen. *Mycteroperca*) were recaptured in sufficient quantities to give us an indication of their yearly and seasonal weight increments. The hind was also observed in the laboratory. Incidentally, the rockfish, the Nassau grouper, and to some extent, the hind, are commercially exploited; in fact the grouper represents 30-40 per cent of Bermuda's fish catch.

It should also be said that neither the rockfish nor the Nassau grouper attain their maximum sizes in the shallow reef environment. It would, however, have been too much to hope for at present to enlist sufficient cooperation from commercial fishermen to allow us to tag and release repeatedly a significant number of large individuals of these species.

Red Hind (*Epinephelus guttatus*)

This species is one of the most prevalent small groupers of the shallow reefs.

It occurs down to about 30 fathoms in fair abundance and some individuals have been taken at 50 and 60 fathoms. The fish grow to an adult size and weight of 18 inches (445 mm) and 3 lbs. (1375 g.) respectively. Their average size and weight is about 350 mm and 600 g. Sexual maturity is reached at 300 mm and 400 g.

Sixty individuals of 300 mm or more were tagged in 1955; 22 of these were recaptured after periods of 50 to 365 days. The annual weight increment, based on measurements at recapture, is 20 to 25 per cent for the fall and winter months and 40 per cent for the period from March to September, the season of more rapid growth. We changed from plastic streamer to monel jaw tags in February 1956. While these tags were faster and easier to apply, it was noticed that some of the streamer-tagged fish had grown more than those which bore metal tags on their jaws. The summer growth figures from the field are therefore believed to be on the low side, compared to untagged fish.

Three size groups of hinds were kept in the laboratory for 21 days and fed on sardines (locally called anchovies) *(Sardinella anchovia)* and pilchard *(Harengula sardina)*. They were given daily as much food as they would consume. Notably different growth rates were found to prevail at different temperatures. At 72°F. (22.2°C.) size group I (240-440 g.) gained 79.1 per cent, size group II gained 132 per cent, while the largest size group (III) hardly fed at all and gained only 5.2 per cent of their initial body weight when growth was prorated annually.

At 83-85°F. (29°C.), in midsummer, the smaller sized fish gained 247 per cent and the medium sized fish gained 273 per cent, on a yearly basis. These figures are extremely high when compared to field data. Presumably this is because the fish would not continue to feed at as high a rate as they did initially for an extended period of time.

Serranids vary in the degree of tameness they exhibit in confinement. Hinds are about the tamest of the lot and begin to feed immediately and voraciously. For a few days, during the summer, they consumed 8 per cent of their body weight daily and tapered off to about 4 per cent after three days. The large discrepancy between laboratory and field data here may further be due to the fact that the fish in the tanks move very little and therefore expend less energy from day to day, and that food in such abundance as is available on saturation feeding is probably never present in the field—at least not for a number of days in succession. The true yearly weight gain of this species is in all likelihood somewhat higher than that obtained from our tagged fish.

The total number of hinds on the experimental reef was estimated from the ratio of tagged to untagged fish and from two "Scuba" counts; 110 red hinds occurred on the 2.47 acre area in midsummer. If we assume then that 44 hinds are present per acre and that they weigh 600 g. (on the average) and gain 40 per cent of their body weight per year, their contribution in growth to the yearly production is roughly 25 lbs. per acre (25 kg./ha.). We considered summer growth ratios representative for the year because of the bias due to jaw tagging.

NASSAU GROUPER (*Epinephelus striatus*)

Twenty-one individuals of various sizes up to 6.6 lbs. (3 kg.) were tagged. Seven were recaptured, some of them repeatedly. They also revealed a decline in growth after jaw tags were applied. Too few fish of this species were

captured to attempt a breakdown into size groups and only an indication of their yearly increment can be given. Nassau groupers of this size are just reaching sexual maturity and many probably move off into deeper water later in their lives. It might therefore be expected that they would grow quite rapidly. However, we measured growth rates of only between 20 and 55 per cent per year, with an average of 38 per cent.

Our reef held 30 groupers (estimated as above). Their average weight was 2.5 lbs. (1115 g.). Therefore there were 12 fish per acre which weighed about 30 lbs. in aggregate. We again assumed a yearly increase of 40 per cent in the body weight because of jaw tag bias and estimated a growth of slightly less than 12 lbs. per acre per year (12 kg./ha.).

ROCKFISH (*Mycteroperca bonaci, M. falcata*)

The shallow reef is a niche for the young of these species; no rockfish over 11.5 lbs. (5.2 kg.) was captured for tagging and only four out of 17 tagged fish yielded fairly reliable growth figures. These indicated that young rockfish of less than 10 lbs. in weight (3.5 lbs. on the average) gained between 60 and 75 per cent of their body weight per year. These figures represent plastic tag recaptures after about one year and are assumed to be representative of true growth.

Eighteen miscellaneous rockfish (other than *E. striatus* and *E. guttatus*) were estimated present on the reef. Seven fish, together weighing about 25 lbs., occurred per care. At 60 per cent gain this represents a yearly rockfish growth of 15 lbs. per acre (15 kg./ha.).

Having estimated the growth of the principal commercial species, even if we do not have the natural mortality rates, we can compare our estimates of accretion due to growth with our assessment of removal by man and see at what level the reef fishes of Bermuda are being exploited.

In the absence of official landing records for the Bermuda fishery one has to resort to the next best method of estimating the landings, that is to secure the cooperation of a few representative fishermen who are willing to supply reliable figures of their daily and seasonal catches. This information is then supplemented with figures obtained from large and small-scale consumers, or middlemen, so that a best guess at the total landings can be made. In a fishery as restricted as ours this procedure has yielded fairly reliable figures. About one and a quarter million pounds of fish in the round have been landed yearly by an odd 80 to 100 full or part-time fishermen. (Bardach and Mowbray, 1956). A quarter million pounds of this are floating fish, carangids and seriolids, and the rest is made up of reef fishes proper, predominantly serranids.

The fishing area extends roughly over 400 square miles of reef shallower than 40 fathoms (Figure 1). It is not of uniform quality as a fishing ground and the bulk of production comes from the two offshore banks, *Challenger* and *Argus*, which extend over about 70 square miles, and the outer reefs, which surround Bermuda at a varying distance of 3 to 10 miles, and cover about 150 square miles. Thus we deal with about 220 square miles of "heavily" fished reef area.

Fishing is done mainly with wire traps and handlines at depths of 2 to 30 fathoms. The regions from ten fathoms down are more heavily fished than the shallows because the size of the larger serranid fish seems to increase with depth. This was borne out by the analysis of 175 trapsets where the average weight of the commercially usable catch per trap was 7.13 lbs. (3.24 kg.)

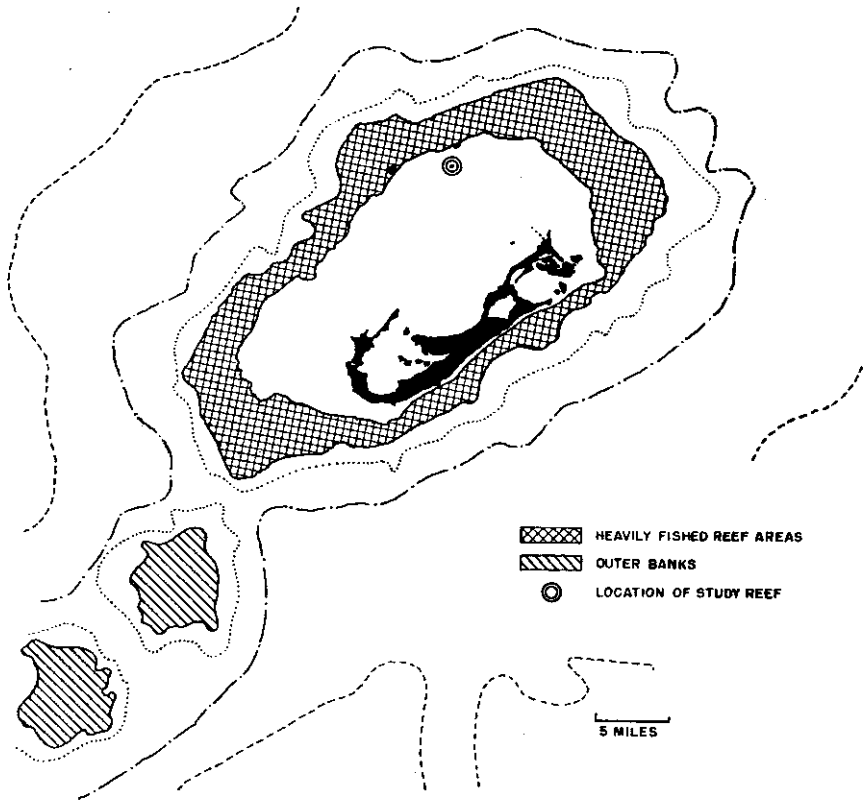

FIGURE 1—Fishing grounds around the Bermuda Islands. The dotted lines indicate the 500, 1000 and 2000 fathom marks.

between 10 and 30 fathoms, against 3.45 lbs. (1.57 kg.) between 2 and 9 fathoms. The fish were mostly serranids; their average weight in the deep traps was almost twice that in the shallow catches. The complement of herbivorous fish per trap also increases in shallow water. Five carnivorous fish, mostly retained for market, to each one herbivore occurred in the 102 traps between 10 and 30 fathoms, while the shallow traps caught one herbivore for each two carnivores, on the average. These herbivores, mostly parrott, angel, and surgeonfish, are not landed but used as bait on the spot.

On the shallow reef studied by us, we estimated the yearly growth of commercially used serranid species at 52 lbs. per acre. Sizes and species composition from the deeper traps suggest a greater proportion of large to small serranids than on the shallow reefs. On the other hand, we may have attracted a number of serranids by continuous baiting. Thus we take our figure of around 50 lbs. per acre as representative for the "heavily" fished reef regions around Bermuda which then produce at least 4,800,000 lbs. of "harvestable" serranids per year. The outer banks, on the same basis, add 2,240,000 lbs. to this figure. The harvest from there is, at present, not believed to exceed 200,000 lbs. a year, while the reef region around Bermuda yields about 700,000 lbs. of demersal

reef fish yearly, with an additional 100,000 lbs. being caught in the inshore and South-shore areas (Figure 1). Most, though not all of these, are serranids.

On the basis of these calculations we can make some general statements about the Bermuda fishery although the growth is probably estimated low and the landings rather high.

1) The harvest from the outer banks is likely to increase more rapidly than that from the Bermuda reef area proper. This development is now in progress and will be accelerated with improved methods of keeping the catch fresh, such as small refrigeration units aboard ship, and antibiotic treatment.

2) A harvest of 10-15 per cent of the yearly weight increase in fish flesh, secured by relatively primitive means because of environment imposed conditions, is not likely to yield a substantial increase with a concomitant increase in fishing effort without a drastic change in technique, for instance, electrofishing. If only serranids are marketed, the entire area is undoubtedly capable of yielding from 50-70 per cent more than it yields at present, but a substantial boost, such as a doubling or trebling of the present Bermuda harvest, will more than likely come from:

a. An increase in the harvest of floating fish.

b. Commercial harvest of the, at present, unused Tuna resources (Mowbray, 1955).

c. Partial harvest of the other now unused and little used species.

It should be mentioned in closing that Bermuda has a population of 41,000 (private communication Colonial Sec., Sept. 1956) and, since the U.S. Forces stationed in Bermuda hardly consume any fish secured through commercial channels, one only has to add to the above figure 2,500 persons which represents the tourists prorated on a yearly basis (Bardach and Mowbray, 1956). A harvest of 568 metric tons (1¼ million lbs.), for a population of 43,5000 results in an average per capita landing of 13 kg., or landings of over five metric tons per fisherman. This is comparable to the estimated per capita fish production of Finland, France and Western Germany and indeed to that of the United States (Morgan, 1956). It certainly exceeds the per capita production of many Caribbean countries, with the exception of Venezuela. One reason for this relatively high degree of efficiency in Bermuda's fishery is to be found in the fact that nearly all fishing vessels are motorized.

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TABLE 1
GROWTH RATES OF CERTAIN BERMUDA REEF FISHES

Species and size groups	*% growth winter (per annum)*		*% growth summer (per annum)*		*Average field growth (prorated)*
	field	lab	field	lab	
Red hind					
600 g.	20		40		38%
250-400 g.		79		247	
500-700 g.		132		273	
800-1200 g.		5			
Nassau Grouper					
700 g.			20-50		40%
Rockfish					
1000 g.					60-75%

A Survey of Spearfishing in the Florida Keys

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IN FLORIDA, spearfishing is defined legally as "the taking of any marine life through the instrumentality of a spear, gig, or other device operated by a person submerged in the water." As a commercial method spearfishing has generally been abandoned in favor of more productive means in Florida, but it is still used to a limited extent where fish can be found concentrated in certain areas or at certain times of the year.

Spearfishing has only recently been practiced as a sport. During the period from 1930 to 1935 a few individuals began this activity in Florida as well as California, Hawaii and in the Mediterranean. The early development was mostly in California and France, and much of the equipment used today comes from these places. Basic equipment includes a diving mask, swim fins and any one of the various types of spearguns or devices.

Prior to World War II there was little interest in the sport, but during the past ten years the number of spearfishermen has greatly increased. They formed many clubs which by 1950 were sufficiently numerous and organized to hold a national competition meet at Laguna Beach, California. In 1956 a national competition was held at Marathon, Florida, under the auspices of the Amateur Athletic Union which has recognized spearfishing as a new sport.

In Florida spearfishing clubs have been formed, principally along the lower east coast and in the Tampa-Sarasota-Bradenton area.

The most common places fished by spearfishermen in Florida are the shallow waters above coral reefs, near jetties, piers and bridges, and in channels or potholes. These places formerly were fished almost exclusively by hook and line fishermen, but since 1950 an increasing number of spearfishermen have been operating there.

In 1951 the Florida State Board of Conservation requested The Marine Laboratory to make a preliminary investigation in Palm Beach County to determine whether the methods of spearfishing used were contrary to conservation

[1]Contribution No. 181, The Marine Laboratory, University of Miami.