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# Growth and mortality of the exploited mangrove crab *Ucides cordatus* (Ucididae) in N-Brazil

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ABSTRACT

Reliable estimates of growth and mortality parameters are crucial for understanding how populations of exploited species may respond to shifts in fishing pressure. Results of previous studies on growth of the ecologically and economically important mangrove crab *Ucides cordatus* in Brazil differ strongly and age estimates for minimum legal capture size (60 mm carapace width) range between less than 1 and 6–10 years. These discrepancies are probably due to inherent problems of the applied methods, namely laboratory based observations and cohort-analyses. The present paper takes a new approach by measuring individual growth increments of *U. cordatus* in situ. Crabs were measured, tagged, released into 100 m² field enclosures and periodically recaptured. There was no indication of an enclosure effect and 209 growth increments were obtained from specimens measuring 20.5 to 89.5 mm in carapace width (CW). For improving the size coverage of the von Bertalanffy growth curve, first instar juveniles were reared in the laboratory up to an age of six months. Their average percent size increase (PI) was 22.57 ± 6.75% during biweekly measurements, resulting in a CW of 7.8 to 11.5 mm after six months. Average PI of the enclosure crabs ranged between 10.87 ± 1.17% (indiv.<40 mm CW) and 1.43 ± 0.87% (indiv.>80 mm CW) per moult and two large females had moulted without growing. Growth analysis revealed a larger asymptotic size in males than in females (89 mm versus 72 mm) while the growth parameter K of the von Bertalanffy growth function (VBGF) was lower in males (0.17 versus 0.25), resulting in similar growth performance of the two sexes (males: 1.16; females: 1.10). Age at legal minimum capture size estimated by the inversed VBGF was 6.13 years in males and 7.38 years in females, corroborating the mid to upper range of earlier growth estimates. Mortality parameters (Z, M and F) were calculated using length converted catch curves. Z in males was higher than in females (0.69 versus 0.49), as expected from the male-biased fishery. M, F and the exploitation rate E were estimated for three different scenarios taking into account the uncertainty of the age/size of functional maturity. Our study provides key information for the sustainable management of the *U. cordatus* fishery and confirms that the species is relatively slow growing and long-lived (>10 years), suggesting a high vulnerability to overfishing.



## 1. Introduction

Knowledge of growth and mortality parameters is fundamental to understand how exploited species respond to fishery and how a shift in fishing pressure may affect populations and ecological performances. This paper aims at determining growth and mortality parameters for the mangrove crab *Ucides cordatus cordatus* (hereafter referred to as *U. cordatus*) in N-Brazil. This large species (carapace width, CW: males >90 mm; females >70 mm) is the main leaf litter feeder in Brazilian mangroves and plays an important ecological role by processing up to 81% of the litter production in some areas (Nordhaus et al., 2006). Artisanal fishermen have been harvesting *U. cordatus* for decades along the Brazilian coast, and in recent years several crab populations have experienced strong declines due to deforestation, a fungal disease and overfishing (Nordi, 1994; Botelho et al., 2000; Alves et al., 2005; Boeger et al., 2007). The fishery targets mostly large males and in some areas yields are still 6 to 8 tons/km²/year (e.g. Caeté estuary, N-Brazil, Diele and Simith 2007, calculated after Araújo 2006; Diele et al., 2010). The current national minimum legal capture size (MLCS) is 60 mm CW (IBAMA N° 034/03-N, 24.06.2003).

To our knowledge, no comprehensive fishery-independant data on mortality parameters of *U. cordatus* have been published as yet. While several studies investigated the growth of the species, large discrepancies exist among measured growth rates. Extrapolations from juvenile growth studied in the laboratory indicate that the species is slow growing, with an age of 6 to 10 years at 60 mm MLCS (Geraldes and de Calventi, 1983; Ostrensky et al., 1995). Cohort-studies from NE-Brazil based upon size-frequency distributions of field-sampled specimens contradict these estimates. They indicate a manifold faster growth of *U. cordatus* with less than a year of age at 60 mm MLCS (Ivo et al., 1999; Vasconcelos et al., 1999; Monteiro and Coelho-Filho, 2000). Pinheiro et al. (2005) also applied cohort-

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analyses, but derived almost five folds higher age estimates at 60 mm MLCS for a southern Brazilian crab population compared to the NE-Brazilian cohort-studies. The large differences among the published growth estimates suggest that methodological problems inherent to cohort-analyses rather than biogeographic differences may be the cause: according to Hartnoll (1982), it is improbable that year classes can be reliably discriminated in later growth of large long-lived crustaceans, where clearly distinguishable cohorts are generally lacking, thus complicating growth analyses. This could well be the case in *U. cordatus*, where all cohort-analyses were based upon size-frequency in which larger specimens were more frequent than smaller ones. Laboratory growth studies (see above) on the other hand, may not adequately represent the growth performance of free-living crabs. Clearly, the strongly diverging growth estimates so far available for *U. cordatus* would result in completely different management scenarios of this ecologically and economically important species. Therefore alternative methods are needed to help estimate the species' growth more reliably.

Here we take a new approach by calculating growth parameters of *U. cordatus* from direct size increment measurements of a wide range of different sized crabs in the field. Data were obtained from tagged and recaptured specimens that were kept in 100 m² enclosures in a N-Brazilian *Rhizophora mangle* dominated forest stand. In addition to these field studies, growth of first instar crabs up to an age of six months was monitored in the laboratory to ensure good coverage of the whole growth curve. Mortality parameters (Z, M and F) were estimated using length converted catch curves derived from the calculated growth parameters and population census data (Diele et al., 2005). Furthermore the exploitation rate (E) of the males was estimated. We compare our results with previous studies and provide important information for the sustainable management of the fishery of *U. cordatus*.

## 2. Material and methods

### 2.1. Study area

The study area is located in northern Brazil, where approx. 65% of the countries' mangrove forests occur. Field experiments were performed in a *R. mangle* dominated mangrove stand in the northern part of Bragança peninsula, Caeté estuary (W 46° 76′–W 46°52′and S 0°80′–S1°07′). The region experiences semidiurnal macro-tides with an amplitude of up to 5 m. Rainfall is approx. 2500 mm/year, mostly falling between January and June, in the rainy season. Average air (24–28 °C) and water (27–30 °C) temperatures vary little over the year (INMET, 1992; unpublished data of the research project "Mangrove Dynamics and Management", MADAM). *U. cordatus* is artisanally fished year round in the study area (Diele et al., 2005, 2010).

### 2.2. Growth studies

A combination of laboratory studies (focussing on first instar crabs) and field studies (focussing on larger/older crabs) was used to obtain growth estimates for specimens of a wide size range.

#### 2.2.1. Laboratory experiments

The growth of seven first instar crabs cultivated from field captured megalopae that had metamorphosed in the laboratory (day of metamorphosis = age 0) was monitored for 16 to 28 weeks in 1998 (size of first instars between 1.37 and 1.55 mm CW). The crabs were kept under ambient light (12 h light/12 h dark) and temperature conditions (26.0 ± 1.3 °C) in a shaded outdoor laboratory at the University of Bragança (UFPa). Each crab was placed in a 500 ml plastic container filled to one side with mangrove sediment and to the other side with estuarine water. The sediment contained infauna, such as the abundant capitellid polychaete *Notomastus lobatus*, that served as a food source. *R. mangle* leaf litter and shredded particles thereof were placed on the sediment surface as additional food. When crabs had reached a size of approx. 3 mm CW, they were transferred to individual 10 l buckets filled two thirds with mangrove sediment and one third with estuarine water. Water was changed every second day. Approx. every two weeks the sediment was carefully sieved and the crabs' carapace width measured to the nearest 0.1 mm under a dissection microscope. Growth increment was calculated by comparing the CWs between subsequent measurements. Due to the small size of the juveniles, their sex was not determined. For reducing mortality, sieving was postponed when burrow entrances were plugged (as an indicator of moulting activities) and crabs thus possibly soft-shelled. Sieving was only performed the day after a closed burrow had been re-opened by the inhabitant to ensure that the crabs' integuments had hardened.

#### 2.2.2. Field experiments

For obtaining growth increment data from free-living crabs, 125 larger burrows plugged over several days, abundant during the dry season, were excavated. According to local fishermen, such burrows are typically occupied by moulting crabs. Seasonal moulting, at least in larger *U. cordatus* specimens, is also known from other areas in Brazil (Nascimento, 1993) while the crabs reproduce during the rainy season only (Alves, 1975; Castro, 1986; Diele et al., 2005). The excavated burrows were carefully searched for recently moulted crabs and their exuviae. Only in five cases (three males, two females) were sufficient parts of the old exoskeleton found to allow reconstruction of the pre-moult size and to compare it with the new size of the already hardened crab. Due to the low success rate of the above approach, several in situ capture–recapture experiments were conducted between 1997 and 2000/2001, with crabs kept in 100 $m^2$ field enclosures. The enclosures were erected in a *R. mangle* dominated mangrove stand, the favoured habitat type of the crabs. Enclosure walls were made of interlocking wooden (1997 and 1998) or PVC laths (1999–2000/2001, see Fig. 1) that reached 1.0 to 1.2 m into the sediment and measured 1.5 m above the surface. Every 10 cm, 15 mm holes were drilled into the walls to allow for unimpeded water flow. Food for the enclosed crabs was provided by natural litter falling from the *R. mangle* canopy above, as well as by younger *R. mangle* trees planted inside the enclosure. Behavioural observations of free-living crabs have shown that *U. cordatus* is very territorial and does not move far away from its burrows during foraging (average: 19 cm, max: 1 m; Nordhaus et al., 2009). Daily *R. mangle* leaf litter fall in the forest was approx. 3 g DW $m^{-1}$ (Nordhaus et al., 2006).

To facilitate recapture, the enclosures were subdivided into one 75 m² compartment for larger specimens and two 12.5 m² compartments for smaller crabs (Fig. 1). Several runs of capture–recapture experiments were performed between 1997 and 2000/2001 (Tables 1

**Fig. 1.** 100 m² PVC field enclosure for *U. cordatus* capture–recapture experiments in mangroves of Bragança peninsula, N-Brazil. The enclosure comprises one 75 m² and two 12.5 m² compartments. See text for explanations.