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A CRITIQUE ON THE RELATIONSHIP OF SURFACE AREA OF LIVE CORAL WITH TOTAL NUMBER OF FISHES AS WELL AS THE BIOMASS OF FISH IN A COEXISTING SYSTEM OF *CHROMIS CAERULEUS* AND *DASCYLLUS ARUANUS* (POMACENTRIDAE) AT MINICOY ATOLL

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ABSTRACT

The pomacentrid fishes *Chromis caeruleus* (Cuvier) and *Dascyllus aruanus* (Linn.) coexist on ramose live corals without apparently displaying aggressive reactions. The population in a coral colony is of many size groups, an obvious result of continual settlement of postlarvae of fishes from plankton, probably a strategy in nature to prevent inbreeding in resident fishes. The relationship between the total number of fishes residing on a coral and the upper surface area of the habitat (coral colony) can be expressed as : $Y = 0.2117 - 0.000064 X$, where Y is the number of fishes per unit area of the coral and X the upper surface area of the coral sampled ; the correlation coefficient (r) being -0.486 . The relationship between the fish biomass and the upper surface area of the habitat can be expressed as : $Y = 0.07888 - 0.00005225 X$, where Y is the weight of fish per unit area of the coral sampled and X is the upper surface area of the coral ; the correlation coefficient (r) being -0.99 . As indicated by these correlation coefficients, there exists a closer relationship (inverse) between the biomass of fish and the surface area of the microhabitat (live isolate coral) than between the total number of fish and the surface area at a time in a coexisting system of resident reef fishes. The ratio of the fish biomass and the upper surface area of the coral (an index of density of fish) is also found to vary in different samples, within a range of 380.3 to 934.25 cm² of the coral and a fish biomass of 22.42 to 30.87 gm weight of fish sampled. The total length of the fishes ranged from 7 mm to 40 mm in the samples. The present study also indicates that neither a numerical nor biomass consistency of fishes can be anticipated in a microhabitat over a prolonged time. Both these factors are ever changing as also the area of the living habitat viz. the live coral colony. This is due to the interplay of many natural and artificial factors, such as, continual recruitment of postlarvae, growth of fish at sites, migration and mortality of fishes as well as the partial death or growth of corals that cause a dwindling or expansion of living space for resident fishes. The above factors in nature control the density of fish population in a coral live isolate. The maximum carrying capacity of the habitat perhaps is never allowed to reach so that coexistence is made possible without the fishes displaying apparent agonistic reaction. However, the present data did not clearly indicate the maximum carrying capacity of unit area of *Acropora corymbosa* sampled ; the systems analysed were in different stages of density level.

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INTRODUCTION

MANY pomacentrids, coexist in both macro- and microhabitats of coral reefs. Some of the earlier studies on the co-existence and related aspects of resident reef fishes, are those of Sale (1978, 1979) and Sale *et al.* (1980, 1984). Based on a study of the pomacentrids, *Eupomacentrus apicalis*, *Abudefduf lacrymatus* (= *Plectroglyphidodon lacrymatus*) and *Pomacentrus wardi* (= *P. tripunctatus*) from the rubble patches of the Heron Island in Great Barrier Reef, Sale (1978, 1979) has stated that availability of living space limits the number of resident fishes on both macro- and microhabitats. He has also pointed out that, in a coexisting system of resident fishes, all the species and individuals are in competition for space and food, 'but do not differ in their abilities to gain or hold this space in any way which would permit identifying one of them as competitively dominant to others' (Sale, 1978).

Chromis caeruleus and *Dascyllus aruanus* are among the resident fishes on corals which coexist on ramose corals (Fig. 3). Both are widely spread in Indo-Pacific. In Lakshadweep *C. caeruleus* is commonly used as a live bait for tunas and is intensively fished. The common species of scleractinians that provide habitat to these fishes at Minicoy include *Pocillopora damicornis*, *Acropora formosa*, *A. teres*, *A. abrotanoides*, *A. aspera*, *A. humilis*, *A. corymbosa* and often *Porites andrewsi*. The local distribution and zonation of these corals in the atoll have been described by Pillai (1971). Both these fishes are diurnal and feed on plankton and are observed during days as to either resting among the interspaces of branches and branchlets of corals or swimming around the corals, but retreating to the corals at the slightest disturbance. When an individual of one of the species leaves the coral, either an individual of the same species or of the other species occupy the vacant space. The living space and food is equally shared. There is no niche partitioning. However, the newly

settled postlarvae do not leave the coral. As they grow they assume a wider home range (Fig. 1). The larger individuals can be lured further out of their normal home range by offering massed meat of crab, a method adopted by local fishermen to free the fishes from corals to facilitate easy fishing by cast nets.

There seems to be no detailed work on the ecology of these two co-existing species in the past, though, recently Madan Mohan *et al.* (in press) and Pillai *et al.* (unpub.) worked out the details of the biology of *C. caeruleus* and *D. aruanus* respectively. The aim of the present work was mainly to assess the relationship between (1) the surface area of the coral colonies and the total number of fishes residing at a time and (2) to establish the relationship, if any, between the biomass of the fishes and the surface area of the coral, with a view to determining which of the above correlations is more significant. The present work is also intended to have a critical examination of some of the general behavioural aspects of these fishes in relation to earlier findings on other species elsewhere. Since, density dependent factors are of importance in co-existence, a few factors that should normally influence the density of these fishes on coral colonies are also discussed.

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MATERIAL AND METHODS

Isolated live colonies of *Acropora corymbosa*, inhabited by *Chromis caeruleus* and *Dascyllus aruanus* were located in the lagoon of Minicoy at low tides during January-April when calm conditions prevailed. All the corals

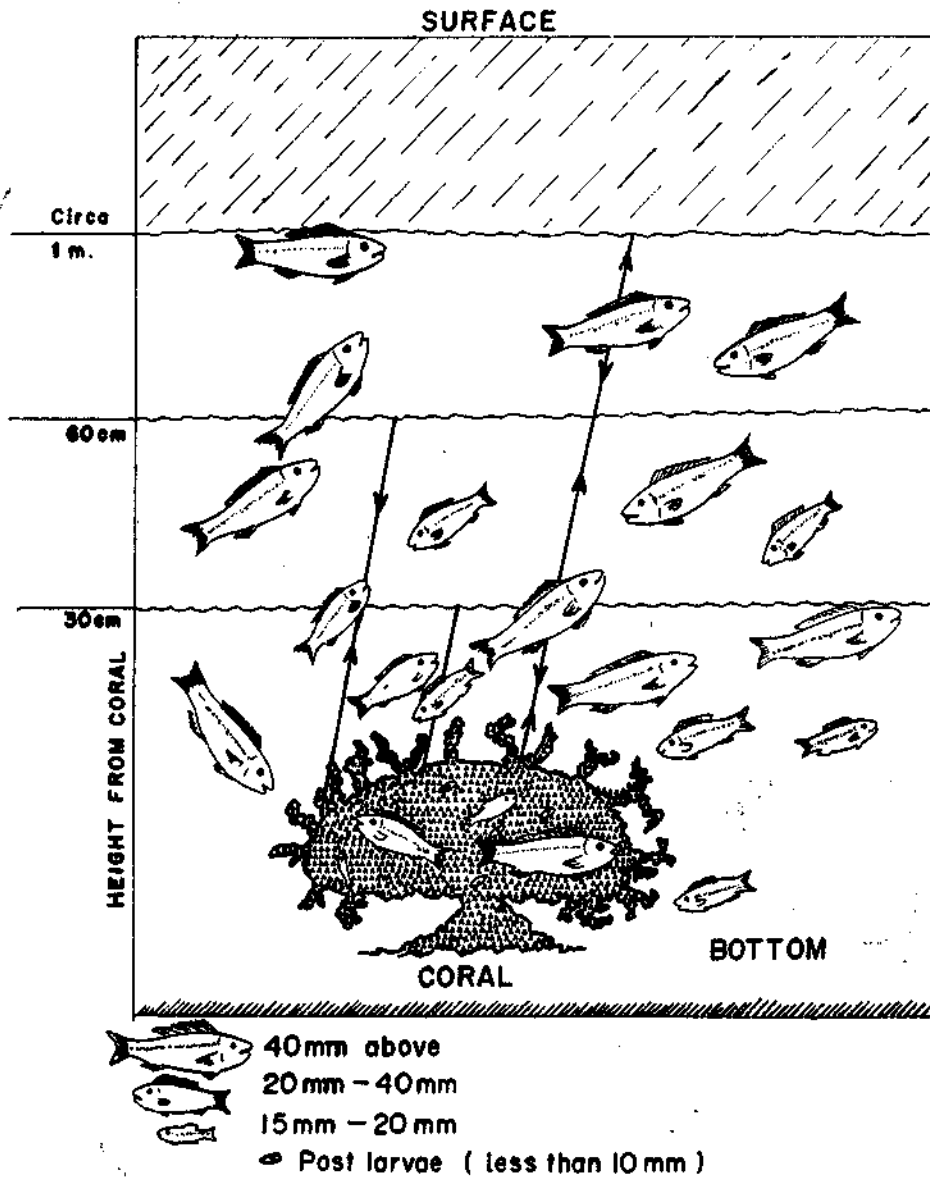


Fig. 1. Territory range of *Chromis caeruleus* in relation to size of fish. Not drawn to scale.

selected had pedicellate corallum with reticulately coalescent branches and more or less circular outline. Only colonies with same growth, form and shape were selected. The greater and lesser diameters of the coral colony was taken in the field with a metre scale and the average was taken to calculate the upper surface area. After a time lapse when the fishes have returned to the coral, they were quickly covered with a large net made of mosquito net. The net was brought closer slowly, taking all possible care, so that no fish escaped. The depth of water at the sites ranged from 25 to 50 cm at low tides and the bottom was sandy. The coral was later broken with a hammer and chisel and all the fishes collected. The total length of the individual fishes, their total number and biomass were estimated in the laboratory soon after collecting. Special care was taken to sample only isolated corals with the same growth form to avoid the chance of mixing or escape of resident fishes to other colonies. *A. corymbosa* among all others was preferred by virtue of its circular, reticulately coalescent corallum which helped a more or less precise estimation of the upper surface area. Further, the upper branchlets in this species is more or less uniform in height in almost all colonies. The paucity of isolated colonies with the same growth form in sandy bottom at shallow waters, mainly account for the fewer number of samplings.

OBSERVATIONS

Size range of population of fishes

The population of *C. caeruleus* and *D. aruanus* on a coral is found to include five to seven size ranges. These include newly settled post-larvae of 7 mm T.L. to adults of 40 mm T.L. during January to April period when samples were collected (Table 1). Though, the fishes are capable of growing to a size of upto 80 mm T.L. in Minicoy (Madan Mohan *et al.*, in press) the present samples included

only individuals upto 40 mm T.L. In some colonies either *C. caeruleus* or *D. aruanus* was only present, though as a general rule they coexist.

Relationship of upper surface area of corals sampled with total number of fishes as well as biomass of fishes

The ratios between total number of fishes and the unit upper surface of the coral as well as between the unit area of the coral and the biomass of the fishes are given in Table 2. The surface area of the different samples of corals ranged from 380.3 to 934.25 cm². The biomass sampled ranged from 22.42 to 38.87 gm fish weight. The relationship between the total number of fishes (*i.e.* *C. caeruleus* and *D. aruanus*) and the upper surface area of the coral inhabited by them can be expressed as :

$Y=0.2117-0.000064 X$, where Y is the number of fishes per unit area of the coral sampled and X is the upper surface area of the coral; the coefficient correlation (r) being -0.486 . The relationship between the biomass of fish and the upper surface area of the coral can be expressed as :

$Y=0.7888-0.00005225 X$, where Y is the weight of the fish per unit area of the coral and X the upper surface area of the coral; the coefficient correlation being -0.99 .

DISCUSSION

In conformity with the reproductive behaviour of reef fishes, both *C. caeruleus* and *D. aruanus* have also an early pelagic larval life. This may last two to three weeks (Sale, per comm.) and at the end of the pelagic life the postlarvae get settled on live ramose corals. A set of postlarvae derived from the adults inhabiting a coral colony getting settled back on to the same coral involves an element of chance (Sale, 1978; Sale, *et al.*, 1980). The present data on the size ranges of population

TABLE 1. Analysis of size ranges and percentage composition of *C. caeruleus* and *Dascyllus aruanus* on *Acropora corymbosa* from *Mtincay Atoll*

Sample No.	Area of coral (cm)	<i>C. caeruleus</i>			<i>D. aruanus</i>		
		Length (mm)	Nos.	Percentage	Length (mm)	Nos.	Percentage
1	24 × 20	40	9	15.5	30	3	33.3
		35	2	3.4	25	5	55.5
		20	26	44.8	10	1	11.2
		17	5	8.6			
		10	16	27.7			
2	35 × 25	35	21	15.4			
		25	30	22.0			
		18	44	32.4		Nil.	
		12	31	22.8			
		7	10	7.7			
3	33 × 35	32	22	14.3	29	1	14.29
		28	7	4.6	25	1	14.29
		25	35	22.84	17	1	14.29
		20	11	7.44	13	1	14.29
		17	12	7.89	10	3	42.84
		15	23	19.94			
		10	43	27.93			
4	37 × 32	33	13	12.87	31	1	14.29
		30	3	3.97	28	1	14.29
		25	24	23.76	25	2	28.55
		22	25	24.75	18	1	14.29
		20	19	18.81	15	1	14.29
		17	6	5.94	11	1	14.29
		10	11	10.89			

TABLE 2. Relationship among, surface area of coral, total number of fishes of both *C. caeruleus* and *D. aruanus* and their biomass based on data in Table 1

Sample No.	Upper surface area of coral (cm ²)	Number of fishes	Biomass of fishes (gms)	No./area of coral	Wt./area of coral
1	380.3	67	22.42	0.176	0.059
2	707.18	136	29.68	0.192	0.042
3	908.33	160	30.87	0.176	0.034
4	934.25	108	26.19	0.116	0.028

(Table 1) clearly indicates that all the size groups represented are not the result of breeding of the largest size group 40 mm T.L. present. The size at first maturity of *C. caeruleus* is 38 mm T.L. (Madan Mohan *et al.*, in press) and that of *D. aruanus* is 40 mm T.L. (Pillai and Madan Mohan, un pub.). It indicates that the resident population of *C. caeruleus* and *D. aruanus* on a coral colony is the result of continual settlement of postlarvae of different parenthood. A similar situation was pointed out by Sale *et al.* (1980) on rubble patches in case of other pomacentrids. Both *C. caeruleus* and *D. aruanus* have a protracted breeding season (Madan Mohan *et al.*, in press) and individuals may spawn more than once in a year.

those entering afresh has been early demonstrated in some reef fishes (Sale *et al.*, 1984) though this behavioural aspect is yet to be experimentally proved in the two species herein considered. Postlarvae and juveniles of many reef fishes restrict their home range to avoid competition from adult, fishes but steadily expand their home range as they grow, with a corresponding increase in their agonistic abilities (Sale *et al.*, 1980). As indicated in Fig. 1 the postlarvae and juveniles of *C. caeruleus* and *D. aruanus* always confine themselves to the interspaces of corals while larger individuals maintain a wider home range. This behaviour of the newly settled postlarvae possibly help them, on their entry into the habitat, to avoid competition with the

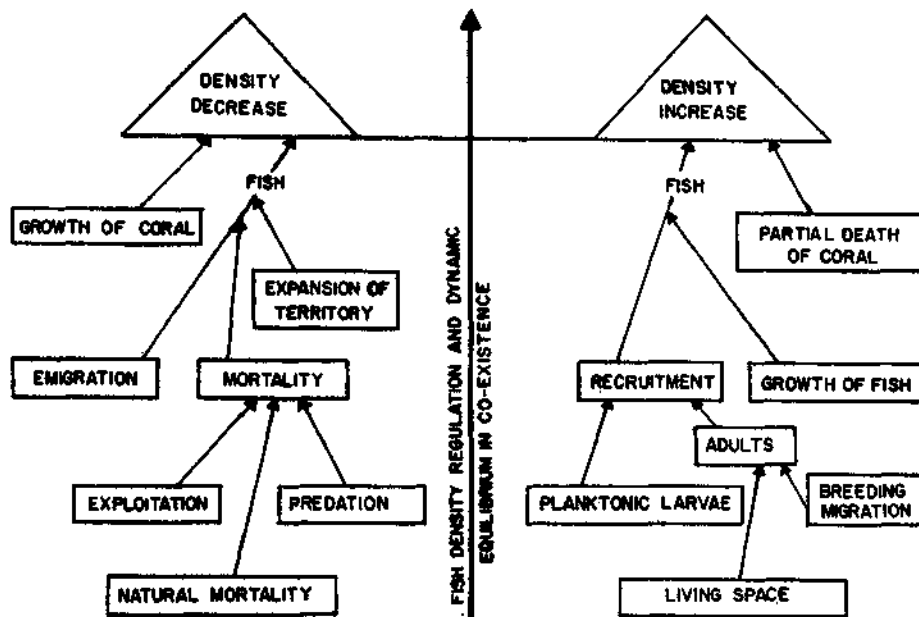


Fig. 2. Schematic representation of interacting factors in density regulation.

The continual settlement of postlarvae to a precise habitat on reef involves both an element of chance and perhaps a strong habitat preference (Sale, 1978, Sale *et al.*, 1980). Aggressive behaviour in a habitat between the individuals, who have already gained foothold and

adults for space and food. Continual settlement of postlarvae into microhabitat like an isolated *Acropora* colony is likely to establish widely different broods and may represent a natural strategy adopted by resident reef fishes to prevent inbreeding.

Smith (1978) has argued in favour of a numerical consistency of resident reef fishes on rubble patches over a long time span, though Talbot *et al.* (1978) and Sale (1980) do not favour the concept of a numerical consistency. During the present study we have not made an attempt to monitor colonies of corals over a long time to study the numerical consistency of fishes. However, the ratios

The present study indicates that the relationship between the biomass of fish and the upper surface area of habitat is more significant than the relationship between the total number of fishes and the area of the habitat. As indicated in Table 2, the ratio of the unit weight of fish and total upper surface area of the coral increases as the area of the coral decreases or the relationship is

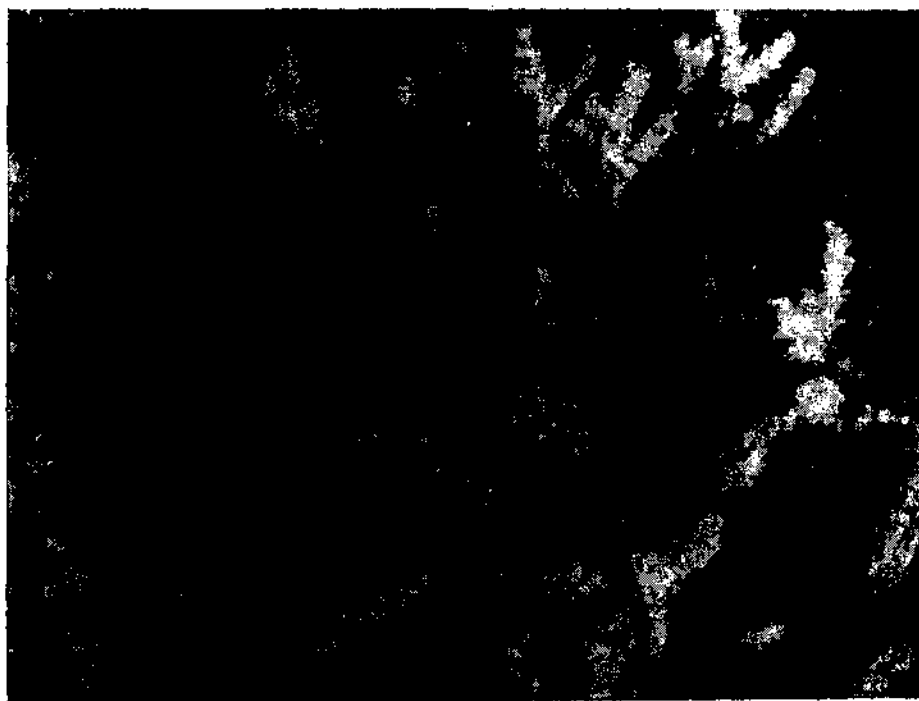


Fig. 3. A colony of *Acropora corymbosa* from Minicoy Atoll with *C. caeruleus* and *D. aruanus*.

obtained between the biomass of fishes and the area of habitat display wide variations in our samples. It seems logical (as the ensuing discussion on density regulating factors will show) to assume that if the systems were allowed to grow unhindered, a steady state of biomass—area relationship may not be maintained. The systems are dynamic with inflow and outflow of fish biomass as well as changes in the total upper surface area of the habitat in a long time span.

inversely proportional. This interpretation is based on a size range of fishes between 7 to 40 mm T.L. and an area of coral between 380.3 to 934.24 cm². Our studies on the biology of these two species of fishes have shown that both the species are capable of growing to a size of 80 mm T.L. The area (Minicoy lagoon) is one which is subjected to intensive fishing for *C. caeruleus* and at present in shallow exploited waters, fully grown adults are rarely found. As already pointed out

by Sale (1978, 1979) and Sale *et al.* (1980) coexistence involves the lack of apparent aggressive behaviour *i.e.* even when the various species are living in the same niche dominance of one of the members over the others is not manifested. All are equally successful, though competition is the general norm among the individuals. The ratio of biomass and area of living habitat is an index of density of fishes at a time. A steady state of numerical or biomass consistency over a time period is not found in the coexisting system of *Chromis caeruleus* and *D. aruanus* on live coral colonies. The system is dynamic and density has to be maintained at all time to sustainable level. The maximum carrying capacity of the unit area of *A. corymbosa* in Minicoy has not been ascertained and the present data do not yield any conclusion on maximum carrying capacity and it is not known whether any of the systems we sampled has reached or not the saturation level.

Many factors are involved in natural regulation of density of fish population on a coral colony (Fig. 2). Factors that favour an enhancement of density of fish in a macro-

habitat as is considered herein include, continual settlement of postlarvae, growth of fishes at site, immigration of subadults. Partial death of coral colonies due to many natural and artificial reasons causes a dwindling of the available living space and a relative increase of fish density. The factors that bring out a relative decrease in the density of fishes include emigration and mortality of fishes as well as the natural growth of corals that increases the available living space. Corals left in the field after depopulating the fishes for biological studies were often found to be repopulated by the adults of *Dascyllus* and *Chromis* after an interval of time indicating emigration and immigration of adults between coral colonies. The tendency of these fishes to increase their home range, as the individuals grow, also helps in the expansion of total feeding territory of the fishes living in a restricted habitat. In essence the equilibrium evident in coexistence is dynamic and the component aspects of the density of fishes per unit area of the habitat is subject to change at different periods of time, though the maximum carrying capacity rarely attained.

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