Investigations into the Use of Scale Circulus Spacing for Derivation of Site-specific Growth Rates in Coral Reef Fishes: A Possible Indicator of Habitat Health

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ABSTRACT

It is hypothesized that growth rates of coral reef fish populations will vary according to the quality of their reef habitat. In St. Lucia, West Indies, levels of anthropogenic stress vary around the coast; thus different areas should generate site-specific growth rates for a given species. Conversely, growth rates of fishes should be good indicators of habitat quality and deterioration. Circulus spacing of fish scales was used to indicate instantaneous growth of fishes from two reef sites. The Blackbar Soldierfish (*Myripristis jacobus*) shows significantly smaller circulus spacing (which implies slower growth) in a heavily impacted site versus a less affected site. Circulus spacing appears to be length-dependent in this species; therefore it is important to obtain fish samples of a limited size-range in order to make multi-site comparisons.

KEY WORDS: Blackbar Soldierfish, circulus spacing, reef monitoring.

INTRODUCTION

Coral reef fishes, being mostly restricted to shallow shelf areas adjacent to the coastline, are likely to be influenced by factors impacting upon coastal waters. Pollution can affect the growth rate of fishes according to the type and level of the stress inflicted, the resistance of the species, and its response to density dependent factors (Ryan and Harvey, 1980). Low concentrations of aquatic contaminants, nitrate and ammonia compounds, unsuitable temperatures, hypoxia, and sediment loads are some stress-inducing environmental alterations which may result from land-based and coastal developments (Wedemeyer and Mc Leay, 1981).

According to Wedemeyer and McLeay (1981), sub-lethal levels of stress factors may reduce growth by loading or limiting physiological systems. Increased susceptibility to disease and any other additional stressors may result. Parameters such as intrinsic growth rate and disease incidence have already been used in biological monitoring and assessment of environmental stress for a wide variety of organisms.

Little is known about growth, mortality and recruitment in coral reef fishes (Pauly and Ingles 1981). In the case of growth studies, failure of hard parts to consistently record annual growth cycles as scale/otolith annuli has meant that temperate- style derivations of growth from size-at-age calculations are not feasible. Indirect growth measurements (versus direct weight/length changes) have thus gained popularity.

One simple and rapid technique (Doyle *et al.* , 1987) uses circulus spacing on fish scales as an estimator of instantaneous growth. Scale growth is proportional to body growth; thus the number and distance between circuli is indicative of successive growth states of both fish and scales. It is generally accepted that a linear relationship exists between scale size and fish length (Ottaway and Simkiss, 1979). Various studies of tropical and temperate fish species (Ikeda *et al.*, 1973; Bilton, 1972; Doyle et al., 1987) have illustrated that circulus spacing is directly related to current growth rate. However, these investigations have all been carried out within controlled environments rather than for natural populations.

In the current study an attempt is made to identify site- specific growth rates, using circulus spacing as an instantaneous growth estimator, for a fish species sampled from different coral reef areas off the island of St. Lucia. Many reef areas off St. Lucia appear to be suffering from a variety of stress factors brought about by land-based development activities such as land clearing for agricultural and construction purposes, and sewage outflow.

The Blackbar Soldierfish (*Myripristis jacobus*) was identified as a suitable species for this study since it displays the following characteristics:

a) a clearly defined feeding guild: eating crabs, shrimps, and their larvae;

b) a highly restricted feeding range, thus conditions within the reef area and external conditions impacting upon the reef are continual influences;

c) as a shallow water species it is confined to the upper zones of the reef (less than 20 m) and therefore is likely to be affected (directly or indirectly) by stressors such as sediment load, sewage outflow etc.

The biological synopsis provided by Wyatt (1976) for the above species specifies these characteristics.

Although very little biological research has been carried out for this species, other members of the Holocentrid family show spawning activity throughout the year, with a peak during the colder months (Wyatt, 1976). Holocentrids cannot be aged through use of skeletal hard parts, but growth appears to be very slow as indicated by tag-recapture efforts for two other Holocentrid species (Randall, 1962).

METHODS AND MATERIALS

Site Selection:

The two survey sites used for the sampling of *M. jacobus* (Figure 1) were known to support an expanse of coral reef with a corresponding multi-species fish community. Selection was based on their history of anthropogenic stress. Resultant ecological contrasts would therefore, it is hoped, generate differing growth rates for the fish species. Sampling took place during May and June of 1987.

Both sites are on the leeward coast. In Site B a previously extensive coral reef area has been largely obliterated by dredging activities and the construction of a causeway during the early 1970s. In contrast, Site A has suffered considerably lower levels of physical damage and supports a long-established reef fishery. It is, however, close to the capital city and an area of urban expansion. It is therefore likely to have experienced a steady rise in urban pollution.

Sampling Strategy

The actual fishery was used as a source of sample individuals. A small number of fishermen were selected from each site in an attempt to limit day to day fluctuations in the area fished. Individuals sampled were kept to a limited size range so as to minimize variance in circulus spacing due to fish/scale size variance. Fork length was measured as an indicator of fish size. The scales used were the 5th to 8th scales on the left side of the fish along the row ventral to the lateral line, counting backwards from the operculum. Scales were preserved in 10% buffered formalin.

Fish Scale Analysis

Each scale was wet mounted on a standard microscope slide and observed under a Neo Promar projection microscope. Scale size (measured at 6.2X magnification) was determined by measuring the scale diameter (Figure 2). This was necessary since no distinct center is seen in scales for the Blackbar Soldierfish.

Circulus spacing was measured using a Mututoyo Digimatic caliper at 100X magnification. This measurement (CIRC) was taken as the sum of the first three circuli at the anterior margin of each scale (Figure 2), corresponding to growth just prior to sampling. Three such measurements were made for each scale, one central and two lateral. Thus twelve CIRC measurements were obtained for each fish, and an average CIRC was derived for each scale and then for each fish. In a few cases scales had to be rejected due to regeneration (which resulted in incomplete circuli). It was therefore necessary to weight average CIRC values according to the number of scales used.

Statistical analysis of the relationship between fish length, scale size and CIRC was carried out (along with relevant between-site comparisons) using the SYSTAT statistical system (Wilkinson, 1988).

RESULTS

As indicated by Table 1, the Blackbar Soldierfish samples for Sites A and B are of a similar size range (as determined by fork length). This is essential in

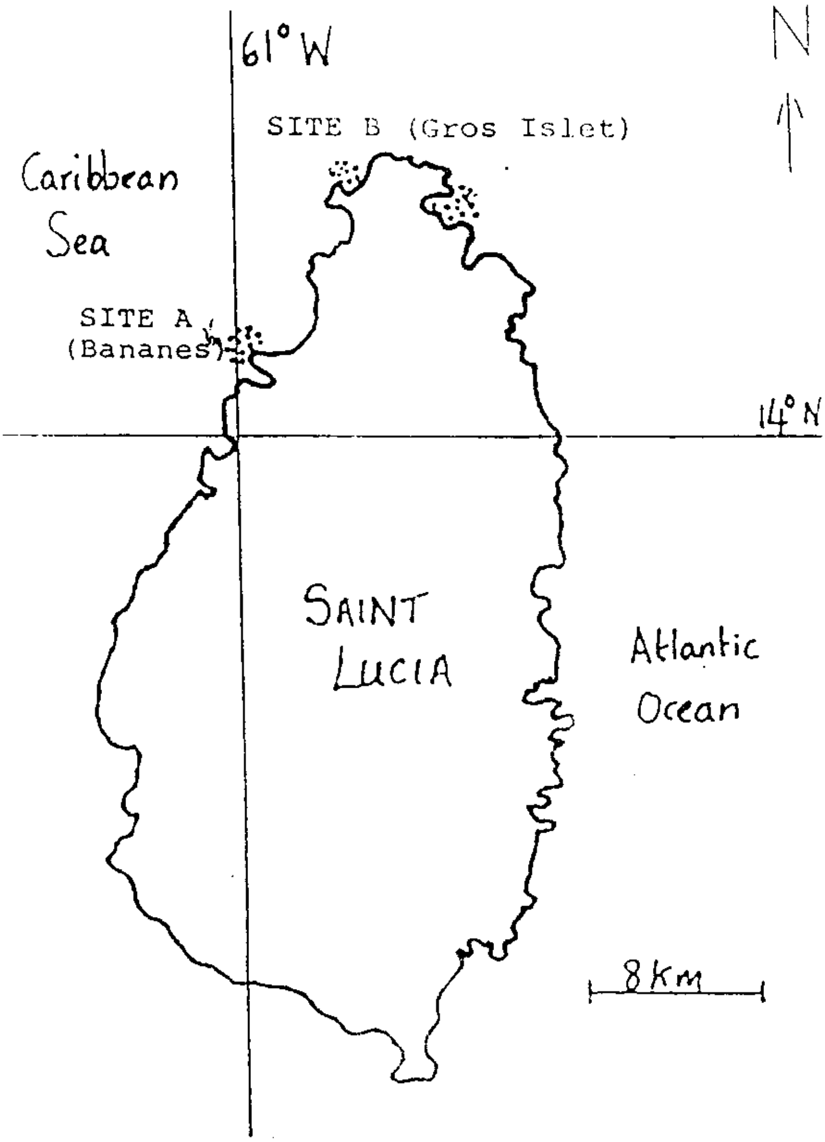

Figure 1. Survey sites selected for analysis of instantaneous growth in the Blackbar Soldierfish *(Myripristis jacobus)*.

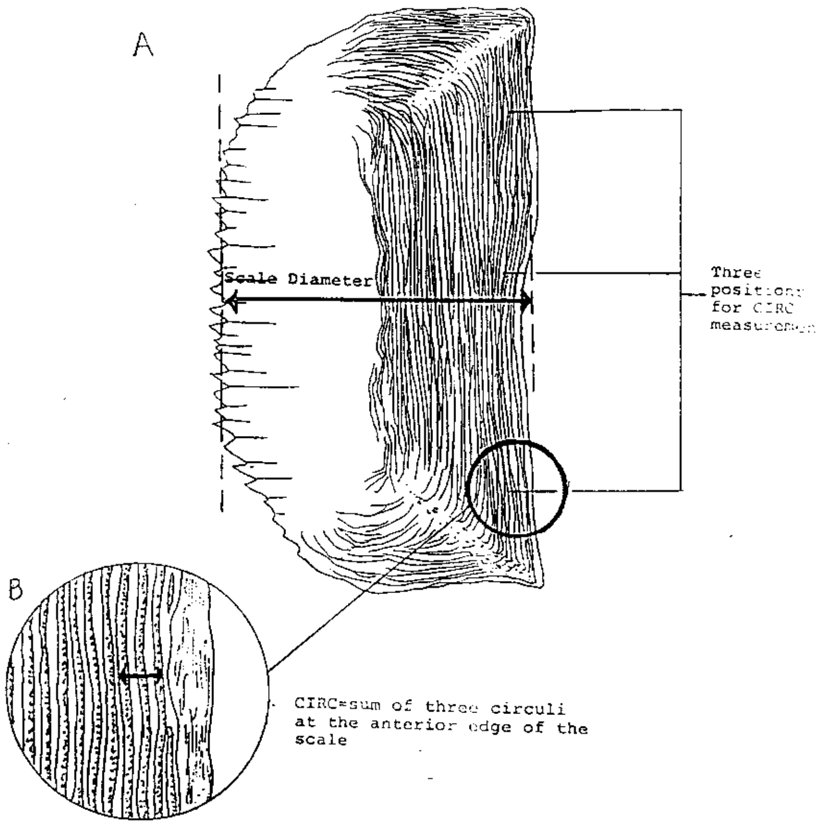

Figure 2. Positions and measurements used for obtaining information on circulus spacing for fish scales from the Blackbar Soldierfish.

order to generate scale samples which greatly overlap in scale size, thus allowing CIRC differences to be predominantly attributed to growth rates rather than scale size. Sample sizes (in terms of the number of fish used) for the two sites are small and unequal (Table 1).

Scale size shows a positive linear relationship with fish length, with r = 0.699. A simple linear regression model is appropriate for expressing the relationship between these two variables (F-ratio = 37.187, P = 0.000), with:

$$\text{Scale Size} = 5.76 + 2.75 \text{ Fish Length}$$

Figure 3 indicates that, with both sites combined, there is minimal correlation between CIRC and scale diameter. However, there is a site-related trend within the scattergram, with scales from Site A having a consistently larger CIRC value for a given scale size. Although scale diameter data from the

Table 1. Fish scale dimensions for samples of Blackbar Soldierfish taken from coral reef sites with contrasting environments.

	SITE A n=26	SITE B n=15
MEASUREMENTS:		
Fish Length (cm)		
MEAN	14.56	15.10
ST. DEV.	0.97	1.04
MINIMUM	13.00	13.30
MAXIMUM	16.50	16.50
Average Scale Diameter (cm)*		
MEAN	45.40	48.05
ST. DEV.	4.03	3.49
MINIMUM	39.30	41.53
MAXIMUM	54.60	53.65
Average Scale CIRC (cm)*		
MEAN	1.58	1.48
ST. DEV.	0.08	0.06
MINIMUM	1.46	1.36
MAXIMUM	1.80	1.59

*Measurements are made at the magnifications detailed in the "Methods and Materials" section.

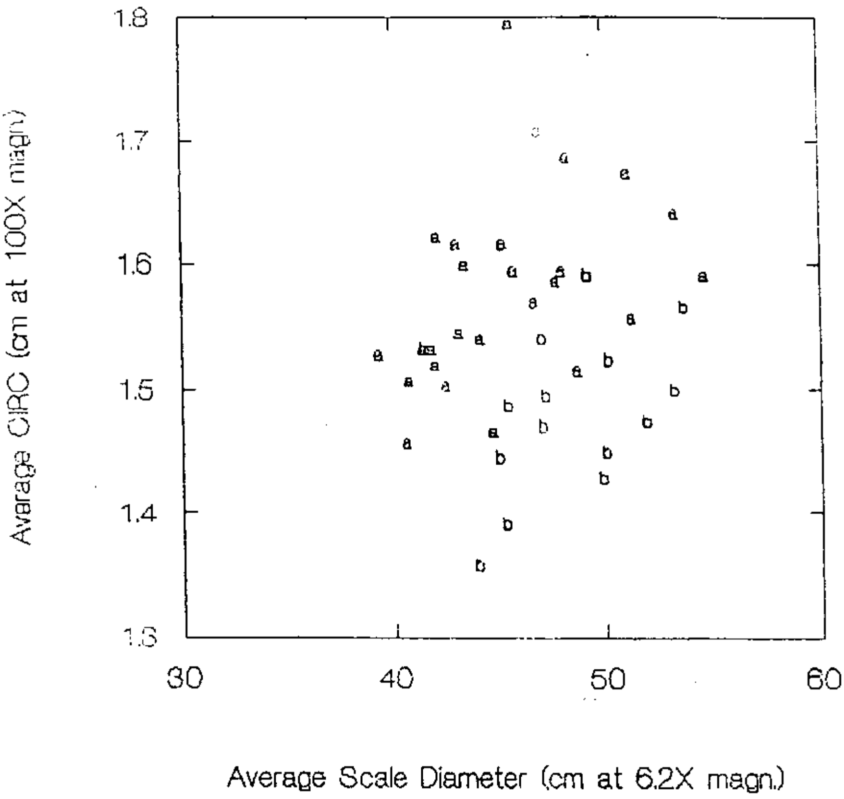

Figure 3. Scattergram of average scale-margin circulus spacing (CIRC) against average scale diameter for the Blackbar Soldierfish sampled from Site A (symbol=a) and Site B (symbol=b). The correlation between the variables is 0.145, n=41.

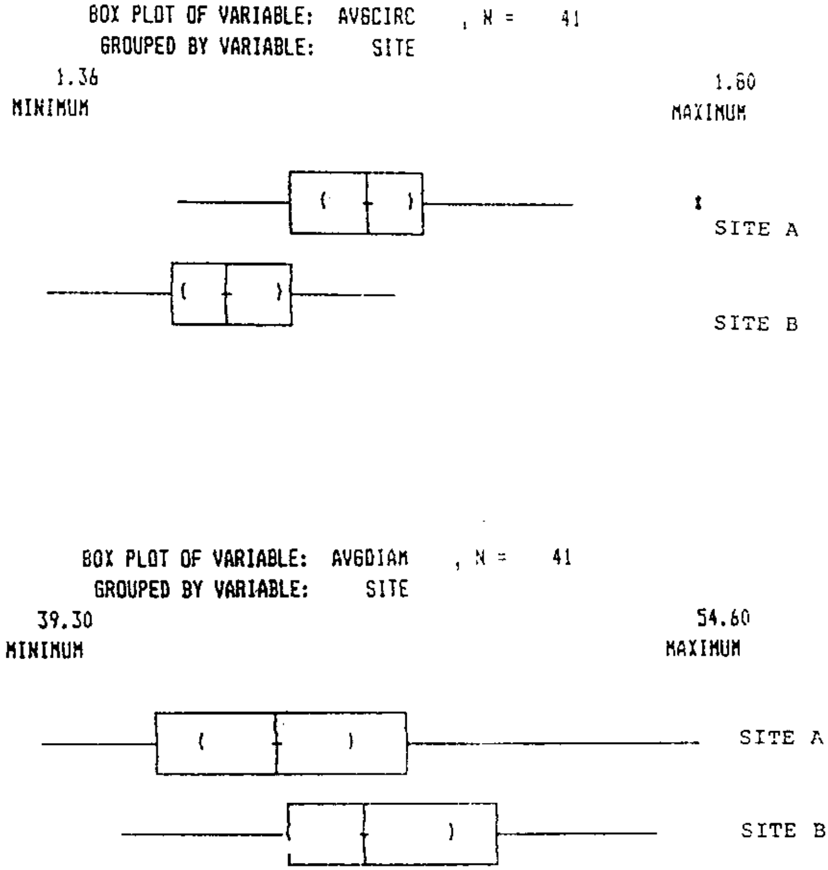

Figure 4. Box plot showing central tendency and variation within average scale-margin CIRC measurements versus scale diameter measurements for the Blackbar Soldierfish sampled from SiteA and Site B.

two sites does not differ significantly, there is a significant difference between average CIRC measurements for these two sites (Figure 4). ANOVA results confirm that a significant difference exists for CIRC (F-ratio = 17.148, P = 0.000, n = 41) and does not for scale diameter (F-ratio = 4.296, P = 0.044, n = 41). Thus CIRC variance cannot be largely explained by variance in scale size within the two samples.

Analysis of site-derived data shows the correlation between fork length and scale size being stronger for Site B (r = 0.857, versus r = 0.582 for Site A).The Pearsons Correlation Matrix results indicate that between scale variability was quite low, with correlation coefficients ranging from 0.633 to 0.80. Between-scale Pearsons correlation in CIRC is higher for Site B (Pearsons r = 0.520 - 0.928) than for Site A (Pearsons r = 0.520 - 0.799).

DISCUSSION

Since neither fish length nor scale size appear to be suitable predictors of CIRC, the data suggests that site-related differences exist for circulus spacing of the fishes from Site A and Site B. Assuming a positive relationship between spacing and growth rate in this species, fishes appear to be growing faster (prior to sampling) in Site A, since CIRC is significantly larger in scales from this site.A large mangrove system and associated coral reef were removed from Site B during the 1970s in order to construct a marina and an 88 acre causeway (Towle 1984). Thereafter, the reef fishery dwindled and subsequent sedimentation smothered the remaining live reef areas. Visual surveys carried out in this area (Department of Fisheries, unpubl. data) show a dominance of algae with very few colonies of silt-sensitive coral species such as Montastrea annularis, in comparison to nearby areas. In general, the Gros Islet reef shows little signs of regeneration, and offers minimal coral habitat to fish species.The data extracted from the two sites shows a variety of interesting differences in scale and fish length relationships. Fishing pressure is quite different at these sites, Site A supports a large trap fishery; whereas the reef fishery in Site B is mostly undertaken by a small group of speargun fishermen. This latter technique, besides being size selective, resulted in lower catches and thus a greater standard deviation in fork length for the sample, due to limited choice in sampling.

One necessary caution is that a fishing technique itself may be growth-selective. Faster growing fish may well have behavioral characteristics which lead to unequal catchability by fish pot as opposed to speargun fishing.In accordance with past studies (Doyle *et al.*, 1987; McNaughton, 1986; Ottaway and Simkiss, 1976), this species also demonstrates a strong positive, linear relationship between fish length and scale size. The lack of a clearly defined center of origin for scales of this species may result in a certain degree of weakening of the relationship between the scale size estimator (in this case, diameter) and fish length. Thus, identifying the true origin for these scales should further strengthen this linear relationship, and thus benefit use of this technique for long term monitoring.

Ottaway and Simkiss (1976) recommend that, due to differential growth along the length of the fish, scales be removed from approximately two-thirds of the way along the body. In this study the anterior region of the fish (just behind the operculum) was used since sampling had to be carried out rapidly while fish were being sold, and this proved to be an easy body region to identify. Further research should investigate whether between-scale variance and CIRC differ based on the location of the scales used.

Circulus spacing is affected by fish age, with the specific growth rate being high in young fish and decreasing with age (Ursin, 1979). Thus Kamonrat (1987) cautions that CIRC, being based on growth at a particular size rather than age, may be less indicative of overall environmental effects within an area, since certain age cohorts may have innate growth advantages due to genetic or maternal influences. Based on the year round spawning activity of the Blackbar Soldierfish, it is likely that size- class samples are made up of a mixture of cohort individuals, thereby leading to enhanced CIRC variability. Nonetheless, site differences for CIRC were significant. The current study failed to reveal any distinct seasonal check marks on the scales sampled. This would prevent identification of distinct age classes from within wild populations of this species, leaving size classes as the only feasible alternative for growth rate analysis.Marginal CIRC could become a valuable method for monitoring the growth rates throughout a number of years, in order to determine whether seasonal oscillations occur within annual growth for reef species throughout the region. Pauly and Ingles (1981) found reduced growth (based on growth curves generated from length frequency data) for five reef species from the Virgin Islands. It will be necessary to determine whether such oscillations exist in order to set up sampling schedules for long term monitoring, which would need to avoid sampling at different reproductive and seasonal growth stages.Concurrent interpretation of marginal CIRC for a herbivorous and carnivorous species from each site, in conjunction with quantitative monitoring of the diversity and coverage of algae and corals and abundance of fishes within sites, should allow considerable insight into the overall condition of an area over time. In this way, the welfare of two species from dramatically different feeding guilds can be monitored simultaneously and related to changes in reef conditions.

No attempt was made to distinguish males from females in this study. This may well have led to increased CIRC variance, since sex-linked differences in growth rates are frequently encountered in fish populations (Weatherly 1972). It is important to note that faster growing fish tend to reach maturity at a different size than slower growing individuals (Eknath and Doyle 1985), and size/age at maturity is also likely to differ according to sex. Samples should preferably be taken at a month when reproductive activity is lowest, since the use of a fixed size range results in combining different individual levels of reproductive development. CIRC data should also be classed according to sex.

If CIRC is used to monitor habitat fitness and condition of fish populations, use of length measurements alone may be inadequate since, as pointed out by Ursin (1979), fish length does not decrease much with a decrease in weight and is therefore a poor condition factor. Thus, the relationship between CIRC and weight-at-length needs to be considered in further studies, since both should be decreased by environmental stressors.

In addition there is a need to validate the CIRC/growth relationship by experimental manipulation of growth rates, using a factor such as food ration. Adjustments in CIRC can then be related to actual length/weight changes and a species-specific growth equation (based on CIRC) can be derived.

In conclusion, the present study demonstrates that scale circulus spacing appears to be a feasible growth rate estimator for the Blackbar Soldierfish, and is probably applicable to other coral reef species. The method warrants further investigation, taking the many shortcomings of the current work and resultant recommendations into consideration.

The recent establishment of a number of protected marine reserves in St. Lucia, along with the many reef areas being presently affected by increased sedimentation and sewage outflow, provides a valuable opportunity to quantify CIRC/growth/stressor interactions. In addition, Pauly (1987) recommends that instantaneous growth estimators (such as CIRC) be used to corroborate inferences made from length frequency data, so as to generate more realistic interpretations of the state of tropical fish stocks. In St. Lucia the Department of Fisheries is currently collecting resource data on local coral reefs in order to identify suitable management measures for this resource (Walters, 1985). Estimates of fish growth will be fundamental to determining suitable management strategies for the associated reef fishery.

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