

# The dynamics of unexploited population of *Corbula trigona* (Bivalvia: Corbulidae) in a brackish-water lagoon, Côte d'Ivoire

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## Abstract

Population dynamics of the bivalve *Corbula trigona* were studied in a brackishwater environment of the Tendo Lagoon in Côte d'Ivoire. By means of FiSAT software 12 consecutive months length frequency data with a pooled sample size of 10 971 specimens were analysed. The seasonalized von Bertalanffy growth parameters were  $L_{\infty} = 21.5$  mm,  $K = 0.49 \cdot y^{-1}$ ,  $C = 0.39$  and  $WP = 0.46$ . The seasonalized catch curve yielded an instantaneous total mortality coefficient  $Z$  of  $1.41 \cdot y^{-1}$ . Recruitment into the population was year-round with a major peak occurring between September and November.

## Kurzfassung

### Die Dynamik einer nichtbefischten Population von *Corbula trigona* (Bivalvia: Corbulidae) in einer Brackwasserlagune, Côte d'Ivoire

In der Brackwasserlagune Tendo in Côte d'Ivoire wurde die Populationsdynamik der Muschel *Corbula trigona* untersucht. 12 Monate lang wurden die Längenhäufigkeitsdaten von insgesamt 10 971 Individuen mit Hilfe des FiSAT-Programms analysiert. Die von den Jahreszeiten abhängigen von-Bertalanffy-Wachstumsparameter errechneten sich mit  $L_{\infty} = 21,5$  mm,  $K = 0,49 \cdot a^{-1}$ ,  $C = 0,39$  und  $WP = 0,46$ . Der jahreszeitlich abhängige Fangertrag ergab eine Gesamtsterblichkeit von  $Z = 1,41 \cdot a^{-1}$ . Die Rekrutierung zur Population erfolgt das ganze Jahr über mit einem Höhepunkt zwischen September und November.

## Introduction

*Corbula* species are small bivalves which inhabit brackish water (e.g. estuaries, lagoons and lakes) in both temperate and tropical areas. Often abounding in eutrophic waters, they have an enhanced capacity to survive in highly polluted areas. *C. trigona* is a characteristic species of some West African coastal waters. Wherever it is found, it constitutes a salient ecological component and occupies an important trophic niche, filter-feeding on plankton. It is, in turn, itself preyed on by a variety of fishes some of which are economically

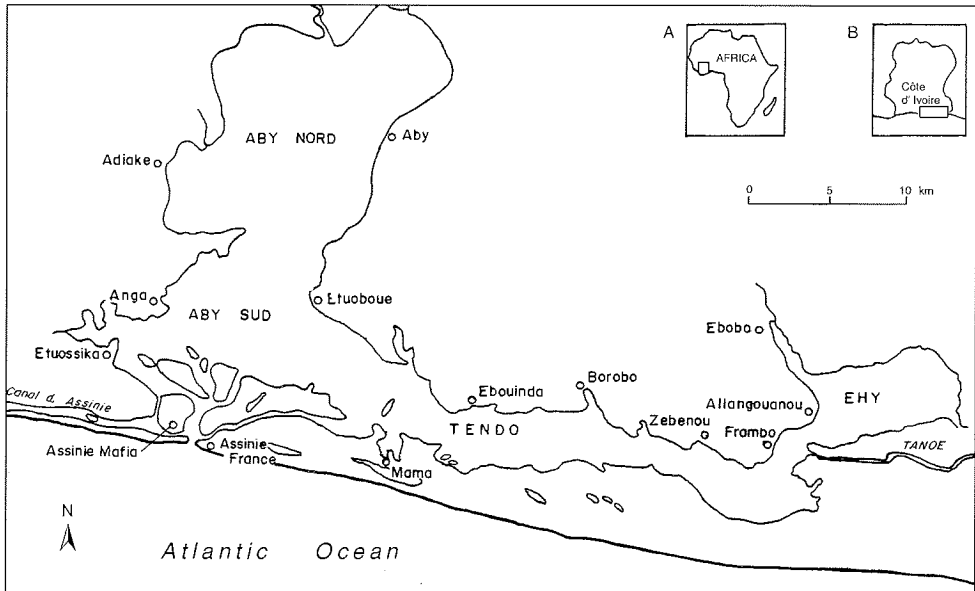


Figure 1: Map of a part of the Atlantic coast of Côte d'Ivoire showing the location of the Tendo lagoon where the samples were taken. Insert A is a map of Africa showing the location of Côte d'Ivoire (insert B).

important, e.g. *Chrysichthys nigrodigitatus*, *C. maurus*, *Tydochromis jintinki*, *Elops lacera*, *Trachionotus teraia*, and crabs, e.g. *Callinectes amniocola* (Maslin and Bouvet 1986).

In West Africa, much of the knowledge on the biology and ecology of *C. trigona* is drawn from the researches on the populations in Ebrie Lagoon in Côte d'Ivoire (Gomez 1978, 1983) and in the Aheme Lake in Benin Republic (Maslin 1986, 1989; Maslin and Bouvet 1988). This small bivalve is found throughout the Ebrie Lagoon on various substrata ranging from sandy to muddy sediments. Its bathymetric distribution in water varies from a few centimetres to 10 m. The species is euryhaline and can withstand salinities ranging from 0.5 to 30 PSU. Its salinity tolerance, does, however, vary with its geographical origin, though still remaining independent of the individual size of the specimen (Maslin 1989). *C. trigona* is able to regulate its respiratory oxygen concentration (Maslin and Bouvet 1988), which, in part, explains its ability to survive in eutrophic and highly polluted waters.

During this investigation, we studied the population dynamics of *C. trigona* as it represents an important ecological component of the Tendo Lagoon in Côte d'Ivoire. Having quantified the von Bertalanffy growth parameters and estimated instantaneous mortality rates and recruitment patterns, we compared our results with those of earlier workers on the Ebrie Lagoon, Côte d'Ivoire (Gomez 1978) populations. We obtained the results on the Ebrie Lagoon populations by extracting and re-analysing the data from the length frequency histogram of Gomez (1978) as presented in Zabi and le Loeuff (1992). The aim was to improve our knowledge on the bionomics of this ecologically important species.

## Materials and Methods

The Tendo Lagoon (Figure 1) which is located on the Atlantic Coast of Côte d'Ivoire is a shallow water with a depth of about 1.5 m. The dominant flora of its swampy banks is represented by *Myrtragyna ciliata*, *Symphonia globulifera*, *Raphaia hookeri*, and the major floating plants are *Eichhornia crassipes* and *Pistia stratiotes*.

Seasonal bottom water temperatures vary between 30 °C in April and 25 °C in January. Surface water temperature may be one or two degrees higher. Salinity is < 2 PSU during the rainy season and between 3 PSU (in the Northern part of the lagoon) and > 20 PSU (in the delta zone) during the dry season (Sankare, unpublished data). Rainfall is a climatic factor which affects the hydrology and limnology of the ecosystem in a most profound way. In Côte d'Ivoire area, there are two major climatic seasons – the rainy season and the dry season – which are further subdivided in: small rainy season (September to December), big dry season (December to May), big rainy season (June to July, and small dry season (August).

Monthly samples of *C. trigona* (taken from January to December 1995) were obtained from the Tendo Lagoon using a cylindrical PVC corer. The specimens were washed and separated from the sediments. The length of each specimen was measured by means of a pair of sliding calipers to the next millimeter. All samples were taken from "Acadja" enclosures which are locally constructed circular fish aggregating fences, constructed with bamboos.

For analysis, we used FiSAT software (Gayanilo *et al.* 1996). With the Powell-Wetherall procedure (Powell 1979, Wetherall 1986) as modified by Pauly (1986) we obtained a preliminary estimate of asymptotic length by a re-arrangement of the Beverton and Holt (1956) length-based Z equation into a linear regression model of the form:

$$\bar{L} - L' = a + bL' \quad (1)$$

where  $L$  = cut-off length *i.e.* the smallest length of fully recruited clam,  $\bar{L} = (L_{\infty} + L') / (1 + Z/K)$  = mean length of all clams  $\leq L'$ . From equation (1),  $L_{\infty} = -a/b$  and  $Z/K = -(1 + b)/b$ .

The seasonalized von Bertalanffy growth function (VBGF) put forward by Pauly and Gaschütz (1979) and later modified by Somers (1988) takes the form:

$$L_t = L_{\infty} (1 - \exp - K (t - t_0) + A - B) \quad (2)$$

where  $L_t$  = length at age  $t$ ,  $L_{\infty}$  = asymptotic length,  $K$  = growth coefficient,  $C$  = amplitude of growth oscillation,  $t_0$  = time when the length of the clam was zero,  $t_s$  = period from birth to the onset of growth oscillation,  $A = (CK/2\pi) \sin 2\pi(t - t_s)$ ,  $B = (CK/2\pi) \sin 2\pi(t_0 - t_s)$ .  $t_s$  is replaced with WP (winter point) as  $WP = t_s + 0.5$ . Expression (2) reverts to the original VBGF when seasonality is not considered, *i.e.* when  $C = 0$ . Using the ELEFAN procedure in FiSAT we fitted equation (2) to our restructured length frequency data set with  $L_{\infty}$  obtained from equation (1) serving as a seeded value.

We used the single negative exponential mortality model (equation 3) to quantify mortality regime within the population:

$$N_t = N_0 e^{-Zt} \tag{3}$$

where  $N_0$  = the initial number,  $N_t$  = the number at time  $t$  and  $Z$  = the instantaneous total mortality coefficient. Seasonalized  $Z$  from equation (3) was obtained from the following regression equation:

$$\ln(N) = a + bt' \tag{4}$$

where  $N$  = the number of clams in cohorts sliced by successive growth curves (as in Figure 2 and 3),  $t'$  = the relative age of the clams in that cohort. From equation (4),  $Z$  was estimated as  $-b$ .  $Z$  was also estimated from the method of Jones and van Zalinge (1981) as well as from the mean length of clams in the pooled sample (Beverton and Holt 1956), thus:

$$Z = [K(L_\infty - \bar{L})]/(\bar{L} - L') \tag{5}$$

where  $\bar{L}$  and  $L'$  are as defined for equation (1).

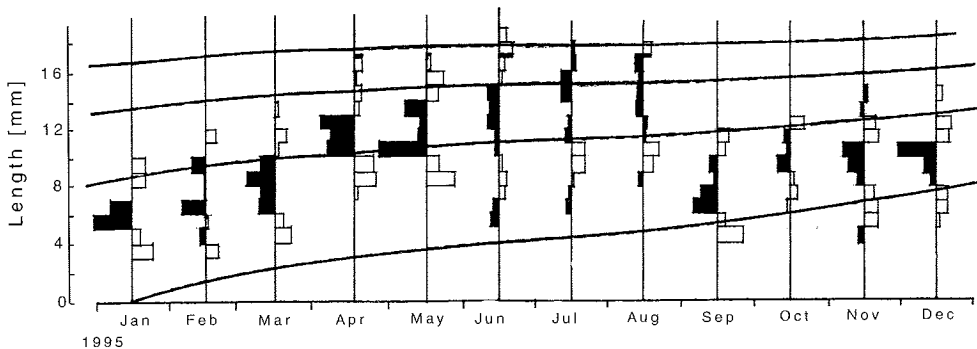


Figure 2: Seasonalized von Bertalanffy growth curves ( $L_\infty = 21.50$  mm,  $K = 0.49 \cdot y^{-1}$ ,  $C = 0.39$ ,  $WP = 0.46$ ,  $R_n = 0.189$ ) of *C. trigona* from the Tendo Lagoon. These growth curves are superimposed on restructured length frequency histograms. The black and white bars represent positive and negative deviations from a moving average of three. The black bars are pseudocohorts.

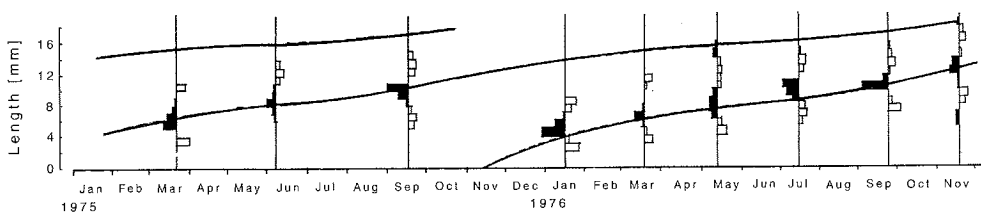


Figure 3: Seasonalized von Bertalanffy growth curves ( $L_\infty = 23.50$  mm,  $K = 0.73 \cdot y^{-1}$ ,  $C = 0.50$ ,  $WP = 0.44$ ,  $R_n = 0.80$ ) of *C. trigona* from Ebrie lagoon. These curves are superimposed on restructured length frequency histograms. The black and white bars are positive and negative deviations from a moving average of three. The black bars are pseudocohorts.

We reconstructed the seasonal recruitment pattern of the clam using the whole set of our length frequency data set. This involves projecting backward, along a trajectory defined by our computed VBGF, all the length frequency data onto a one-year time scale (Pauly 1987). Using the maximum likelihood method, we separated subsequently the normally distributed components by means of the NORMSEP (normal separation) method of Hasselblad (1966).

## Results and Discussion

There are marked differences, both in time and space, between the two sets of data used in this analysis. The data from the Ebrie Lagoon are historical ones having been collected about two decades ago. On the other hand, our data from Tendo Lagoon population are nascent, as they were collected at monthly intervals and accumulated over a period of 12 consecutive months. The Ebrie Lagoon data consist of 8 samples with unequal time intervals, spread over a period of 2 years. To compensate for the effect of this unequal time interval, we transformed the data by the square root transformation procedure given in Gayanilo *et al.* (1996). While *C. trigona* samples from the Ebrie Lagoon were collected from the open lagoon, we obtained samples of *C. trigona* from the Tendo Lagoon within "Acadja" enclosures. Despite these differences, our re-analysing of the data of Gomez (1978) from the Ebrie Lagoon and comparing with our recently collected data from the Tendo Lagoon serve heuristic and historical purposes and allows for the comparison of *C. trigona* data from such diverse settings and environments.

Asymptotic size is the largest hypothetical size a species may attain (granted it grows throughout life) in its habitat given the ecological peculiarities of that environment. It is an index whose value is influenced by several factors, *e.g.* environmental condition, sampling procedures, nature of data, *e.g.* length frequency, marked re-capture, growth annuli marks on hard parts, and on the mathematical and computing procedures used. The length frequency data obtained from the Tendo Lagoon population is given in Table 1. The analysis of these data using both the Powell-Wetherall and the ELEFAN methods yielded comparable asymptotic sizes (Table 2). Considering the values of  $K$  which is an indicator of the rate the species approaches its asymptotic size, the growth rate of both populations are different. Ebrie Lagoon population exhibits a high  $K$  value of  $0.73 \cdot y^{-1}$  while the Tendo Lagoon population exhibits a moderate growth rate with  $K = 0.49 \cdot y^{-1}$ . The Aheme Lake population with  $K = 0.3377 \cdot y^{-1}$  (Maslin 1986) has the slowest growth rate. In Lake Aheme, Maslin (1986) observed spatio-temporal differences in growth rate of *C. trigona* and attributed it to variations in salinity.

Though direct comparison of growth coefficients may be mathematically feasible it is not plausible in biological respect as growth curves of fishes and aquatic invertebrates do not occur in a linear way. One stock may grow old faster than another when young, and slower than the other when old. This implicates that comparison of growth curves must take into consideration both the asymptotic size ( $L_{\infty}$ ) and growth rate ( $K$ ) simultaneously. The growth performance index  $\phi'$  ( $= 2 \log L_{\infty} + \log K$ ) (Pauly and Munro 1984) does meet these criteria. Additionally,  $\phi'$  seems preferable as it displays the least variance when compared

Table 1: Length frequency data of *Corbula trigona* collected from January to December 1995 in the Tendo Lagoon, Côte d'Ivoire. N = 10 971. ML = mid length of class interval in mm.

ML	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.45	30	26										
4.45	100	110	15						14		17	
5.45	351	122	45			14			85		10	15
6.45	276	25	150			15	15		243	60	25	27
7.45	150	155	174	6		15	15		250	65	50	49
8.45	49	150	247	11	9	21	15	9	176	105	145	147
9.45	24	147	157	21	54	46	15	9	149	200	186	185
10.45		75	76	155	285	89	26	10	59	151	203	285
11.45		30	30	160	171	121	109	54	29	150	49	65
12.45		24	26	202	162	165	144	74		30	39	44
13.45		11	10	75	150	160	155	149			29	31
14.45				49	43	144	205	161			15	14
15.45				30	17	79	200	150				
16.45				15	11	44	99	145				
17.45				10		10	75	60				
18.45						8	45	56				
Sum	980	1103	930	734	902	931	1118	877	1005	761	768	862

with alternative indices, e.g.  $\omega = K \cdot L_{\infty}$  (Moreau *et al.*, 1986). In descending orders of magnitudes, our computed overall growth performance indices are 0.61 in the Ebrie Lagoon, 0.36 in the Tendo Lagoon and 0.33 in the Aheme Lake.

Maslin (1986) often observed a high mortality in all age groups among the *Corbula* populations of the Aheme Lake, especially in the dry season when salinity is very high, particularly in the southern part of the lake. The Z values from our seasonalized length converted catch curve showed that mortality in the Tendo Lagoon was lower than that of the Ebrie Lagoon population (Table 2, Figure 4). For each lagoon population, the seasonalized catch curve produced a lower Z value than the Jones and van Zalinge method. However, the Z values from seasonalized catch curves were comparable to Z from the Beverton and Holt (1956) method. Both the Beverton and Holt model and the Jones and van Zalinge methods are based on length. Like other length-based methods for Z estimation, they assume equilibrium (steady-state) age composition together with constant mortality with age and time and constant recruitment. There are scarcely any populations that meet these conditions. Thus, the Z value is often overestimated in length-based methods. Such bias may be very high in animals whose values of C (in equation 2) are high and close

*Dynamics of unexploited Corbula trigona in Côte d'Ivoire*

Table 2: Growth and mortality estimates for *C. trigona* in Tendo and Ebrie Lagoons. Z(cc) = Z estimated from length-converted catch curve, Z (BH) = Z from Beverton and Holt method, Z(JV) = Z from the Jones and van Zalinge method.

	Powell-Wetherall Plot		ELEFAN analysis				Z estimation		
	$L_{\infty}$	Z/K	$L_{\infty}$	K	C	WP	Z(cc)	Z (BH)	Z(JV)
Tendo	19.52	2.258	21.5	0.49	0.3	0.46	1.41	1.546	3.301
Ebrie	21.593	5.282	23.5	0.73	0.5	0.4	5.45	4.199	6.99

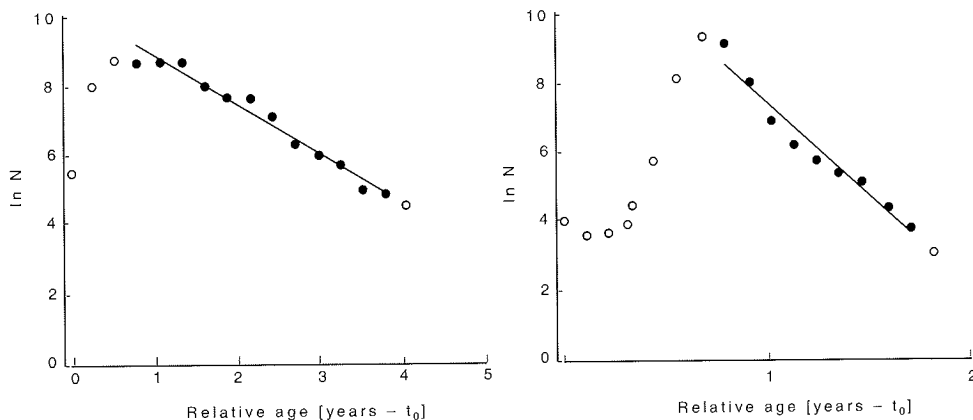


Figure 4: Left: seasonalized length-converted catch curve of *C. trigona* in the Tendo lagoon. Y-intercept  $a = 10.279$ ,  $sd = 0.208$ , confidence interval = 9.815 to 10.743; slope  $b = -1.411$ ,  $sd = 0.0835$ , confidence interval = 1.225 to  $-1.597$ ;  $r = -0.983$ ;  $n = 12$ . Right: Seasonalized length converted catch curve of *C. trigona* in the Ebrie Lagoon. Y-intercept  $a = 12.851$ ,  $sd = 0.535$ , confidence interval = 11.584 to 14.119; slope  $b = -5.45$ ,  $sd = 0.417$ , confidence interval = 6.44 to  $-4.465$ ;  $r = -0.980$ ;  $n = 9$ .

to unity (Pauly *et al.* 1995). Although the computation of Z from these length-based methods entails pooling together all the length frequency data to simulate an equilibrium (steady-state) condition, Pauly (1990) and Pauly *et al.* (1995) showed that they still overestimated Z by a margin that could be as large as 180 %. On the contrary, seasonalized length-converted catch curves produce Z values which are similar to age-structured catch curves (Pauly *et al.* 1995). Age structured catch curves are unbiased as growth in age is not affected by season. Within this context, we assume that our seasonalized value of Z is not biased. In this work, the Jones and van Zalinge method overestimated Z in Tendo Lagoon population of *C. trigona* by about 134 % while that for Ebrie population is biased upward by about 44 %.

The  $Z/K$  ratio, as obtained from the Powell-Wetherall plot, is useful in ascertaining the relative importance and quantifying the interplay between mortality and growth in any population both exploited and unexploited. If  $Z/K < 1$ , the population is dominated by growth; if  $Z/K > 1$ , the population is dominated by mortality; if  $Z/K = 1$ , mortality balances growth in that population (Barry and Tegner 1989). The  $Z/K$  ratios in Table 2 show that the Tendo and Ebrie Lagoon populations of *C. trigona* were dominated by mortality; and Ebrie population is much more so than the Tendo population.

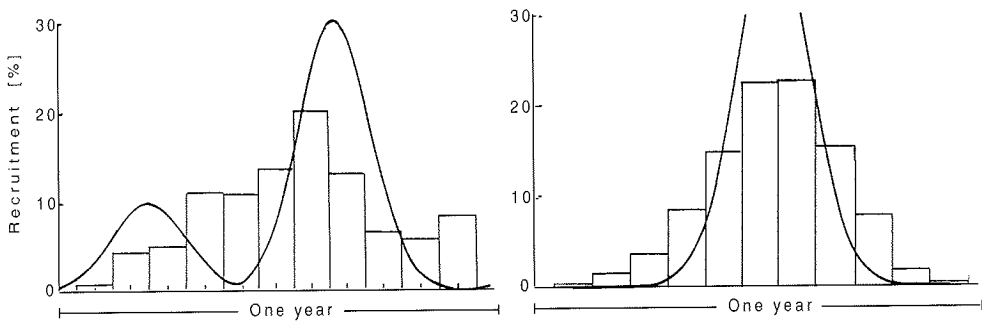


Figure 5: Recruitment pattern of *C. trigona* from the Tendo lagoon (Left) and Ebrie lagoon (Right) obtained by backward projection of the length frequency data onto a one-year time scale. The trajectory of projection was defined by the VBGFs from Figure 2 and Figure 3, respectively. Likelihood ratio procedure was used in the normal separation (NORMSEP) into Gaussian components using the method of Hasselblad (1966).

Figure 5 shows the recruitment patterns of *C. trigona* into both lagoons. In the Tendo Lagoon, there was a major and a minor peak of recruitment in the population. Both overlapped in time and spread throughout the year. From Table 1 and Figure 2, the major recruitment peak occurred between January to March and the smaller pulse of recruitment occurred in September, November and December. Figure 5 shows that there was one pulse of recruitment in Ebrie Lagoon, and from Figure 3 the temporal occurrence of this peak was in January. Gomez (1978, 1983) reported that in Ebrie Lagoon, *Corbula* larvae appear in plankton from September to November and stay there for another two months. Normally, reproductive period is succeeded by the period of larvae appearing in plankton and is in turn succeeded by the period when young adults are recruited into the population. This means that the larvae which appeared in plankton in September must have been spawned during the previous period which was a rainy season. In the tropics, seasonal patterns of reproduction in aquatic animals are usually linked to patterns of rainfall, directly affecting salinity. In Lake Aheme, there is a spatial variation in the reproduction patterns of *C. trigona*. According to Maslin and Bouvet (1986) the population in the northern part of the lake reproduces year-round with a peak in the rainy season. The population in the Southern part of the lake reproduces exclusively during the rainy season.



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