UNIVERSIDADE ESTADUAL PAULISTA
INSTITUTO DE BIOCIÊNCIAS DE BOTUCATU
CURSO DE PÓS-GRADUAÇÃO EM CIÊNCIAS BIOLÓGICAS
ÁREA DE CONCENTRAÇÃO - ZOOLOGIA

DOUTORADO

DINÂMICA POPULACIONAL DO CAMARÃO PEDRA *SICYONIA TYPICA* (BOECK, 1864) (PENAEOIDEA: SICYONIIDAE) NO LITORAL NORTE DO ESTADO DE SÃO PAULO

Bruno Gabriel Nunes Pralon

Orientadora: Drª. Maria Lucia Negreiros-Fransozo
Co-orientador: Dr. Antônio Leão Castilho

Botucatu – São Paulo
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1. Camarão - Reprodução. 2. Camarão - População.

Palavras-chave: Decapoda; Fauna acompanhante; Recrutamento; Reprodução.

“A ignorância gera confiança com mais frequência do que o conhecimento: são aqueles que sabem pouco, e não aqueles que sabem muito, que tão positivamente afirmam que esse ou aquele problema jamais será resolvido pela Ciência.” Charles Darwin

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RESUMO

O estado atual do conhecimento sobre a dinâmica populacional de espécies de invertebrados, que ocorrem ao longo da costa brasileira, pode ser considerado ainda pouco significativo. Estudos ecológicos envolvendo crustáceos decápodos marinhos são importantes para a manutenção e preservação das espécies, sejam elas exploradas pela pesca de arrasto, ou ainda, aquelas que são capturadas como fauna acompanhante de tal atividade. Deste modo, este trabalho analisou a dinâmica populacional do camarão-pedra *Sicyonia typica*, enfocando a distribuição espaço-temporal, a estrutura populacional e os padrões reprodutivos, em Ubatuba, e Caraguatatuba, litoral norte do Estado de São Paulo. Os camarões e os fatores abióticos foram coletados mensalmente de janeiro de 1998 a junho de 2003, em estações de amostragem estabelecidas em diversas profundidades. No entanto, os dados provenientes de 5,5 anos de coleta foram utilizados apenas nas análises do primeiro capítulo, o qual abordou a biologia reprodutiva desta espécie. Para estas coletas, utilizou-se um barco camaroeiro equipado com redes de arrasto para a captura dos camarões, uma garrafa de Nansen (água) e um coletor de sedimento tipo Van Veen para as coletas dos fatores ambientais (temperatura e salinidade da água, textura e concentração de matéria orgânica do sedimento). De modo geral, as fêmeas de *S. typica* atingiram tamanhos maiores que machos, evidenciando um dimorfismo sexual relacionado ao tamanho corpóreo. A atividade reprodutiva quase que constante ao longo do ano, mas com um pico reprodutivo em certo período (inverno) é uma tendência que indica que a população segue um padrão de reprodução característico de regiões tropicais/subtropicais. O tipo de sedimento, a temperatura e salinidade de fundo estão entre as mais importantes variáveis que afetam a distribuição ecológica de *S. typica* na região estudada. Os parâmetros de crescimento de von Bertalanffy foram estimados apenas para as fêmeas (CL_∞ = 17,29; K = 0,0125; t_0 = - 0,167 e longevidade = 1,01 ano) e foram similares aos de outras espécies de camarões do gênero *Sicyonia*. Uma possível migração de indivíduos adultos durante determinadas épocas do ano pode ocorrer. No entanto, investigações mais detalhadas são necessárias para confirmar que esta espécie realmente se move para encontrar melhores condições e quais fatores induzem estes possíveis movimentos.

PALAVRAS-CHAVE: Decapoda, reprodução, recrutamento, fauna acompanhante.

CONSIDERAÇÕES INICIAIS

Ambientes complexos e elevada diversidade de espécies pertencentes a vários grupos taxonômicos são características comuns dos ecossistemas tropicais e subtropicais, sejam terrestres ou aquáticos (Wilson, 1988). Em ecossistemas aquáticos, do ponto de vista biológico, o conhecimento das espécies de uma comunidade ou ecossistema é a base para se entender o funcionamento do ambiente, permitindo, desta maneira, detectar se o desaparecimento de determinadas espécies (devido à perda de habitat ou pesca predatória, por exemplo) ou a presença de espécies exóticas ou introduzidas irão influenciar a dinâmica das comunidades a médio e em longo prazo (Colloca e*t al.*, 2003).

Dentre os organismos que compõem ecossistemas aquáticos, a megafauna bentônica exerce um importante papel estruturando comunidades por completo ao realizarem interações de predação e competição, além da bioturbação do sedimento superficial, entre outras (de Leo & Pires-Vanin, 2006). A macrofauna bentônica também compreende um importante recurso para a pesca mundial, especialmente em regiões de elevada produtividade das águas pelágicas (Pauly *et. al.* 2002). Dentre a fauna que vive associada aos leitos dos ambientes aquáticos, os Crustacea (Brunnich, 1772) Decapoda, (Latreille, 1802) compreendem um grupo de animais extremamente explorado pela pesca ao redor do mundo (Kyomo, 1999). Pode se resumir a pesca de crustáceos à captura de lagostas, caranguejos e camarões. No entanto, sem dúvida os camarões são os mais importantes invertebrados pescados, chegando a atingir cerca de 98 % da produção (FAO, 2009). Portanto, crustáceos são uma importante fonte de alimento para o homem e outros animais. As espécies de crustáceos de menor porte se alimentam de produtores primários muitas vezes e servem de alimento para predadores um pouco maiores, enquanto que as espécies que atingem tamanhos maiores tem alta importância econômica para os humanos (Branco, 2005).

Todos as espécies de camarões (aproximadamente 4019) podem ser divididas em 4 grandes grupos nomeadamente os Sergestoidea Dana, 1852 (cerca de 114 espécies), os Penaeoidea (Bate, 1888) (cerca de 524 espécies), os Stenopodidae Bate, 1888 (cerca de 71 espécies) e os Caridea Dana 1852 (pelo menos 3310 espécies) (De Grave *et al.* 2009). A superfamília Penaeoidea constitui, junto com os Sergestoidea, a subordem Dendrobranchiata Bate, 1888, por apresentarem brânquias do tipo dendríticas, presença de petasma nos machos e pela ausência de cuidado parental com fêmeas não incubando seus ovos. Holthuis (1980) listou as espécies de Dendrobranchiata que são de interesse para a pesca e as agrupou como aquelas que são largamente utilizadas para o consumo humano, aquelas que constituem a fauna acompanhante derivada da pesca de outras espécies-alvo e aquelas espécies que não são exploradas comercialmente, porém são consideradas por especialistas com potencial para se tornarem espécie-alvo valiosas comercialmente.

Dentre os Dendrobranchiata, a superfamília Penaeoidea é conhecida por apresentar várias espécies de camarões que constituem importantes recursos pesqueiros e para a Aquicultura. Entre os Penaeoidea, os camarões Peneídeos (Penaeidae Rafinesque, 1815) representam a maioria das capturas mundiais de camarões, enquanto representantes de outras famílias como Sicyoniidae Ortman, 1898 e Solenoceridae Wood-Mason & Alcock, 1891 são mais raros nas embarcações pesqueiras (D’Incao, 1995). De 1970 a 2000 os camarões Peneídeos foram os camarões mais capturados representando 42,2% da captura mundial de camarões (FAO, 2009). Segundo Reis & D’Incao (2000) as capturas de camarões na costa Sul-Sudeste do Brasil diminuíram de modo considerável nos anos noventa, quando comparadas às capturas nos anos setenta, possivelmente, devido à diminuição dos estoques oceânicos pelo excessivo esforço de captura. O arrasto de fundo é o método de captura responsável pela maior parcela da produção anual de animais demersais nas regiões sudeste e sul do Brasil e estimativas recentes têm indicado, que essa pescaria se encontra em situação crítica, já que os estoques de peixes demersais e camarões que a sustentava estão plenamente explotados ou sobre-explotados (Haimovici & Habiaga 1982; Valentini *et al.*, 1991). Superdimensionadas, as frotas de ‘arrasteiros’ têm buscado sua sustentação através do aproveitamento de espécies acompanhantes, da diversificação de alvos e da expansão de áreas de atuação.

Os leitos oceânicos ao largo da região norte do Estado de São Paulo são intensivamente explorados por redes de arrasto para pesca comercial e artesanal em diferentes profundidades. Neste contexto, analisar os componentes dos ecossistemas ao longo do espaço e tempo pode ser uma ferramenta útil para investigar os efeitos diretos e indiretos da pesca (Gasalla & Rossi-Wongtschowski, 2004).

Na região de Ubatuba, a pesca do camarão é voltada principalmente sobre os estoques de camarão sete-barbas *Xiphopenaeus kroyeri* (Heller, 1862), dos camarões-rosa *Farfantepenaues brasiliensis* (Latreille, 1817) e *Farfantepenaeus paulensis* (Pérez-Farfante, 1967) e do camarão branco *Litopenaeus schmitti* (Burkenroad, 1936), todos pertencentes à família Penaeidae (Costa *et al.* 2005). Como resultado desse esforço de pesca na região, uma fauna acompanhante diversificada é também capturada constantemente nas embarcações. A fauna acompanhante, ou o termo anglo-saxão "*by-catch*", se refere ao conjunto de organismos de outras espécies que são capturados junto às espécies alvo da pesca e que geralmente são rejeitados junto com indivíduos das espécies alvo que não atingiram o tamanho comercial ou são devolvidos ao mar (Robert *et al.* 2007). A pesca efetuada por barcos providos com redes de arrasto com portas captura acidentalmente uma enorme quantidade de organismos bentônicos que compartilham o mesmo ambiente das espécies comercialmente procuradas (Fonseca *et al.* 2005). Um importante componente dessa fauna acompanhante nos desembarques da frota pesqueira de camarões do litoral norte de São Paulo são os camarões pertencentes à família Sicyoniidae Ortmann, 1898, conhecidos popularmente como camarões-pedra (Costa, 2002).

A família Sicyoniidae é composta por um único gênero e 52 espécies descritas no mundo até o momento (De Grave *et al.* 2009). São representados na costa brasileira por 6 espécies (D'Incao 1995): *Sicyonia burkenroadi* Cobb 1971, *Sicyonia dorsalis* Kingsley 1878, *Sicyonia laevigata* Stimpson 1871, *Sicyonia olgae* Pérez Farfante 1980, *Sicyonia parri* (Burkenroad 1934) e *Sicyonia typica* (Boeck 1864) (figura 1). Entre essas espécies, 4 ocorrem na região sudeste do Brasil: *S. dorsalis*, *S. laevigata*, *S. parri* e *S. typica* (Costa *et al.* 2000), sendo esta última encontrada no Atlântico Ocidental, dos Estados

Unidos (Carolina do Norte) até o Brasil (Amapá até o Rio Grande do Sul), e em águas rasas até 100 metros de profundidade (Costa *et al.* 2003). Os Sicionídeos quase não são pescados comercialmente no mundo, apesar de o camarão-pedra do mediterrâneo *Sicyonia carinata* Brunnich 1768, ser bastante saboroso, embora a rígida carapaça seja um empecilho para a sua venda e *Sicyonia bevirostris* Stimpson, 1871 ter alguma importância comercial na região noroeste do oceano Atlântico (Tavares & Martin, 2009). As espécies de camarões-pedra não são exploradas comercialmente no Brasil devido ao pequeno tamanho e rigidez da carapaça, porém, como já mencionado, pertencem à fauna acompanhante da pesca de arrasto (atividade não seletiva) de espécies comerciais. Entre os camarões Sicionídeos, *S. dorsalis* representa a maior porcentagem de captura anual, seguida de *S. typica* na região de Ubatuba (Costa, 2002). Vários autores relataram a ocorrência de *Sicyonia* spp na pesca de arrasto de espécies com valor comercial (Graça Lopes *et al.* 2002; Severino-Rodrigues *et al.* 2002, 2007).

Além da pesca predatória, crescem também as populações humanas habitando as linhas de costa o que corresponde a um aumento dos impactos antropogênicos nas comunidades naturais de invertebrados associadas a estes ambientes (Castilho *et al.* 2008a). Talvez a principal consequência negativa das ações humanas seja a desestruturação da comunidade marinha, o que ocasiona alterações em cadeia, muitas das vezes irreparáveis (Mantelatto & Fransozo, 1998). Conseguir informações acuradas e periódicas sobre espécies que compõem as comunidades bentônicas é, dessa forma, algo urgente e necessário para o manejo e conservação adequada dos ecossistemas costeiros (Bertness, 1999). O declínio do estoque de camarões marinhos, seja pelo esforço de pesca excessivo, seja pela degradação de habitat, prejudica as demais comunidades marinhas, pois esses animais viabilizam uma importante concentração de energia para os demais níveis tróficos ao extraírem uma variedade de recursos alimentares (bactérias, protozoários, diatomáceas, fungos, meiofauna, e matéria orgânica), quando processam um grande volume do sedimento (Bertness 1999). Por isso, é necessário conhecer a ecologia e a dinâmica populacional de espécies que são capturadas pelos apetrechos de pesca, para que os recursos pesqueiros sejam explorados de forma racional.

Além disso, a comparação de dados entre períodos distintos de coleta na mesma região permite a identificação e avaliação de possíveis alterações ocorridas, tanto nas condições físico-químicas do ambiente, quanto nos padrões estruturais das populações em uma região.

Os estudos relacionados à biologia e ecologia de crustáceos na região norte do Estado de São Paulo iniciaram-se em Ubatuba com os pesquisadores do NEBECC (Núcleo de Estudos em Biologia, Ecologia e Cultivo de Crustáceos), no ano de 1988 na Enseada da Fortaleza, tendo gerado diversos trabalhos relevantes (Fransozo *et al.* 1991, 2000, 2002, 2004; Negreiros-Fransozo *et al.* 1991, 1997; Pinheiro *et al.* 1994, 1997; Santos *et al.* 1994, 1995; Mantelatto *et al.* 1995, 2005; Negreiros-Fransozo & Fransozo 1995). Entre esses estudos, poucos foram relacionados aos camarões Penaeoidea, podendo destacar Fransozo *et al.* (2002, 2004). Posteriormente, foram efetuados estudos comparativos entre enseadas na região de Ubatuba (Ubatumirim, Ubatuba e Mar Virado), com o objetivo de analisar se a variação ambiental em enseadas próximas proporcionaria uma diversificação na seleção por habitat dos camarões marinhos (Costa 2002; Costa *et al.* 2004, 2005, 2007). A partir de 2001, o grupo ampliou seu espaço de estudo para outras regiões do litoral paulista desenvolvendo um projeto maior conhecido como BIOTA-FAPESP (98/07090-3), cujo um dos objetivos era a elaboração de um levantamento sobre a biodiversidade dos Decapoda, em três regiões do litoral norte do estado de São Paulo (Ubatuba, Caraguatatuba e São Sebastião), com características ambientais distintas espaço-temporalmente, o qual foi obtido com êxito.

A maioria das informações sobre a biologia de *Sicyonia* sp são baseados nos estudos realizados no hemisfério norte, podendo destacar os trabalhos relevantes de Kennedy *et al.* (1977), Bauer (1992ab, 1996ab) e Anderson *et al.* (1985) sobre aspectos reprodutivos. Já na costa brasileira, os estudos biológicos referentes à família Sicyoniidae são raros, sendo possível mencionar trabalhos sobre registros taxonômicos e biogeográficos (D'Incao 1995), distribuição ecológica (Costa *et al.* 2005; Castilho *et al.* 2008a) e biologia reprodutiva (Castilho *et al.* 2008b), todos referentes à *S. dorsalis*, sendo inexistentes trabalhos com a espécie *S. typica*. Foram realizados também, estudos sobre composição (Fransozo *et al.* 2002), ocorrência (Costa *et al.* 2000) e comunidade (Castilho *et al.* 2008c) de camarões Penaeoidea na região de Ubatuba, os quais apenas citam a ocorrência de *S. typica*.

Dinâmica populacional

Um dos objetivos em estudos sobre ecologia reprodutiva de invertebrados bentônicos é propor e testar generalizações sobre variação latitudinal em padrões de reprodução e recrutamento das espécies (Bauer, 1992a). O “paradigma do efeito latitudinal” sobre os camarões Penaeoidea é proposto por vários autores (Bauer 1992b; Bauer & Rivera Vega 1992; Boschi 1997; Gavio & Boschi 2004; Costa & Fransozo 2004b; Castilho 2004; Castilho *et al.* 2007ab; Castilho 2008b). Tal paradigma é usualmente utilizado para formular hipóteses sobre estímulos ambientais específicos (fatores proximais) e pressões seletivas (fatores finais) que agiriam nos padrões de desova e de recrutamento de juvenis, podendo avaliar se as variações em tais padrões seriam respostas das alterações ambientais em cada gradiente latitudinal ou das ações antrópicas.

Apesar de estudos sobre biologia reprodutiva de crustáceos serem bastante numerosos, trabalhos sobre dinâmica populacional de camarões marinhos são relativamente raros. Os poucos trabalhos existentes para o litoral norte paulista enfocam a estrutura populacional e a biologia reprodutiva de *X. kroyeri* (Nakagaki & Negreiros-Fransozo 1998; Castro *et al*. 2005), *Artemesia longinaris* Bate 1888 (Castilho *et al*. 2007ab), *Pleoticus muelleri* (Bate 1888) (Castilho *et al.* 2008b), *Rimapenaeus constrictus* (Stimpson 1874) (Costa & Fransozo 2004ab) e *Sicyonia dorsalis* (Castilho *et al.* 2008c).

Vários aspectos abordados nesta tese estão relacionados com os estudos sobre biologia populacional, tais como: distribuição da freqüência de tamanho dos indivíduos, razão sexual, variação sazonal da estrutura populacional, determinação do espaço e do período de desova de fêmeas e recrutamento de juvenis. O conhecimento sobre a dinâmica populacional de cada espécie capturada diretamente ou acidentalmente pela pesca camaroneira, serviria de subsídio para a implantação de alternativas para uma pesca racional e sustentável. Apenas assim, seria possível preservar o equilíbrio da comunidade como um todo, tanto dos camarões marinhos quanto dos demais integrantes da biota marinha.

No primeiro capítulo da presente tese, foi realizado o estudo da biologia reprodutiva de *Sicyonia typica* ao longo de 5,5 anos sobre a plataforma continental ao largo do litoral norte paulista, bem como as comparações de aspectos reprodutivos dessa população com de outras espécies que habitam diferentes latitudes. O segundo capítulo verifica a relação entre variações ambientais e a abundância de camarões-pedra *S. typica*, ou seja, como os parâmetros ambientais direcionam e influenciam a distribuição espaço-temporal dos camarões-pedra no litoral norte paulista. Finalmente, no terceiro capítulo encontra-se a análise da estrutura da população e o crescimento populacional ao longo das estações de cada ano e das diferentes profundidades onde os camarões foram coletados. De um modo geral o objetivo deste estudo foi testar a hipótese de que a dinâmica populacional de *S. typica* apresenta um padrão anual similar a outras espécies de invertebrados que habitam latitudes similares. Por fim, no item considerações finais faz-se uma síntese dos resultados obtidos neste estudo e discutem-se as conclusões e sugestões para futuros trabalhos com a espécie *S. typica* na costa brasileira.

Figura 1. *Sicyonia typica* (Boeck, 1864). Acima, vista dorsal de um exemplar coletado durante as campanhas e abaixo vista lateral da espécie estudada.

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CAPÍTULO 1

REPRODUCTION AND RECRUITMENT OF THE ROCK SHRIMP *SICYONIA TYPICA* (BOECK, 1864) FROM THE NORTHERN COAST OF SÃO PAULO STATE, BRAZIL

ABSTRACT

The rocky shrimps are not the main targets exploited in the Brazilian shrimp fishery. Nevertheless, these shrimps are important component of the by-catch fauna because trawls are not species-selective. Temporal reproductive biology, sexual maturity and recruitment of juveniles of the penaeoid shrimp, *Sicyonia typica* (Boeck, 1864), are described from monthly samples, which were carried out from January 1998 to June 2003 at three different areas in the northern coast of the State of São Paulo. The reproductive condition of females was assessed by observing the degree of ovarian maturity. Recruitment was estimated by variations in the proportion of individuals in juvenile size classes of carapace length (CL $\leq$ 9.9 mm) in relation to the total number of shrimp collected. The relative frequency of reproductive females correlated negatively with the percentage of recruits ($p < 0.05$). Mature organisms were found all year round, but spawning pattern analysis indicates that massive reproduction occurred from March to May and October. The continuous reproduction with peaks in determined seasons of the year, suggested here for *S. typica*, is in agreement with the idea that during spring and summer the primary production of phytoplankton is higher due to the intrusion of South Atlantic central waters in upwelling events in the studied region. Thus, the food availability in the plankton for newly hatched larvae may be a relevant selective factor shaping the breeding pattern of *S. typica*. A possible migration of adult individuals during determined year seasons might occur. But further detailed investigations are required to confirm that this species really moves to find better conditions and which cues are inducing such possible movement.

KEYWORDS: Penaeoidea, spawning, ovary development, continuous reproduction.

RESUMO

Os camarões pedra não são os principais alvos explorados pela pesca de camarões no Brasil. No entanto, esses camarões são componentes importantes da fauna acompanhante desta pesca, pois os arrastos de fundo não são seletivos. A biologia reprodutiva temporal, a maturidade sexual e o recrutamento juvenil do camarão peneóideo, *Sicyonia typica* (Boeck, 1864), são descritos a partir de coletas mensais, conduzidas de Janeiro de 1998 a Junho de 2003, em três diferentes áreas na costa norte do Estado de São Paulo. A condição reprodutiva das fêmeas foi verificada observando-se o grau de maturidade ovariana. O recrutamento foi estimado pelas variações na proporção de indivíduos juvenis nas classes de tamanho de comprimento de carapaça (CL ≤ 9,9 mm) em relação ao número total de camarões coletados. A frequência relativa de fêmeas reprodutivas correlacionou-se negativamente com a porcentagem de recrutas ($p < 0{,}05$). Organismos maduros foram encontrados ao longo de todos os anos, mas uma análise do padrão de desova indica que uma reprodução massiva ocorreu de Março a Maio e durante Outubro. A reprodução contínua com picos em determinadas épocas do ano, sugerida aqui para *S. typica*, está em acordo com a ideia que durante a primavera e verão a produção primária do fitoplâncton é mais alta devido a intrusão das Águas Centrais do Atlântico Sul em eventos de ressurgência na região estudada. Assim, a disponibilidade de alimento no plâncton para as larvas recém liberadas deve ser um fator seletivo relevante que define o padrão de reprodução de *S. typica*. Uma possível migração de indivíduos adultos durante determinadas épocas pode ocorrer. No entanto, investigações mais detalhadas são necessárias para confirmar que esta espécie realmente se move para encontrar melhores condições e quais fatores induzem estes possíveis movimentos.

PALAVRAS CHAVE: Penaeoidea, desova, desenvolvimento ovariano, reprodução contínua.

INTRODUCTION

According to Bauer & Rivera-Vega (1992), the first steps necessary to identify which factors (specific environmental conditions and selective pressures) influences on marine invertebrate reproduction are detailed basic studies about temporal patterns of gonadogenesis and breeding in the natural populations. In a similar way, the comprehension of how occurs the reproduction and recruitment process of a species is needful information for a sustainable fishing and to identify recruitment trends with success (Bauer & Lin, 1994).

There is a paradigm commonly accepted that considers the reproduction and recruitment of near-shore, benthic invertebrates with indirect development uninterrupted throughout one year in tropical latitudes, becoming more restricted during the year in those species that occur at temperate regions (Thorson, 1950; Giese & Pearse, 1974; Sastry, 1983). However, some exceptions in this tendency were noted, what have shown that make ecological generalizations are a difficult task (Sastry, 1983). Periodical changes of water temperature were identified as, perhaps, the main factor that triggers the beginning of the reproductive period in species that presents peaks of reproduction during the year, although variation in others parameters like salinity, photoperiod, lunar cycle and food availability for mature adults also have been considered as specific environmental cues for those events (Sastry, 1983). Among the final factors (selective pressures) responsible for breeding patterns in invertebrates with planktonic development, the periodicity of larval food supply, i. e. planktonic productivity, hydrological conditions, competition for habitat and food are considered some of characteristics that influences the larval life success (Scheltema, 1986). At all latitudes, the temporal and spatial variability of the ecological patterns of an aquatic community is leaded mainly by the variations on primary productivity, sediment types, disturbances and biotic interactions (Lenihan & Micheli, 2001). The complex seasonality of reproductive cycles can be affected by others variable environmental factors including rainfall and depth (Crocos *et al.*, 2001). Therefore, identify the proximate and the final factors responsible for the reproduction and posterior recruitment of a species is essential information to provide a basis to predict possible changes caused by natural or anthropogenic impacts (Bauer & Rivera-Vega, 1992; Bauer & Lin, 1994; Castilho *et al.,* 2007).

Although the non-commercial species of penaeid are abundant and ecologically important members of coastal and shelf habitats of the southern Atlantic, a review of the literature demonstrated that basic information on their temporal patterns of breeding and recruitment are virtually scant. The shrimp *Sicyonia typica* (Boeck, 1864), a non-commercial species that occurs as a by-catch in commercial prawn trawl fisheries of southern Brazil is widely distributed along the western Atlantic coast; it is found from North Carolina (USA) trough Gulf of Mexico including Central America; in Brazil, is distributed from Amapa state to Rio Grande do Sul state, in depths varying from shallow waters to 101 meters (Costa *et al.*, 2005). It occurs on muddy, sandy, shelly bottoms, mainly those densely covered with algae (D'Incao, 1995). This species is fished commercially in southwestern Cuba and occurs in commercial quantities in the Gulf of Campeche (Dore & Frimodt, 1987). In Brazil, it is often caught with shrimp trawls, but has a secondary commercial importance, as cited above (Costa *et al.*, 2005). This species, in Brazil, is not explored commercially due to its rigid carapace and small size, however, it constitute an important component of the trophic web in marine environments that occurs (Costa *et al.* 2005). The capture of this fauna in Brazil, is a result, first, of the low selectivity of the fisheries tools that causes a strong impact in those populations and second, by the high richness of penaeid species in tropical and subtropical areas (Severino-Rodrigues *et al.*, 2002). Most of the studies related to by-catch fauna of shrimp fisheries refers to fish species, although there are few works with decapod species (Costa & Fransozo, 1999; Severino-Rodrigues *et al.* 2002, Castilho *et al.*, 2008b; Souza *et al.*, 2008).

The majority of the obtained information on seasonal patterns of breeding of sicyoniids up to date was assessed in areas off California (Anderson *et al.* 1985), Puerto Rico (Bauer, 1992b; Bauer & Rivera, 1992) and Mexico (Smith, 1988; Lopez-Martinez *et al.*, 1999). The few studies in south Atlantic with *Sicyonia* spp. just records its occurrence in determined areas and depths

(D'Incao, 1995; Costa *et al.* 2000; Fransozo *et al.* 2002; Castilho *et al.* 2008a; Costa *et al.*, 2005), excepting the study on reproduction realized with *Sicyonia dorsalis* (Kingsley, 1878), by Castilho *et al.*(2008b).

The reproductive and recruitment pattern of populations of *S. typica* in the southeastern coast of Brazil are totally unknown. Thus, the aims of this research with *S. typica* in the southeastern coast of Brazil were to determine the morphological sexual maturity; to provide biological information on spawning and recruitment patterns in *S. typica* by observing temporal variations in reproduction seasons and comparing the results obtained here with those previously reported for the genus from other areas. This kind of information is essential in fisheries management, and will assist with the development of regulations for the small-scale seine fishery in São Paulo coastal waters, in order to ensure sustainable production.

MATERIAL AND METHODS

Samplings

Specimens of *S. typica* were collected monthly on the southeastern coast of Brazil at three different locations, in Ubatuba (23^0 30' S; 45^0 09'W), Caraguatatuba (23^0 37'S; 45^0 25' W) and São Sebastião (23^0 48'S; 45^0 23'W) northern region of São Paulo State, down to the 40-m isobath, from January 1998 to July 2003 (Figure 1).

From January 1998 to December 1999, shrimps were collected at Mar Virado (MV), Ubatuba (UBA), and Ubatumirim (UBM) bays, located in the Ubatuba region. Each bay was divided into six transects selected based on their relation to the bay mouth, the presence of a rocky outcrop or a beach along the shore, the inflow of river water, the proximity of offshore water, depth, and sediment texture. Four transects were established at mean depths of 5(IV), 10 (III), 15 (II) and 20 m (I), and the other two transects were located near to rocky shores (an exposed and a sheltered shore, transects V and VI, respectively).

During the year of 2000, from January through December, the same three bays cited above were sampled, but apart from those other sites were chosen. Four sites were determined on soft bottoms, at depths of 2, 5, 10 and 15 m, and another two rocky shore sites, being one exposed and the other sheltered, as we have already explained above. Two island neighboring sites were also sampled during 2000, Couve (CI) and Mar Virado (MVI) islands, on their sheltered sides, parallel to the coastline. In those sites, the campaigns of samples were done once during each season of the year. Additionally, extra trawls were made monthly at the offshore middle zones of these bays along the 20, 25, 30, 35 and 40 m isobaths.

From January 2001 to June 2003, shrimps were collected monthly in the Ubatuba, Caraguatatuba and São Sebastião regions. In each month, 14 stations (2 km) were trawled for 30 min, covering 18,000 m^2 each, at depths between 5 and 45 m.

A shrimp-fishing vessel provided with double-rig nets (20 and 15 mm mesh size in the net body and cod end, respectively) was used for trawling. We adopted only the bottom temperature measurements for analysis, which was monitored with a thermometer at each station, because the species studied here is benthic. Depth was measured at the beginning, midpoint, and end of each transect with an ecobathymeter coupled with a GPS. Detailed descriptions of sampling procedures methods and analysis of environmental factors for the period studied is available in the Chapter 2.

The shrimp were sexed (presence of petasma in males and thelycum in females) and measured (to the nearest 0.1 mm). Carapace length (CL) was adopted as the body size dimension, and measured from the posterior margin of the orbit and the middorsal posterior edge of the carapace using a slide caliper. Size-frequency distribution were made separately for each sex, bimonthly, to estimate the seasonality, using 0.3 mm CL size intervals, and the ratio of females to males compared by the Kolmogorov-Smirnov two-sample test (Sokal & Rohlf, 1995). The differences in sex ratio were tested for significant divergence from expected 1:1 proportion by using a Chi-square (χ^2) test (Sokal & Rohlf, 1995).

Reproductive conditions of females were determined from the degree of ovarian maturity. Ovary maturation stages were determined based on macroscopic criteria, such as color and volume occupied by the gonads, according to Castilho *et al.* (2007, 2008b). Ovaries categorized as immature (juveniles) varied from thin, transparent to thicker strands. Ovaries of adult females were classified as spent when they were much larger and thicker than immatures, and white. And the female gonads were considered developed if they were light green; or as ripe (mature) if they were green to olive green. Spawning intensity of the population was estimated analyzing the percentage of mature (reproductive) females (developed and ripe gonad) in relation to the total of adult females in each month or season (e.g., winter: July to September, and so on).

In penaeid shrimps sexual maturity of males usually is indicated by fusion of the petasmal lobes. The juvenile male has totally separately petasmal lobes (pleopodal endopods. Then, the stage and size of maturity of *S. typica* males was assessed by examining the shape of the petasma, being fused in adult males (Boschi, 1989; Bauer & Rivera Vega, 1992).

In the present study, recruitment refers to the youngest age (carapace length) at which the shrimps becomes vulnerable to fishing gear (Sparre & Venema, 1998; Castilho *et al.* 2008b). Recruitment patterns of the *S. typica* population studied here were obtained, according Bauer & Rivera Vega (1992), with the proportion of the population sample in the smaller size classes of combined male/female size-frequency distributions, and calculating the percentage lower 25% of all possible size classes (*S. typica* = 9.9 mm of CL), as in Bauer (1989) for caridean shrimp. The proportion of recruitment was defined as the percentage of recruits (≤ 9.9 mm CL) of the total number of shrimp caught in each month or season sample.

Off the northern coast of São Paulo, it is common to observe a transition of species abundance influenced by variations of environmental factors, mainly water current masses (Boschi, 2000; Castilho *et al.* 2008b). In some months of the sampling period, the abundance of *S. typica* was higher than others when fewer or none individuals were caught. In order to calculate the modal (cohort) progressions of the size of *S. typica*, we first identified the peaks of percentage of reproductive females and recruitment. Thus, we summed the abundance of females by year (e.g., January 1998 + January 1999 + January 2000 + January 2001 + January 2002 + January 2003) in each 1-mm size class of CL, and identified the cohorts (Bhattacharya's method) in the length-frequency distribution (LFD) in each summed month. Further, we calculated the mean percentage of reproductive females and recruitment by month (January-December) to compare with the observed cohorts.

Bhattacharya's method assumes normal distributions of the components in a composite LFD. This technique, calculated in the FISAT software package, identifies and separates one or more cohorts included in polymodal LFDs (Bhattacharya, 1967). Values less than 2 show a huge overlap between cohorts, and are considered statistically unacceptable (Sparre & Venema, 1998). Spearman's correlation coefficient was used to test the null hypothesis of no association between bottom temperature and (a) the frequency of recruits, and (b) the frequency of mature females, and the relation between (a) with (b).

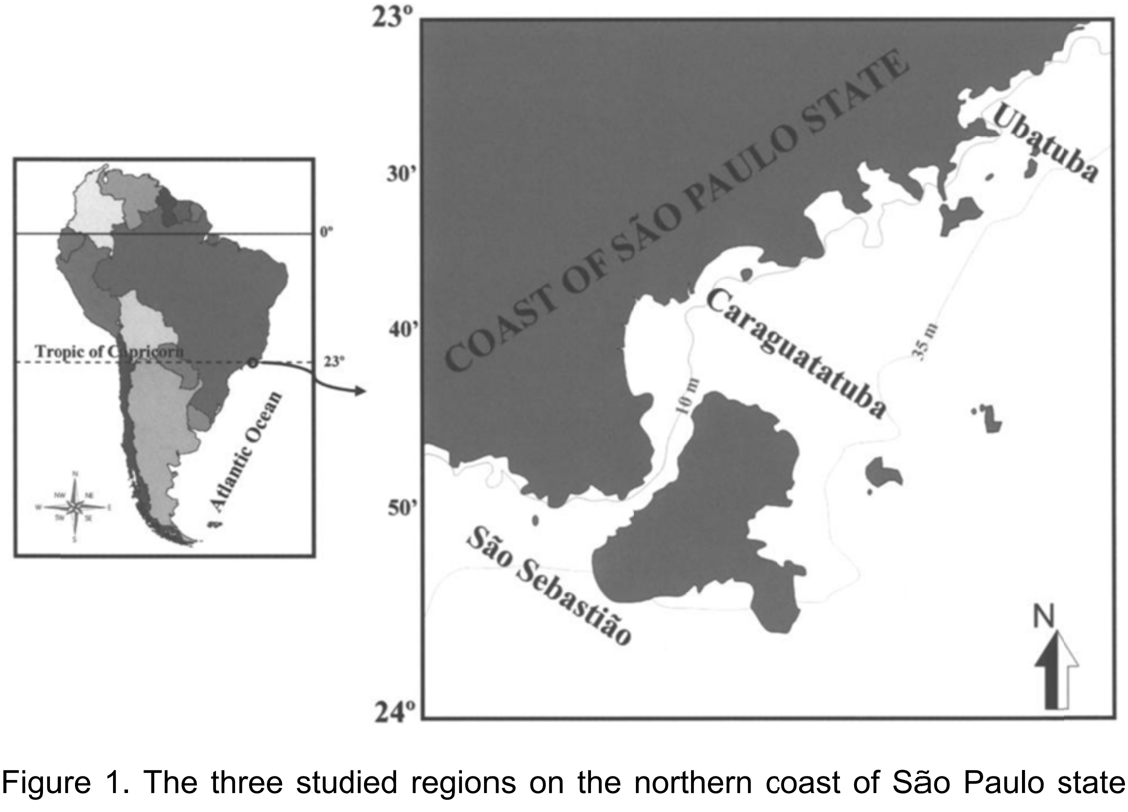

Figure 1. The three studied regions on the northern coast of São Paulo state, Ubatuba, Caraguatatuba and São Sebastião. Adapted from Castilho *et al.* (2008b).

RESULTS

During this study, a total of 942 (313 males and 629 females) rocky shrimp was caught, but only 914 totally preserved specimens (310 males and 604 females) were utilized in the statistical analysis. For females, the mean size recorded was of 12.28 ± 2.57 mm CL, ranging from 5.3 mm to 20 mm. The mean size of males was 10.62 ± 2.28 mm CL, ranging from 4.8 mm to 18.4 mm. A chi-square ($\chi^2 = 94.96$, $p<0.01$) result demonstrated that the ratio male/female was significantly different from 1:1 (0.51:1 biased females). According to the Kolmogorov-Smirnov two-sample test, the size-frequency distributions for females and males (figure 2) were also significantly different (dmax= -0.269; $p<0.01$). The recruits were considered the shrimps with size smaller than 9.9 mm CL.

The frequency, bimonthly, of mature females (adult females with developed and ripe ovaries), in each year, since 1998 to 2003 is illustrated in Table I. The spawning by mature females of *S. typica* occurred in almost all period sampled, except for March-April/1999, when no mature females appeared. Low percentages of females with mature gonads were recorded in Mar-Apr/1998, Jan-Feb/1999 and May-Jun/2000, 2001. The bottom temperature oscillated between 17^0 C and 28^0 C and correlated negatively with the percentage of spawning females from January 1998 to June 2003 (Spearman correlation, $p<0.05$, r= -0.285).

The recruitment occurred uninterrupted only in the period from Nov-Dec/2000 to Sep-Oct/2002 in the 5,5 years of samples (fig. 3). Smaller recruits were obtained in Jan-Feb/1998 (mean = 7.09±1.95mm CL) and during Mar-Apr periods of 1999 (mean = 7.67±0.84 mm CL), 2000 (mean = 8.20±0.28 mm CL) and 2001 (mean = 8.28 ±1.42 mm CL). The high percentages of recruits were recorded in Jan-Feb/1998, 1999, Mar-Apr/1998, 1999 and May-Jun/2001. The major absolute frequency of recruits was recorded in May-Jun/2001 (40 specimens, 50%).

The relationship of occurrence of the frequency of mature females with frequency of recruits is expressed in fig. 4. The frequency of reproductive females correlated negatively with the percentage of recruits (Spearman correlation, $p<0.05$, $r_S = -0.629$). The most intense recruitment period occurred during March to May, in response to the reproductive activity during February, and there was another peak of recruitment in August, as a reflex of the reproductive effort during June to September.

In the figure 5 the cohorts for LSF of females in the annual cycle can be observed and shows the cohorts of recruits (≤ 9.9 mm of CL). The recruitment season is evident and can be identified with the first cohort of March (9.53 ± 1.31mm of CL), and the cohorts of April (9.61 ± 1.19 mm of CL) ad May (9.79 ± 1.56 mm of CL). After these months a modal progression was observed in June (11.50 ± 2.38 mm of CL), in the first cohort of July (11.96 ± 1.79 mm of CL), in August (12.00 ± 1.57 mm of CL) and September (11.82 ± 1.62 mm of CL). The first cohort in October (9.93 ± 1.11 mm of CL) and the cohort of November (9.23 ± 0.82 mm of CL) were, again, months with cohorts of recruits (≤ 9.9 mm of CL) and evidence of recruitment.

Table I. *Sicyonia typica* (Boeck, 1864). Absolute number and percentage of mature females and mean bottom water temperature (^{0}C) measured bimonthly at the study region from January 1998 to June 2003. Percentage of females with mature ovaries in relation to the total of adult females.

Period	**bimonthly**	**N**	**%**	**Mean of bottom temperature (^{0}C)**
1998	Jan - Feb	11	85	25.1
	Mar - Apr	11	55	24.7
	May - Jun	9	75	23.5
	Jul - Aug	11	92	22.3
	Sep - Oct	5	83	22.3
	Nov - Dec	4	100	21.9
1999	Jan - Feb	1	50	25.7
	Mar - Apr	0	0	25.5
	May - Jun	4	100	23.3
	Jul - Aug	30	83	21.4
	Sep - Oct	23	92	21.4
	Nov - Dec	4	100	18.6
2000	Jan - Feb	1	100	21.7
	Mar - Apr	6	100	21.3
	May - Jun	10	67	21.9
	Jul - Aug	32	94	19.5
	Sep - Oct	5	100	19.7
	Nov - Dec	7	88	21.4
2001	Jan - Feb	31	89	23.2
	Mar - Apr	14	87	23.4
	May - Jun	30	59	23.5
	Jul - Aug	97	95	20.7
	Sep - Oct	27	71	19.9
	Nov - Dec	6	75	19.6
2002	Jan - Feb	15	88	22.7
	Mar - Apr	4	80	22.6
	May - Jun	61	85	23.3
	Jul - Aug	11	100	22.3
	Sep - Oct	17	94	21.5
	Nov - Dec	1	100	21.7
2003	Jan - Feb	8	73	21.4
	Mar - Apr	7	78	25.0
	May - Jun	2	100	23.2

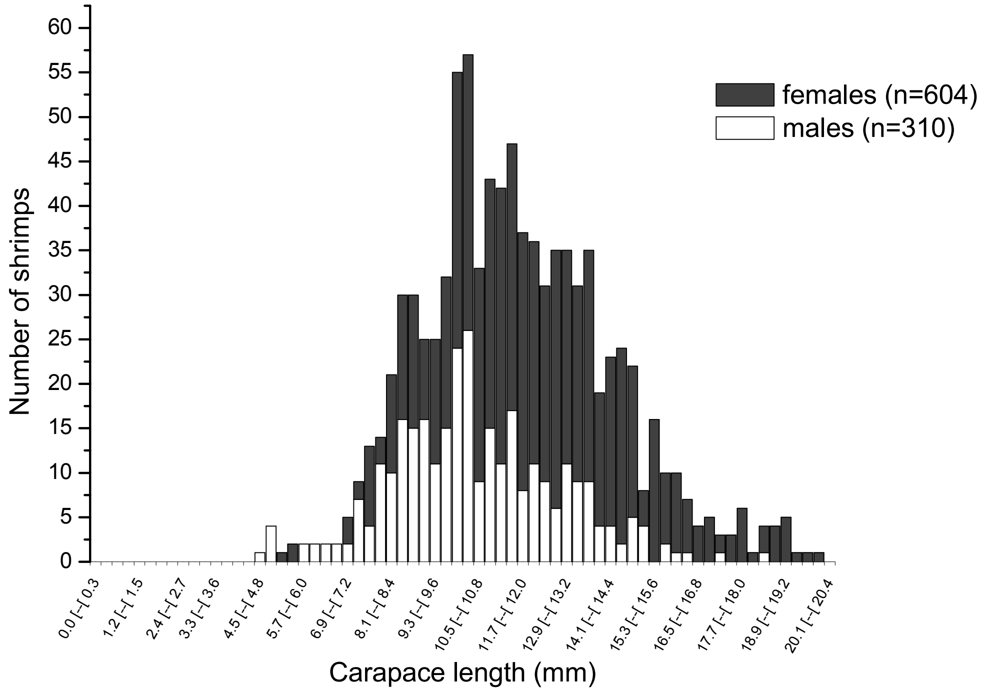

Figure 2. *Sicyonia typica* (Boeck, 1864). Size-frequency distribution (CL) of males and females obtained in the study region from January 1998 to June 2003.

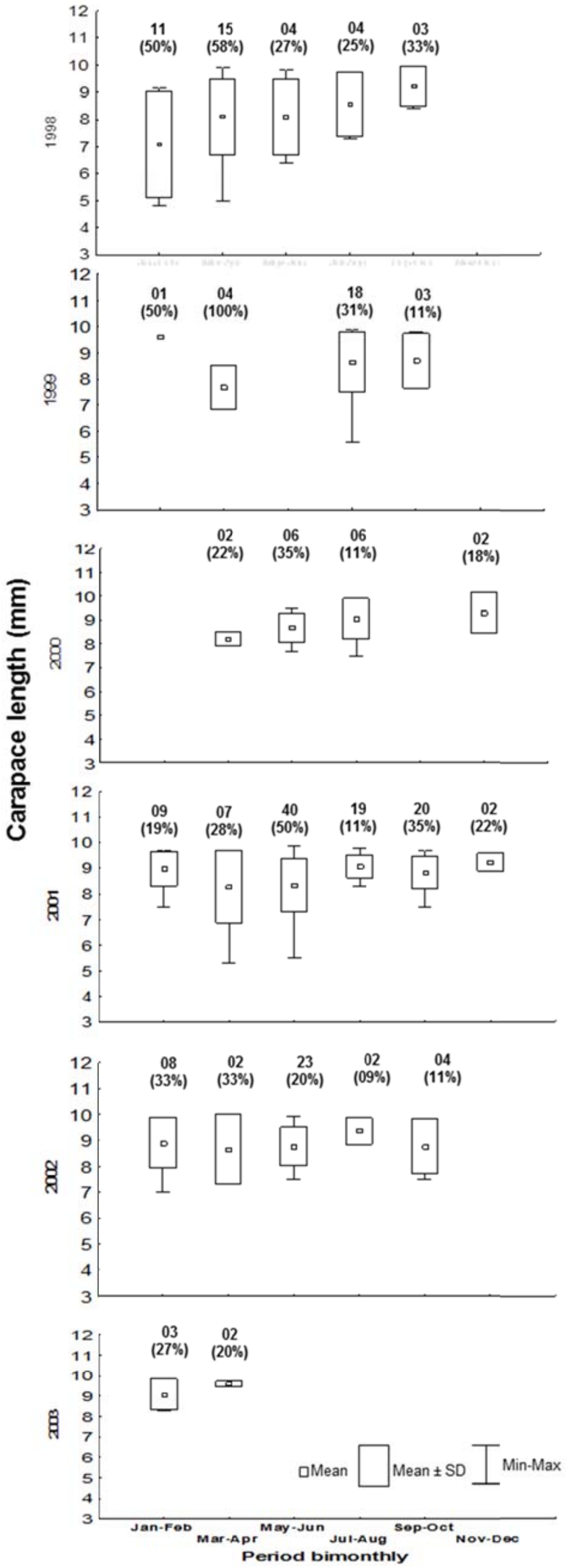

Figure 3. *Sicyonia typica* (Boeck, 1864). Recruitment temporal pattern, presenting the abundance, relative frequency and the carapace length variation of the recruits , bimonthly, over the 5,5 years period of samplings. Percentage of recruits in relation to the total number of individuals in the population.

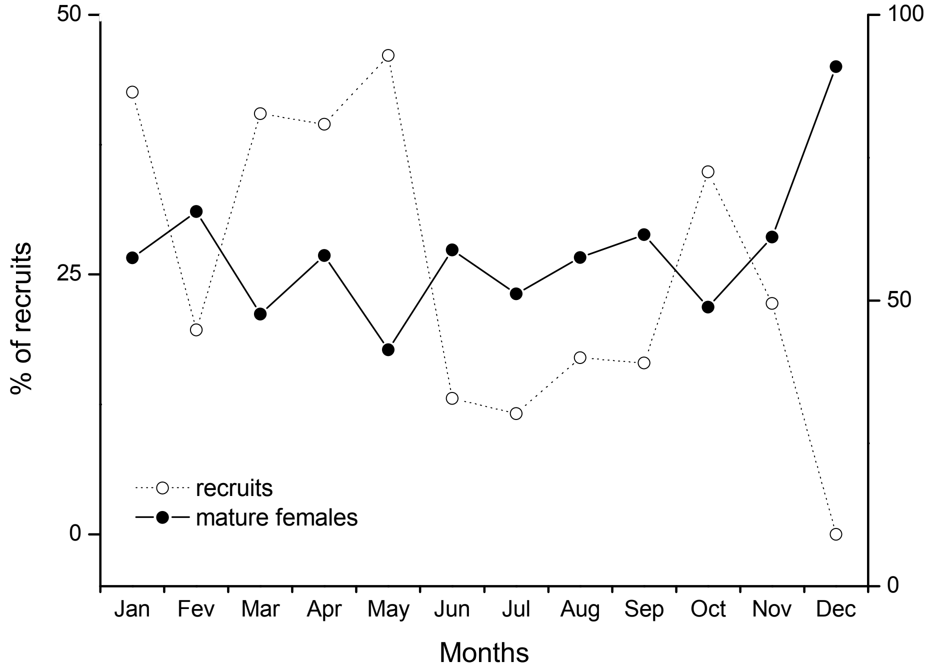

Figure 4. *Sicyonia typica* (Boeck, 1864). Variation in the frequency of reproductive females and the percentage of recruits in the annual pattern in the study region. Abundance of recruits and females of each month was summed, e.g., Jan/1998 + Jan/1999 + Jan/2000 + Jan/2001 + Jan/2002 + Jan2003.

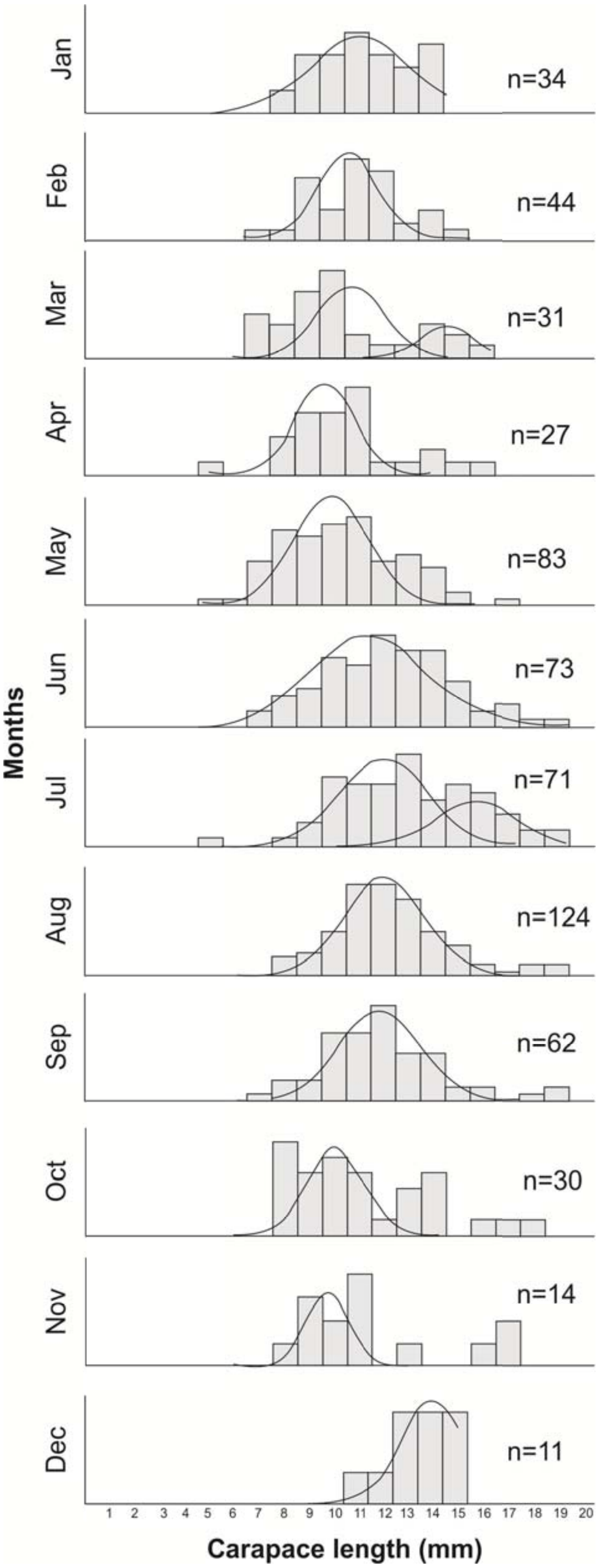

Figure 5. *Sicyonia typica* (Boeck, 1864). Female cohorts identified in monthly size-frequency distributions from the study region. Monthly abundance of females was summed by years (Jan 1998 + Jan 1999 + Jan 2000 + Jan 2001 + Jan 2002 + Jan 2003 and so on) in each 1-mm size class of CL. Fitted curves correspond to the cohorts calculated by Bhattacharya's method.

DISCUSSION

According to the present results, the females of *S. typica* grew larger than males, which indicate an evident sexual dimorphism of size in this species, and that there is a differential growth rate between sexes. For Boschi (1969) sex-related differences in relation to the carapace length size between females and males are a general trend among penaeids. The same pattern of difference in size between sexes could be observed in other species of the genus *Sicyonia:* as in *S. brevirostris* Stimpson, 1871 by Cobb *et al.* (1973) and Kennedy *et al.* (1977), *S. penicillata* Lockington, 1879 studied by López-Martinez *et al.* (1999) and *S. dorsalis* Kingsley, 1878 by Castilho *et al.* (2008b). For instance, this pattern was also evident in many penaeid species as *Rimapenaeus constrictus* (Stimpson, 1871) studied by Costa & Fransozo (2004) and *Artemesia longinaris* Bate, 1888 by Castilho *et al.* (2007); and in the Solenoceridae species as *Solenocera membranacea* (Risso, 1816) by Demestre & Abelló (1993) and *Pleoticus muelleri* Bate, 1888 by Castilho *et al.* (2008a).

According to Bauer (1996), smaller males and larger females is a rule in Sicyoniid shrimps as a result of the reproductive process. Female fecundity increases with size in decapod populations, promoting larger female size (Castilho *et al.*, 2007). For males, there are no significant larger size advantages in mating interactions, as they executes the “pure searching” mating system in which males do not fight over or defend females or mating territories (Bauer, 1996).

There is a deviation in the sex ratio from 1:1, for *S. typica*, highly skewed towards females, mainly in the upper size classes. Plausible explanations for these results are proposed by Castilho *et al.* (2008b) that have found similar data for *S. dorsalis* and hypothesized that, if the skewed sex ratio is not true, it is because the sampling method can bias against males. The smallest individuals may not have been adequately sampled because of the mesh size of the net (Teikwa & Mgaya, 2003). As females of *S. typica* reach larger sizes than males, they are less susceptible to the net sampling bias. However, in the upper size classes of the population that the specimens were, in theory, adequately sampled by the net mesh utilized, what is observed is that the sex ratio until is strongly skewed for females. Then, another hypothesis was formulated by Pianka (1983), in a study of evolutionary Ecology. This author discussed that some invertebrate species have active selection for biased sex ratio towards females when this sex is polyandrous in the population. From laboratory observations on other species of *Sicyonia* spp., Bauer (1992b) detected repetitive copulation and polyandry of newly molted females, and suggested that the polyandry of females could be an adaptive advantage for the offspring, as it may increase genetic diversity. For the present population, females can be polyandrous and might be able to detect and adjust sex ratio of spawns. However, more detailed studies focusing in spatio-temporal variation in the sex ratio of penaeoidean species, specifically Sicyoniids, are necessary to make comparisons and confirm this hypothesis. According to Signoret (1974) and Cha *et al.* (2002), the sex ratio biased for females can be due to a greater longevity of females, as sex ratios may be related to the growth and mortality of shrimp populations.

The spawning pattern shown by *S. typica* suggests continuous year-round reproduction at the level of the population, with a slightly decrease of mature females in the summer-autumn months of some years (Table I). However, this decrease cannot be considered a strong evidence of seasonal component or peak in reproduction. The relative low values in the percentage of adult females with mature ovaries registered in some months suggests a relatively long refractory period in individual females between one spawning and subsequent re-maturation of the ovary prior to the next spawning (Bauer & Rivera-Vega, 1992). There is a classical paradigm of continuous reproduction at lower latitudes, with increased seasonality of breeding period at higher latitudes (Thorson, 1950; Sastry, 1983; Bauer, 1992a; Boschi, 1997; Costa & Fransozo, 2004; Costa *et al.*, 2005; Castilho *et al.*, 2007) and for this species that occur at tropical and subtropical regions, this tendency seems to apply. The breeding pattern of *S. typica* can be compared to those of other *Sicyonia* species from tropical and subtropical latitudes, like *S. dorsalis* studied by Castilho *et al.*, (2008b), *S. parri* (Burkenroad, 1934) and *S. laevigata* Stimpson, 1871 studied by Bauer and Rivera-Vega (1992), and nine caridean species from a tropical location (Bauer, 1989) with imminent spawning. Females of the genus *Sicyonia* from higher latitudes live at least 2 years and the natural selection permits that breeding occur intensely during periods which might be most favorable for larval development and settlement, i. e., higher temperature that accelerate metabolism and food availability for larvae. Habitat conditions apparently do not allow (physiologically) continuous reproduction year-round on the population level at high latitudes. On the other hand, small tropical Sicyoniid species lives less than one year (*S. parri* and *S. dorsalis*) and may settle and grow to sexual maturity throughout the year, with female breeding activity happening at any time of the year (Castilho *et al.*, 2008b).

The absence of mature females verified during March and April 1999 may occur as a signal of population migration and the spawning of rocky shrimps may have occurred over a wider area than was sampled in the present study. Migration to deeper areas may occur in this species that was sampled in other studies (D'Incao, 1995; Costa *et al.*, 2005) in habitats with 60 meters of depth or more, but it is not conclusively proved here because of poor sampling far the 45 meters in the continental shelf. The factors which trigger and ends this possible migration to areas not available to the fisheries must be investigated in future studies. Kennedy *et al.* (1977), in their study with *S. brevirostris* observed that adult populations from the Fort Pierce region was very patchy and may explain the absence of mature females in the present work.

Throughout January 1998 and June 2003 juveniles of *S. typica* were collected in all months, except for December (fig. 4). However, there were annual variations of the presence and in the size of young shrimps bimonthly (fig. 3), with more intensity of recruitment in late summer and fall. The results of this study show that the recruitment in this species is a continuous process, although there was a lack of information in some months. The Bauer's hypothesis about reproduction and recruitment periodicity in tropical rocky shrimps has been confirmed one more time in the present work. Bauer & Rivera-Vega (1992) found the same pattern of continuous recruitment with high peaks in April-June and October for *S. parri* and *S. laevigata*. In a study in the same region and period of the work here, Castilho *et al.* (2008b) found that for *S. dorsalis*, the recruitment occurs throughout the year, but mainly in pulses beginning in March to June and October, after the principal spawning peaks of December and July, respectively. These results obtained by Castilho *et al.* (2008b) are very similar with the results of the present study indicating that similar factors controlled recruitment of these two sympatric Sicyoniids. Cobb *et al.* (1973) and Kennedy *et al.* (1977) found a strong seasonal pulse of recruitment in the months after the spawning period in the subtropical species that occur in Florida coast region, *S. brevirostris*. According to Bauer (1989) and Jerí (1999) different processes affected the relative frequency of juveniles arriving from the plankton to the nursery grounds in populations of Sicyoniids, depending on the habitat characteristics.

In the north littoral of São Paulo state, during summer, the upwelling event of intrusion of SACW (South Atlantic Central Waters) causes an increase in the ocean chlorophyll content (Véga-Perez, 1993) and promote high quantities of phytoplankton, herbivorous zooplankton and heterotrophic bacteria in the water column (Pires-Vanin *et al.*, 1993). In coastal marine invertebrates, spawning events typically coincides with primary production by phytoplankton on which newly larvae feed, a phenomenon called “match-mismatch” process (Cushing, 1975). For Cushing (1975), the maximum reproductive investment of marine planktotrophic species coincides with the seasonal maximum abundance of phytoplankton. Unfortunately, the chlorophyll and primary production was not measured, as well as the newly hatched larvae of *S. typica*, in the plankton, were not collected in the present study, but the late spring and summer spawning, verified here, was similar in *S. dorsalis*, *A. longinaris* and *P. muelleri* studied by Castilho *et al.* (2007; 2008a and 2008b, respectively) in the same region.

Several studies on penaeid reproduction have demonstrated that variation on water temperature is an important proximate factor acting on spawning (Pérez-Farfante, 1969; Bauer & Lin, 1994). There was not a significant correlation between bottom temperature and percentages of females with mature ovaries for *S. typica* which imply that this parameter was not the main proximate factor that influences the breeding of *S. typica*, same pattern of

S. dorsalis verified by Castilho *et al.* (2008b). The bottom temperature certainly is important to reproduction of *S. typica*, however, other factors as precipitation, salinity, lunar cycle and river discharge should be considered relevant to reproduction in the area of this study (Jerí, 1991).

The cohorts for LSF of females (fig. 5) show that *S. typica* possible has multiple spawning between each molt event. In a laboratory study, Anderson *et al.* (1985) observed until seven spawning events in a mean of 52 days between molts. In a study with *Fenneropenaeus indicus* (H.Milne Edwards, 1837), Emmerson (1980) found that recently wild caught females could spawn up to three times without a molt. In the present work it is evidenced by the modal progressions of recruits to adult (puberty) and other of adults at the end of reproduction peaks.

The lack of knowledge on the reproduction of the rocky shrimp *S. typica* does not allow us to make comparisons and generalizations about the period of spawning and recruitment in the south Atlantic. The complex life history of Penaeoids and the high variability of the tropical system make other studies focusing *S. typica* necessary in order to establish a model of reproduction and compare it with species of the same taxon at different sites and latitudes. However, a recruitment of juvenile individuals is shown from March to May and in October, and two cohorts of young shrimps can be detected. Future studies, in the same region and in other latitudes, with this species are necessary to evaluate the possible migration of mature females in some seasons of the year and in order to detect the real effect of environmental variables on the reproductive rhythms of natural stocks. The results presented here suggest that the Ubatuba region is an important area to the life-cycle of *S. typica*. The “by-catch” fauna, in which Sicyoniid shrimp are included in Brazilian shrimp fisheries, can, in the future, serve as food source for human beings and the knowledge about their reproductive biology is very important to explore it with sustainability.

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CAPÍTULO 02

ECOLOGICAL DISTRIBUTION OF THE ROCK SHRIMP *SICYONIA TYPICA* (BOECK, 1864) (DECAPODA, PENAEOIDEA) IN THE SOUTHEASTERN OF THE BRAZILIAN COAST

ABSTRACT

The general biology of a species includes the knowledge about its ecological distribution and the modulating factors. Abundance and spatio-temporal distribution of the rock shrimp *Sicyonia typica* (Boeck, 1864) were investigated from January 1998 through June 2003 in Ubatuba (UBA) and from January 2001 through June 2003 in Caraguatatuba (CAR), both at the northern coast of São Paulo state, Brazil. In both sites, the samplings were made monthly at several depths (stations) using a trawling shrimp boat equipped with double-rig nets. A total of 452 and 297 shrimps were obtained at UBA and CAR, respectively. During the 1998/1999 campaign (or survey) the distribution of *S. typica* differed among stations and also seasons as well as during that of 2001/2003. The highest abundance was verified at sheltered area of Ubatuba bay in deeper stations, mainly in which the sediment was composed by a high quantity of mud. The shrimps most were captured during winter season, in periods of lower mean bottom temperatures and high salinity values. The intrusion of SACW during last spring and summer seemed only affects the *S. typica* population during the first year of samples. There was no significant difference in abundance between UBA and CAR that suggests the scale selection used here was not appropriated to establish a south-north movement pattern for *S. typica*. The sediment type and bottom water temperature and salinity are among the most important variables affecting the ecological distribution of *S. typica* at this studied region.

KEYWORDS: Abundance, abiotic factors, coastal zone, marine currents.

RESUMO

A biologia geral de uma determinada espécie inclui, entre outras informações relevantes, o conhecimento sobre como ocorre sua distribuição no tempo e no espaço e os fatores que modulam esta distribuição. A abundância e a distribuição espaço-temporal do camarão pedra *Sicyonia typica* (Boeck, 1864) foram investigadas desde Janeiro de 1998 até Junho de 2003 em Ubatuba (UBA) e de Janeiro de 2001 até Junho de 2003 em Caraguatatuba (CAR), ambas na costa norte do litoral de São Paulo, Brasil, Em cada local as coletas foram realizadas mensalmente, em diversas estações estabelecidas conforme a profundidade e perpendiculares a linha da costa. Para tanto foi utilizado um barco camaroeiro com duas redes tipo “double-rig”. Um total de 452 e 297 camarões pedra foram capturados em Ubatuba e Caraguatatuba, respectivamente. Durante a campanha de 1998/1999 a distribuição de *S. typica* diferiu significativamente entre as estações de coleta e, também, entre as estações do ano, bem como durante a campanha de 2001/2003. A maior abundância de indivíduos foi verificada nos locais abrigados da baía de Ubatuba e em estações de coleta mais profundas, principalmente, nas quais o sedimento era composto por uma grande quantidade de lama. Durante o inverno, em todos os anos de coleta, registrou-se o maior número de camarões pedra, períodos de baixos valores médios de temperatura de fundo e altos valores de salinidade. A entrada da ACAS (Águas Centrais do Atlântico Sul) no fim da primavera e verão pareceu apenas afetar a população de *S. typica* no primeiro ano de amostragem. Não houve uma diferença significativa na abundância de camarões entre UBA e CAR, o que sugere que a escolha da escala de amostragem não foi a mais apropriada para estabelecer um padrão de migração norte-sul para esta espécie. O tipo de sedimento, a temperatura e salinidade de fundo estão entre as mais importantes variáveis que modulama distribuição ecológica de *S. typica* na região estudada.

PALAVRAS-CHAVE: Abundância, fatores abióticos, zona costeira, correntes marinhas.

INTRODUCTION

Coastal zones are variable environments directly subject to continental, atmospheric and oceanic influences (Santos & Pires-Vanin, 2004). The instability of the coastal zone affects the benthic biota, determining the patterns of distribution and density of invertebrate species. The Brazilian coastline around the 23^0 S of latitude, next to the Tropic of Capricorn line, nowadays offers adequate living conditions for several species of shrimps, including Carideans, Stenopodid and Penaeoidean. A proof of that is the high intensity of fisheries activity in the northern littoral of São Paulo State aiming penaeid shrimp, mainly the most profitable target species such as the pink-shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez-Farfante, 1967), the white-shrimp *Litopenaeus schmitti* (Burkenroad, 1938) and the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Costa *et al.*, 2005).

A peculiar aspect of the region, investigated here (Ubatuba, Caraguatatuba and São Sebastião areas), is its hydrographic structure. Three water masses are present on the continental shelf with different seasonal distribution patterns. Coastal Water (CW) has a high temperature and low salinity ($T > 20^0$ C; $S < 36.0$ ‰), Tropical Water (TW) has both a high temperature and salinity ($T > 20^0$ C; $S > 36.0$ ‰) and South Atlantic Coastal Water (SACW) shows both low temperature and salinity ($T < 20^0$ C; $S < 36.0$ ‰)(Castro-Filho *et al.*, 1987). During spring and summer, the cold SACW intrudes inshore from the shelf break near the bottom and gives rise to a strong thermocline in midwater, at the depth of 10 and 15 m, approximately (Pires-Vanin *et al.*, 1993; DeLeo & Pires-Vanin, 2006). At the same time the warm and light CW is compressed along the coast by northeasterly winds, filling the surface layer. By autumn and winter, the SACW retreats offshore to the shelf break and is replaced by CW. As a result, no stratification is present over the inner shelf in winter months. To complete the hydrological structure of the area frontal eddies occur in both seasons (summer and winter) on the outer shelf (Pires, 1992). An important detail of the hydrographic dynamic of the region is that SACW is rich in nutrients (N and P), and when it reaches shallow areas in summer months, promotes intense eutrophication, enhancing the organic material available to the benthic species of shrimp (Pires, 1992).

The shrimp ecological distribution may depend on influence of environmental factors (Boschi, 2000). Dall *et al.* (1990) cited various abiotic factors that might be fundamental determinants of the spatial and temporal distribution of penaeid shrimps, such as water temperature, salinity, bathymetric depth and sediment type. Also, other ecosystem characteristics may influence on ecological distribution of shrimps, e.g., bottom features, sheltering degrees, food availability, patterns of tides and sea level, current speed, composition of the community, prey-predator relationships, interactions among species, reproduction strategies, etc (Abele, 1974; Negreiros-Fransozo *et al.* 1991; Boschi, 2000).

Therefore, the distribution of a shrimp species, at any stage of its life cycle, is known to be influenced by many environmental factors and may lead this species to the occupation of many different habitats, or may be restricted to some localized areas (Mantelatto & Fransozo, 1999). The organisms occur at a given space in which environmental conditions insure at least the minimum necessary for its survival (Mantelatto *et al.* 1995).

Some authors have been appointed the sediment texture and the bottom water temperature in each depth gradient as the main factors in the distribution of penaeoideans during benthic phases (Dall *et al.*, 1990; Costa & Fransozo, 2004; Fransozo *et al.*, 2004; Costa *et al.*, 2004, 2005; Castilho *et al.*, 2008). However, it is a consensus that the distribution boundaries of the benthic marine fauna are determined by the action of a set of interrelated factors that each one has a variable degree of importance, depending on the species and habitat in question (Mantelatto & Fransozo, 1999).

The genus *Sicyonia* H. Milne-Edwards, 1830 is the exclusive component of the family Sicyoniidae and has a large occurrence area in tropical and subtropical oceans (D'Incao, 1995). Crosnier (2003) reviewed the family and has been recognized 31 species from the Indo-West Pacific, 10 from the eastern Pacific, seven from the western Atlantic, two from the eastern Atlantic (one of which also occurs in the Mediterranean), and two that occur both in the eastern Pacific and the western Atlantic, bringing the current global fauna of rock shrimps to 52 valid species.

Species of this genus are more common inhabiting, after the planktonic phase of the life cycle, a variety of substrates on the continental shelf, and some species can extend their distribution down to the continental slope (D'Incao, 1995; DeGrave *et al.* 2009). According to Costa *et al.* (2000), four *Sicyonia* species occur in the north littoral of São Paulo state: *S. dorsalis* Kingsley, 1878, *S. laevigata* Stimpson, 1871, *S. parri* (Burkenroad, 1934) and *S. typica* (Boeck, 1864). In this region, rock shrimp are captured as 'bycatch' of commercial trawls and have an important ecological role as members of marine food webs, responsible for part of the energy flow (Castilho *et al.*, 2008). The species *S. typica* is morphologically distinguished from the other congeneric species of the Brazilian southeastern region by a rostrum with a straight or convex ventral margin and 2 or, rarely, 1 dorsal tooth (D'Incao, 1995). The few accounts treating the biology of *S. typica* has been given emphasis only on its ecologic distributional aspects (bottom features and depth) as that by Pérez-Farfante (1952), who mentioned that this species occur in a muddy and rather consolidated bottom, with a certain amount of mollusk shells, but free from vegetation, at the Gulf of Batabanó, Central America. By the other hand, D'Incao (1995), rewiewing the genus *Sicyonia* in Brazilian coast, cited that *S. typica* occurs on bottoms of mud, sand, shell which are densely covered with algae; from shallow to101 m water depths. Therefore, studies on the ecology of *S. typica* are virtually scarce, and, in the south hemisphere, most concern the biodiversity of marine shrimps (Costa *et al.*, 2000, 2003) and the general distribution of Penaeoidea as that byFransozo *et al.*(2002).

The goal of this study was investigate the spatial and temporal distribution patterns of *S. typica* in two areas (Ubatuba and Caraguatatuba), both from northern coast of São Paulo state. Abundance patterns were also verified with respect to some environmental factors at each area cited above, reaching as far as 45 m deep.

MATERIAL AND METHODS

The examined data in this investigation was collected along the northern coast of São Paulo state, where traditional fishermen usually work. The Ubatuba bay (23^0 25’ S; 45^0 03’ W) was sampled monthly, from January 1998 to December 2003, whereas the Caraguatatuba was sampled monthly from January 2001 to December 2003. Each region was grouped into several stations according to depth and degree of exposition to waves energy (Figure 1). During the first campaign, from January 1998 to December 1999, it was established six stations as follow: I (20 m); II (15 m); III (10 m); IV (5 m); V (exposed area) and VI (sheltered area). The second campaign, from January to December 2000 had nine stations at different depths: I (2 m), II (5 m), III (10 m), IV (15 m), V (20 m), VI (25 m), VII (30 m), VIII (35 m) and IX (40 m). The third campaign was carried out at Ubatuba (UBA) and Caraguatatuba (CAR) areas during 2001 and 2003; and in both regions we established seven stations: I (5 m), II (10 m), III (15 m), IV (20 m), V (25 m), VI (30 m) and VII (35 m). Indeed, during this period, some extra trawls were done at the depth of 45 m at both areas. A shrimp fishery boat equipped with two double-rig nets (mesh size 20 mm, 15 mm in the cod end) was used to trawling. Each station was trawled over a period of 30-min (18,000 m^2), at approximately 1.5 knots, enough to prevent significant shrimp escape from nets.

The environmental factors were measured, monthly, at each station of each location. Salinity (‰) and Temperature (^{0} C) were measured in bottom-water samples, obtained using Nansen bottle. An ecobathymeter coupled with a GPS was used to record depth (m) at sampling sites. The Salinity was measured with an Atago $S/_{1000}$ optic rephrractometer, whereas the Temperature (^{0} C) was recorded using a thermometer attached to the Nansen bottle. The sediment samples were collected at each station with a Van Veen grab, enclosing a bottom area of 0.06 m^2. In the laboratory, the sediment samples were dried at 70 ^{0}C for 72 h. For the analysis of grain size composition, two 50-g sub-samples were separated and treated with 250 ml of a 0.2 N NaOH solution, and stirred for five minutes to release silt and clay particles, and then rinsed on a 0.063-mm sieve. Grain size categories followed the Wentworth (1922) American standard, for which sediments were sieved at 2.0 mm (gravel); 2.0 – 1.01 mm (very coarse sand); 1.0 – 0.51 mm (coarse sand); 0.50 – 0.26 mm (medium sand); 0.25 – 0.126 mm (fine sand); and 0.125 – 0.063 mm (very fine sand); smaller particles than 0.063 mm were classified as silt-clay. Cumulative particle-size curves were plotted on a computer using the phi scale, with values corresponding to the 16th, 50th, and 84th percentiles being used to determine the mean diameter of the sediment using the formula:

$Md = (\phi_{16} + \phi_{50} + \phi_{84})/3$, thus accounting for the central tendency of sediment samples (Suguio, 1973).

Finally, phi was calculated using the formula: phi (ϕ) = $-\log_2 d$, where d = grain diameter (mm) (Tucker, 1988). Graphic representation of sediment texture was performed by plotting a triangular diagram using the three most important granulometric classes, following Magliocca & Kutner (1965). Granulometric class A corresponds to sediments in which intermediate sand (IS), coarse sand (CS), very coarse sand (VCS) and gravel (G > 0.25 mm) account for more than 70% by weight. In class B, fine sand (FS), and very fine sand (VFS) compose more than 70% by weight of sediment samples (0.25 -] 0.0625 mm). The class C is formed by more than 70% by weight of silt and clay (S + C). These three categories are further combined to form six different groups:

PA = (IS + CS + VCS + G) > 70% by weight;

PAB = prevalence of A over B (FS + VFS);

PAC = prevalence of A over C (S + C);

PB > 70%;

PBA = prevalence of B over A;

PBC = prevalence of B over C;

PC > 70%;

PCA = prevalence of C over A;

PCB = prevalence of C over B.

The organic matter content (%) was obtained by ash-weighing: 3 parts of 10g each per station were placed in porcelain crucibles, heated for three hours at 500 ^{0}C, and then weighed again (Mantelatto & Fransozo, 1999).

Shrimp abundance at each sampling station is represented as the total (absolute) number of individuals sampled during each of the campaigns. Abundance of shrimps was compared among years, regions, depths (stations), seasons (summer, autumn, winter and spring) of the year by means analysis of variance (ANOVA, $p< 0.05$), complemented with the Tukey test (5%) for pairwise comparisons of average values. The contribution influence of each environmental factor on species abundance was evaluated by multiple linear regression (MR) and also compared through analysis of variance (ANOVA, $p < 0.05$). For the campaign of 2001/2003, data from the depth of 45 m were not used in the analysis of variance because of the lack of some statistical requirements, such as the number of repetitions. The correlation between shrimp abundance and each abiotic factor was evaluated by the non-parametric Spearman test, at 5% significance level. The homocedasticity (Levene test) and normality assumptions were examined and, then, data were transformed by natural logarithm for the purpose of satisfying the premises of the statistical analyses (Zar, 1999).

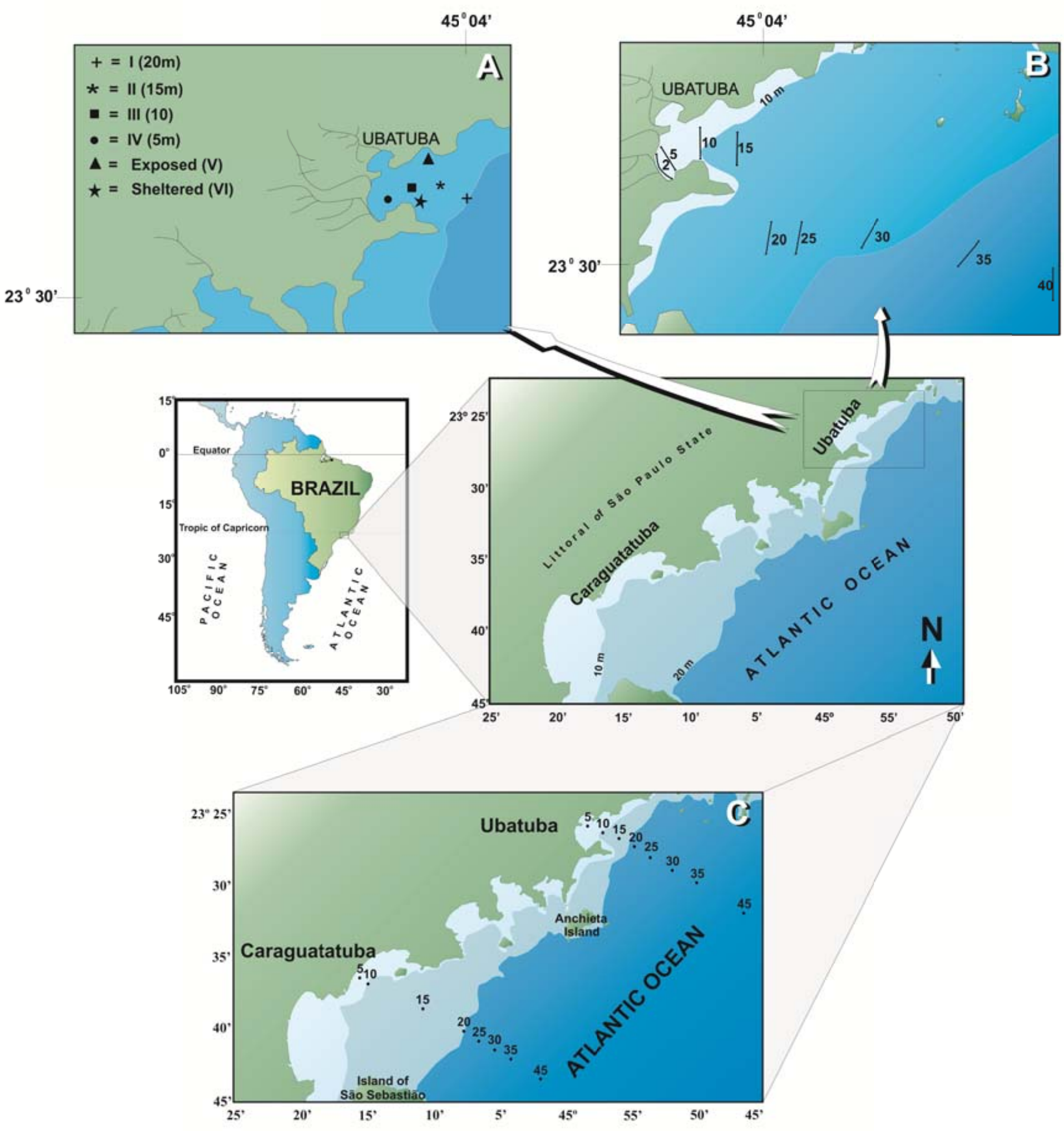

Figure 1. Map of the study region indicating the location of sampling sites. A = period of January/1998 to December/1999; B = period from January/ 2000 to December/2000; C = period from July/2001 to June/2003.

RESULTS

A total of 749 shrimps were captured from a total of 588 trawls conducted throughout the sampling period at Ubatuba (from January 1998 to June 2003; 452 individuals) and Caraguatatuba (from July 2001 to June 2003; 297). The majority of shrimps occurred in winter months, mainly in August, and lower abundance values were recorded in spring. In 2001 it was registered the greatest number of shrimps (n = 175 at Ubatuba and n = 160 at Caraguatatuba) (Table I).

During the period of 1998 and 1999, the mud content and the average grain diameter of sediment (Phi) increased with depth, that is, from 5 m to 20 m, and the exposed area had greater values of grain size and percentage of silt and clay than the sheltered area (Table II). The great number of individuals in the period of 1998 and 1999 was recorded at station VI, the sheltered area, where predominated the group of PCA and organic matter content around 6 % (Table II). In a similar way, in the year of 2000, a same pattern of sediment distribution was observed at the Ubatuba, with the deeper stations showing low values of mud content and grain size of sediment (Table III). The majority of individuals was also obtained in stations far away from the coast, with almost 53 % of the individuals collected in 2000 at stations above 30 m deep (Table III). In the period from 2001 to 2003, the highest abundance of individuals occurred at depths with a predominance of fine grains in the sediment. Shrimps were obtained at the shallowest (5 m) stations and the deepest ones (35 and 45 m) at Ubatuba; and the intermediate and deepest ones (25, 30, 35 and 45 m) at Caraguatatuba (Table IV).

Bottom temperature was, in general, lower in the deeper stations than the shallower ones, and very similar in the exposed and sheltered areas, during 1998 and 1999 at Ubatuba; winter and spring, as expected, they were the coldest seasons (figure 2). These same situations were observed in 2000, as shown in tables V and VI. Higher values of bottom temperature also occurred at shallow stations in all the four seasons in the period 2001/2003 (fig. 3). In Caraguatatuba, higher bottom temperatures at shallow stations were also common, but only in the winter bottom temperature was low at almost all stations, with slightly variation among stations (fig. 4).

The variation in the mean bottom salinity during 1998 and 1999 period is presented in figure 5. Differences among stations are evident and the station IV (5 m of depth) had the lowest mean salinities registered in all seasons. For 2000, the tables V and VI present the values of salinities and the highest mean values were recorded at the deeper stations, being summer the season showing the low mean values. Figures 6 and 7 present the mean variation of bottom salinity during 2001/2003 in Ubatuba and Caraguatatuba , respectively. In both areas the mean value of bottom salinity was lower at shallow stations than deeper ones.

Although *Sicyonia typica* was collected in the majority of stations from 1998 to 2003 at the sampled areas, most of them were retrieved at stations above the 25 m of depth. An exception was the period of 1998/1999, at Ubatuba, where a great number of individuals were sampled at the sheltered area. This fact can be seen in figure 8.

In general, shrimps' abundance did not vary seasonally or between years, but varied among stations for the period of 1998/1999 (ANOVA, $F = 12.4$, $p < 0.01$). However, the interaction between season and year was significant (table VII). Surprisingly, during the year of 2000, at Ubatuba, no differences in the shrimps' abundance were verified among stations and seasons (table VIII). On the other hand, there was a clear difference among stations in the period of 2001/2003, with higher values at station VII (35 m) (*post hoc* Tukey test, $p = 0.0025$), as well as among seasons, when during winter were recorded the higher values of shrimp abundance (table IX).

As shown in figure 9, *S. typica* was recorded mainly at sites with salinities varying from 32 to36 ‰, temperature 20-23^{0}C, high values of organic matter content and Phi values varying from 3 to 7, during the period 1998/1999. In the period of 2000, another situation was verified at Ubatuba, with a higher abundance of shrimps in sites with low organic matter content, low temperatures and high salinities values (fig. 10). Figure 11 shows the distribution of individuals in each class of abiotic parameter during 2001/2003, similar to the period of 2000.

The analysis performed using the environmental variables and the abundance of *S. typica* during 1998/1999 showed a positive association of sediment organic matter content ($t = 2.25$, $p < 0.05$) and a negative association with the Phi ($t = -3.58$, $p < 0.01$) (Table X). In the period of 2000, only the bottom salinity showed a positive association with the shrimp abundance ($t = 3.31$, $p < 0.01$) (table XI) and during 2001/2003, bottom salinity ($t = -2.2$, $p < 0.05$) and bottom temperature ($t = -2.58$, $p < 0.01$) negatively associated with shrimps' abundance as shown in table XII.

Table I. *Sicyonia typica* (Boeck, 1864). Monthly catch of shrimps in each bay and region from 1998 to 2003; and total catch for each season. UBA = Ubatuba; CAR= Caraguatatuba.

Months/ year	UBA						CAR			
	98	99	00	01	02	03	01	02	03	Season
Jan	12	0	0	0	7	2	10	12	0	Summer
Feb	3	0	0	41	5	5	0	0	4	137
Mar	12	0	7	1	1	1	9	1	4	
Apr	10	2	1	0	3	1	3	1	4	Autumn
May	9	0	11	0	1	0	38	12	2	156
Jun	5	0	3	0	7	0	0	43	0	
Jul	15	1	11	4	1	*	93	5	*	Winter
Aug	0	52	40	79	0	*	3	17	*	387
Sep	0	20	0	11	3	*	0	32	*	
Oct	2	1	2	30	0	*	4	0	*	Spring
Nov	0	0	9	8	2	*	0	0	*	69
Dec	4	4	2	1	0	*	0	0	*	
Total	72	80	86	175	30	9	160	123	14	749

* There was no sampling during those months

Table II. Sicyonia typica (Boeck, 1864). Groups of sediment classes, Phi values, quantity of mud (% silt-clay) and organic matter (%) and number of shrimp on each station sampled at Ubatuba from 1998 to 1999. The meaning of PB, PCB, PC and PCA are explained in the Material and Methods section.

Station	Phi	Group	% mud	Organic matter (%)	Number of individuals
I	3.21	PB	16	3.6 ± 3.7	8
II	3.99	PB	21.2	4.2 ± 2.6	2
III	5.29	PCB	61.9	8.0 ± 3.9	4
IV	5.74	PC	76.3	5.7 ± 2.8	4
V	4.83	PCB	47.3	7.5 ± 4.8	0
VI	3.61	PCA	36.8	6.1 ± 4.1	129
Total					147

Table III. *Sicyonia typica* (Boeck, 1864). Groups of sediment classes, Phi values, quantity of mud (% silt-clay) and organic matter (%) and number of shrimp on each station sampled at Ubatuba during 2000.

Stations (m)	Phi	Group	% mud	Organic matter (%)	Number of individuals
2	5.45 ± 0.77	PC	58.78 ± 33.53	4.73 ± 2.65	3
5	5.48 ± 0.54	PC	69.04 ± 4.76	5.2 ± 0.63	20
10	5.30 ± 0.75	PCB	62.10 ± 9.12	6.19 ± 0.48	0
15	4.52 ± 0.89	PBC	40.13 ± 2.13	4.06 ± 0.80	1
20	3.00 ± 1.18	PBA	21.81 ± 11.22	2.43 ± 2.45	2
25	3.22 ± 0.66	PB	12.89 ± 15.71	3.43 ± 3.31	2
30	2.96 ± 0.15	PB	6.19 ± 2.97	2.15 ± 0.59	15
35	2.22 ± 1.31	PBA	7.77 ± 4.80	2.66 ± 0.45	35
40	3.66 ± 0.84	PBC	19.99 ± 8.42	3.28 ± 0.96	11
Total					89

Table IV. *Sicyonia typica* (Boeck, 1864). Groups of sediment classes, Phi values, quantity of mud (% silt-clay) and organic matter (%) and number of shrimp (N) on each station (m) sampled at Ubatuba and Caraguatatuba from 2001 to 2003.

Stations	Regions									
	Ubatuba					Caraguatatuba				
	Phi	Group	% mud	Organic matter (%)	N	Phi	Group	% mud	Organic matter (%)	N
5	5.59	PC	73.72 ± 6.76	7.1 ± 2.34	51	3.88	PB	17.92 ± 22.77	1.74 ± 0.50	0
10	4.77	PCB	67.71 ± 13.58	7.1 ± 1.82	14	3.82	PB	24.07 ± 13.52	2.34 ± 1.39	0
15	4.31	PBC	33.23 ± 19.78	4.38 ± 1.54	6	5.37	PCB	64.43 ± 13.45	3.95 ± 1.02	14
20	3	PBA	12.83 ± 11.19	2.3 ± 1.02	3	4.97	PCB	54.27 ± 16.98	5.85 ± 1.48	11
25	2.71	PB	10.23 ± 7.14	1.81 ± 0.57	3	3.76	PBC	36.01 ± 18.71	4.9 ± 0.92	48
30	2.25	PBA	2.48 ± 2.93	1.68 ± 0.30	6	2.78	PBA	14.11 ± 14.90	2.5 ± 0.92	47
35	1.91	PBA	3.55 ± 4.08	1.58 ± 0.43	42	2.13	PBA	4.31 ± 2.87	2.3 ± 0.19	127
45	3.95	PB	3.16 ± 2.27	0.8 ± 0.0	89	3.15	PBA	10.28 ± 4.59	4.15 ± 1.65	50
Total					214					297

Table V. *Sicyonia typica* (Boeck, 1864). Descriptive values (mean ± sd) of the bottom temperature and salinity recorded from January to December 2000 at each sampling station in the Ubatuba.

Stations(m)	**Bottom salinity (‰)**	**Bottom temperature (^{0}C)**
2	33.05 ± 2.54	23.69 ± 3.36
5	33.69 ± 2.58	23.11 ± 2.78
10	34.50 ± 2.08	21.98 ± 2.27
15	34.52 ± 2.24	21.18 ± 2.48
20	34.44 ± 1.96	20.17 ± 1.55
25	34.55 ± 1.69	20.09 ± 1.49
30	34.97 ± 2.31	19.39 ± 1.19
35	35.05 ± 1.99	19.55 ± 1.28
40	35.36 ± 1.96	19.01 ± 1.22
Exposed	34.1 ± 2.3	22.6 ± 2.9
Sheltered	34.1 ± 2.7	22.9 ± 3.0

Table VI. *Sicyonia typica* (Boeck, 1864). Descriptive values (mean ± sd) of the environmental factors recorded in each season of 2000.

Year Season	**Bottom salinity (‰)**	**Bottom temperature (^{0}C)**	**Phi**	**Organic matter (%)**
Summer	33.74 ± 1.50	22.28 ± 3.58	4.00 ± 1.33	3.77 ± 2.00
Autumn	34.22 ± 1.34	21.82 ± 2.51	3.79 ± 1.59	3.29 ± 1.68
Winter	36.92 ± 1.02	19.96 ± 1.10	4.11 ± 1.44	3.99 ± 2.25
Spring	32.96 ± 2.33	19.58 ± 1.14	4.00 ± 1.40	3.86 ± 2.25

Table VII. *Sicyonia typica* (Boeck, 1864). Results of the analysis of variance (ANOVA) of the mean catch by stations, year and season of the sampling period from 1998 to 1999.

Source	**df**	**MS**	**F**	**p**
Season	3	0.68	1.09	0.353506
Station	5	7.67	12.4	0.000000
Year	1	1.36	2.19	0.141304
Season x Station	15	0.63	1.01	0.443840
Season x Year	3	2.71	4.38	0.006120
Station x Year	5	0.18	0.29	0.914524

df = degrees of freedom, MS = mean square, F = MS factor/MS residual and p = probability of significance; α = 0.05.

Table VIII. *Sicyonia typica* (Boeck, 1864). Results of the analysis of variance (ANOVA) of the mean catch by station and season of the sampling period from January to December 2000.

Source	**df**	**MS**	**F**	**p**
Season	3	2.13	2.27	0.087651
Station	8	4.7	1.88	0.076217
Season x Station	24	4.57	0.6	0.913255

df = degrees of freedom, MS = mean square, F = MS factor/MS residual and p = probability of significance; α = 0.05.

Table IX. *Sicyonia typica* (Boeck, 1864). Results of the analysis of variance (ANOVA) of the mean catch by station, season and region of the sampling period from 2001 to 2003 at Ubatuba and Caraguatatuba.

Source	**df**	**MS**	**F**	**p**
Season	3	1.19	2.95	0.032863
Station	6	1.85	4.59	0.000181
Region	1	0.18	0.46	0.495642
Season x Station	18	0.47	1.16	0.291110
Season x Region	3	0.83	2.07	0.104288
Station x Region	6	1.59	3.95	0.000816

df = degrees of freedom, MS = mean square, F = MS factor/MS residual and p = probability of significance; α = 0.05.

Table X. *Sicyonia typica* (Boeck, 1864). Results of the multiple regressions for the association between environmental factors and the number of individuals from 1998 to 1999 at the Ubatuba.

Environmental factors	**t**	**p**
Bottom temperature	1.11	0.268587
Bottom salinity	-0.87	0.383879
Sediment organic matter	2.25	0.025911
Phi (sediment)	-3.58	0.000465

p = probability of significance; α = 0.05.

Table XI. *Sicyonia typica* (Boeck, 1864). Results of the multiple regressions for the association between environmental factors and the number of individuals during 2000 at the Ubatuba.

Environmental factors	**t**	**p**
Bottom temperature	0.63	0.524593
Bottom salinity	3.31	0.001294
Sediment organic matter	-0.55	0.582934
Phi (sediment)	0.92	0.359249

p = probability of significance; α = 0.05.

Table XII. *Sicyonia typica* (Boeck, 1864). Results of the multiple regressions for the association between environmental factors and the number of individuals from 2001 to 2003 at the Ubatuba and Caraguatatuba.

Environmental factors	**t**	**p**
Bottom temperature	-2.58	0.010190
Bottom salinity	-2.2	0.028364
Sediment organic matter	0.04	0.961080
Phi (sediment)	-1.2	0.227751

p = probability of significance; α = 0.05.

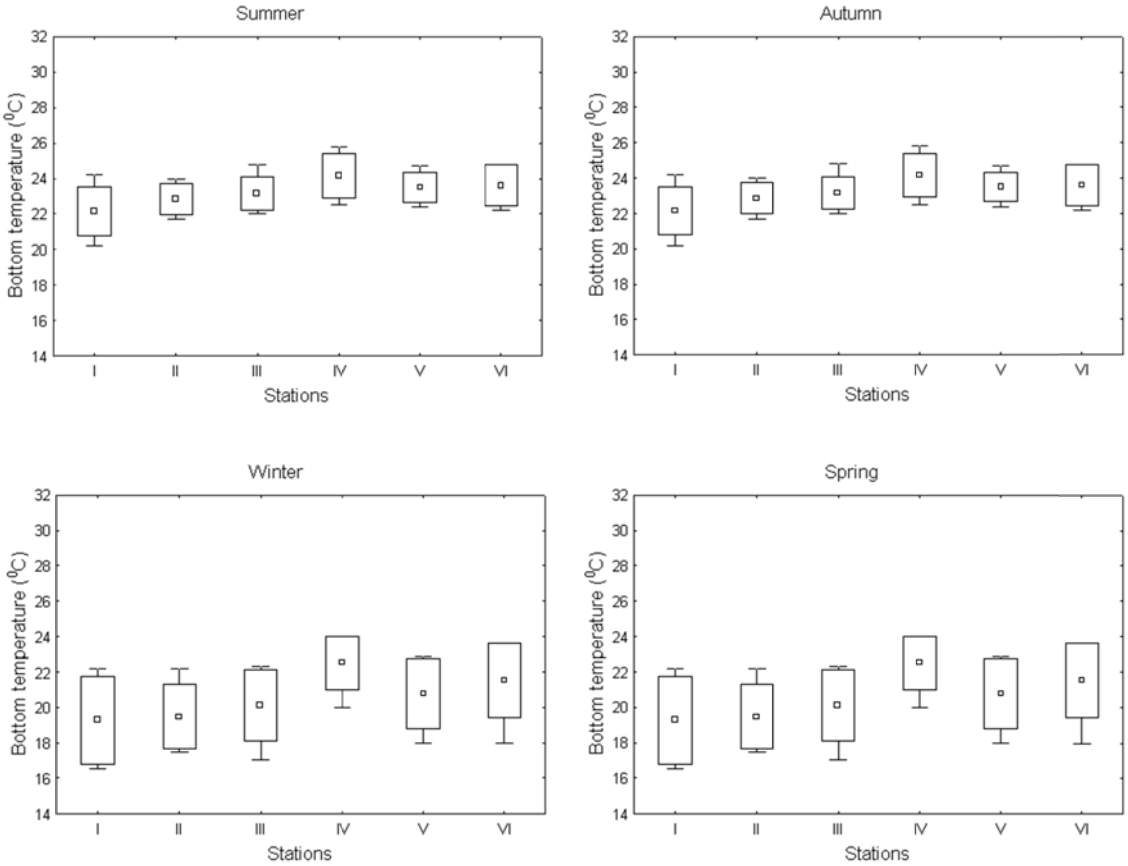

Figure 2. Bottom temperature, mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 1998 to 1999.

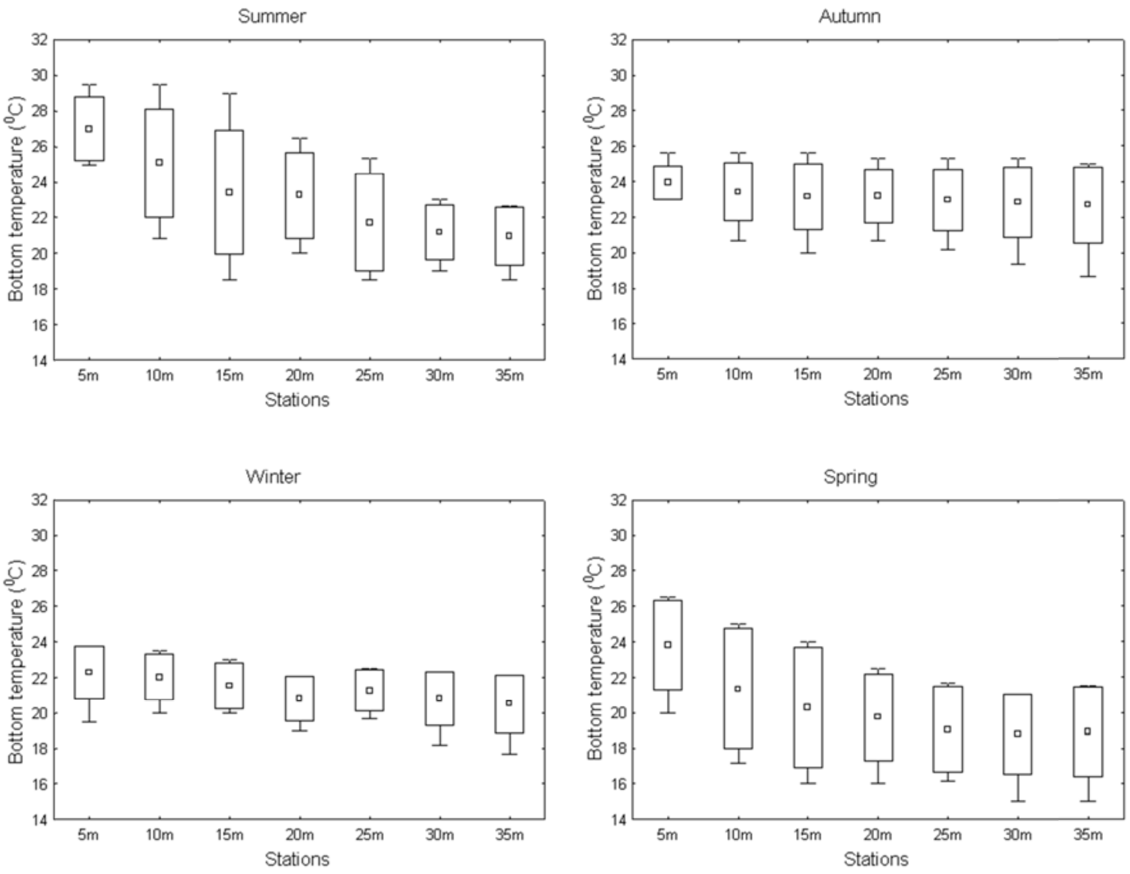

Figure 3. Bottom temperature, mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 2001 to 2003 at Ubatuba.

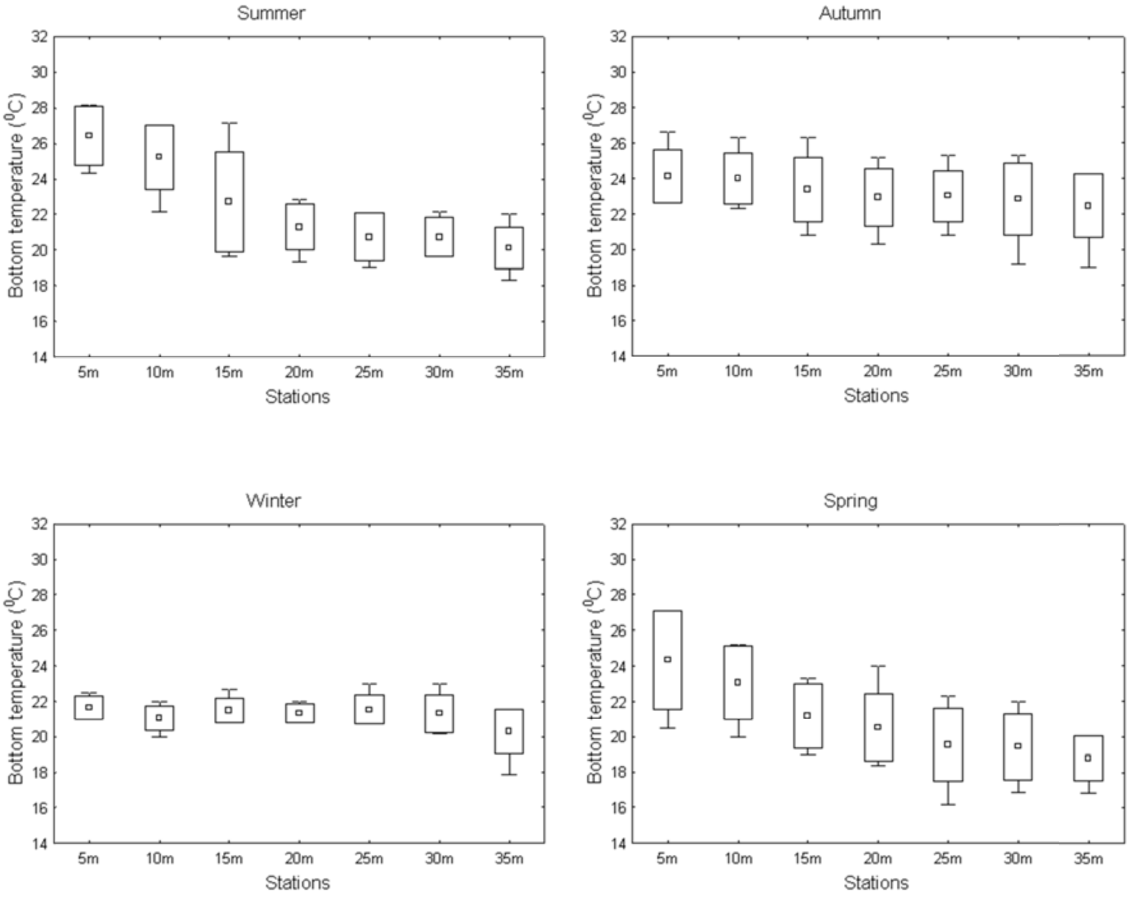

Figure 4. Bottom temperature, mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 2001 to 2003 at Caraguatatuba.

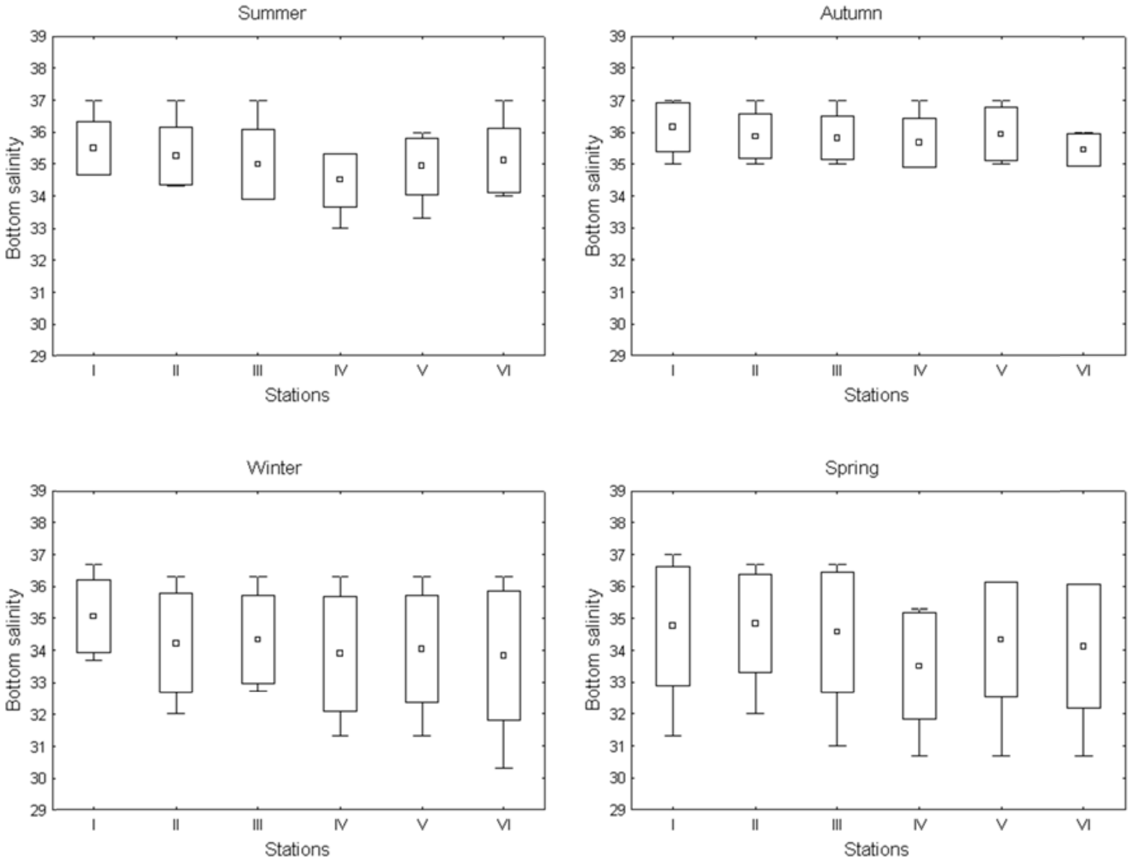

Figure 5. Bottom salinity (‰), mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 1998 to 1999 at Ubatuba.

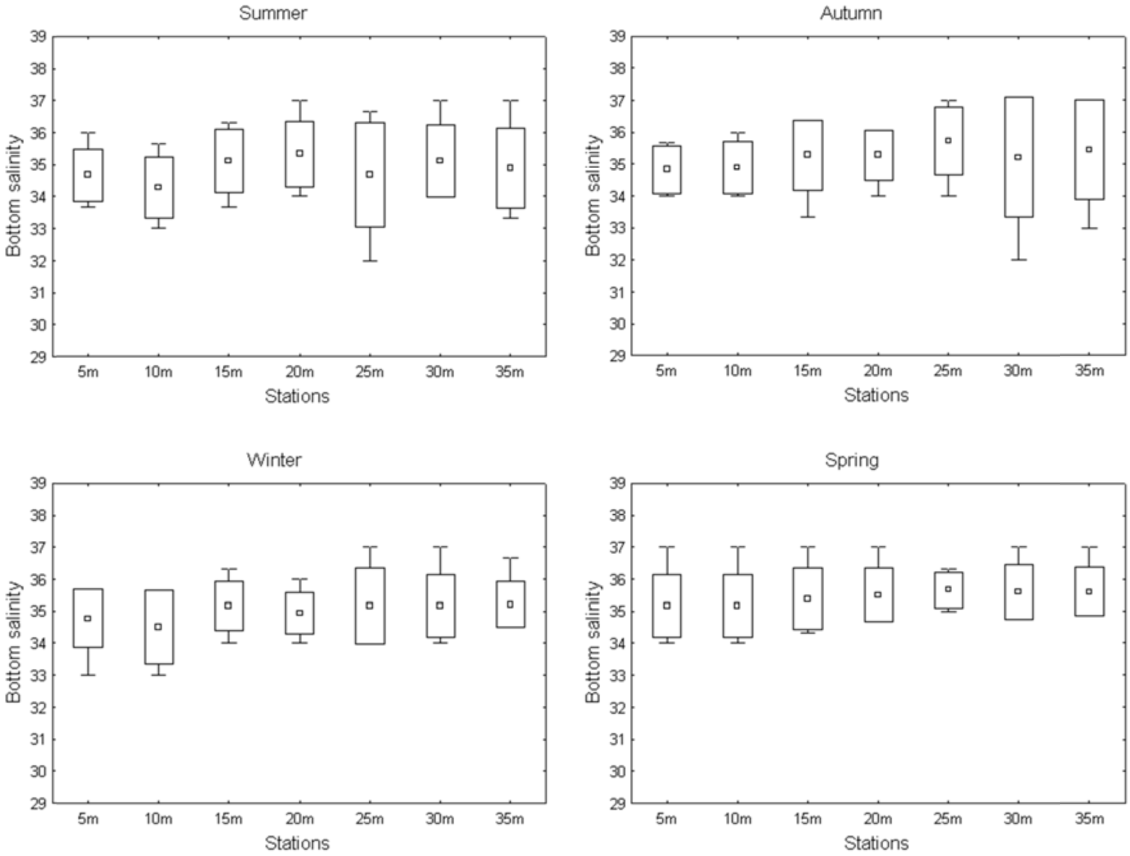

Figure 6. Bottom salinity (‰), mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 2001 to 2003 at Ubatuba.

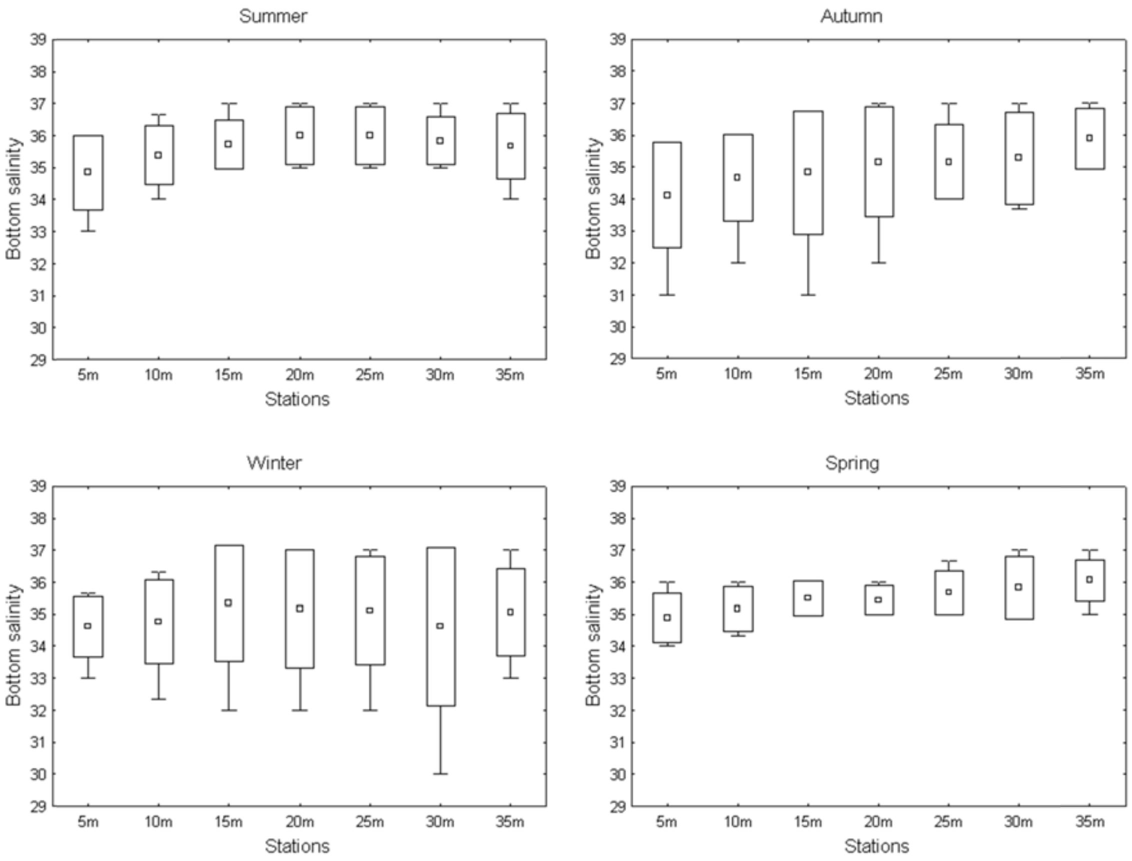

Figure 7. Bottom salinity (‰), mean, standard variation, maximum and minimum values for each station and season of the year during the sampling period from 2001 to 2003 at Caraguatatuba.

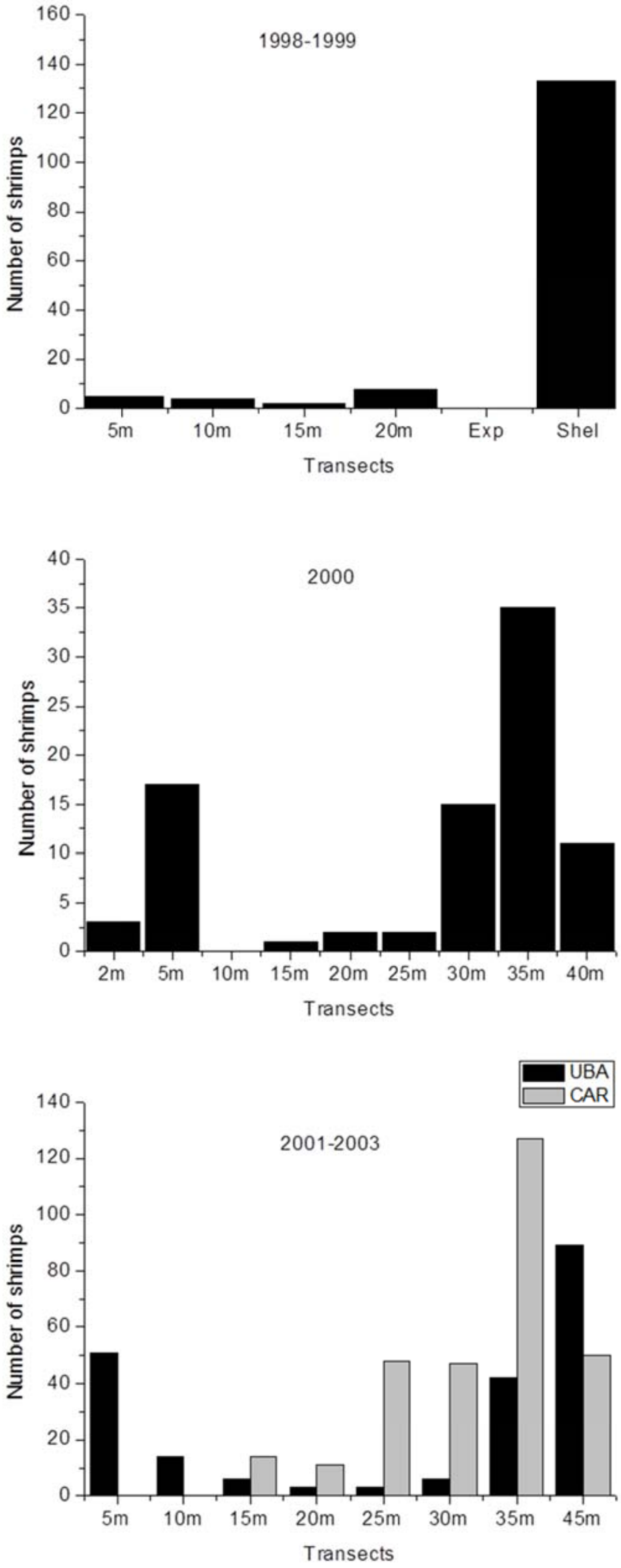

Figure 8. *Sicyonia typica* (Boeck, 1864). Number of shrimps obtained at each station (depth) during each campaign of sampling. Dark bars (UBA) = Ubatuba; Gray bars (CAR) = Caraguatatuba.

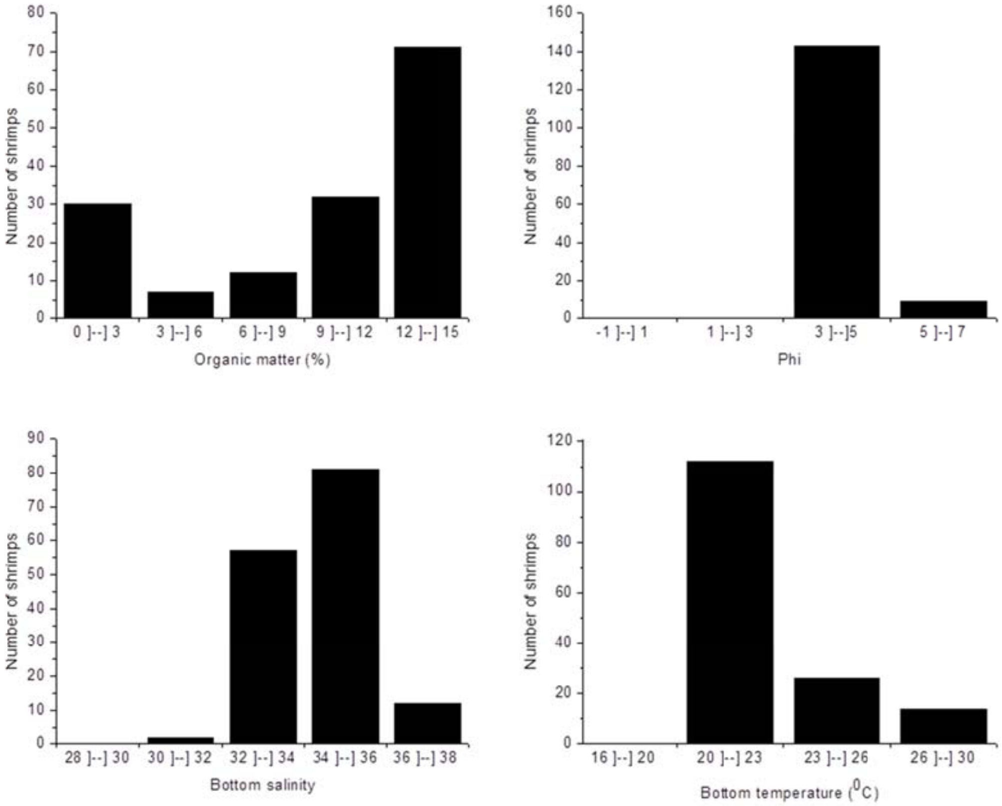

Figure 9. *Sicyonia typica* (Boeck, 1864). Distribution of the number of shrimps in each class of environmental factor recorded during 1998 and 1999 at Ubatuba.

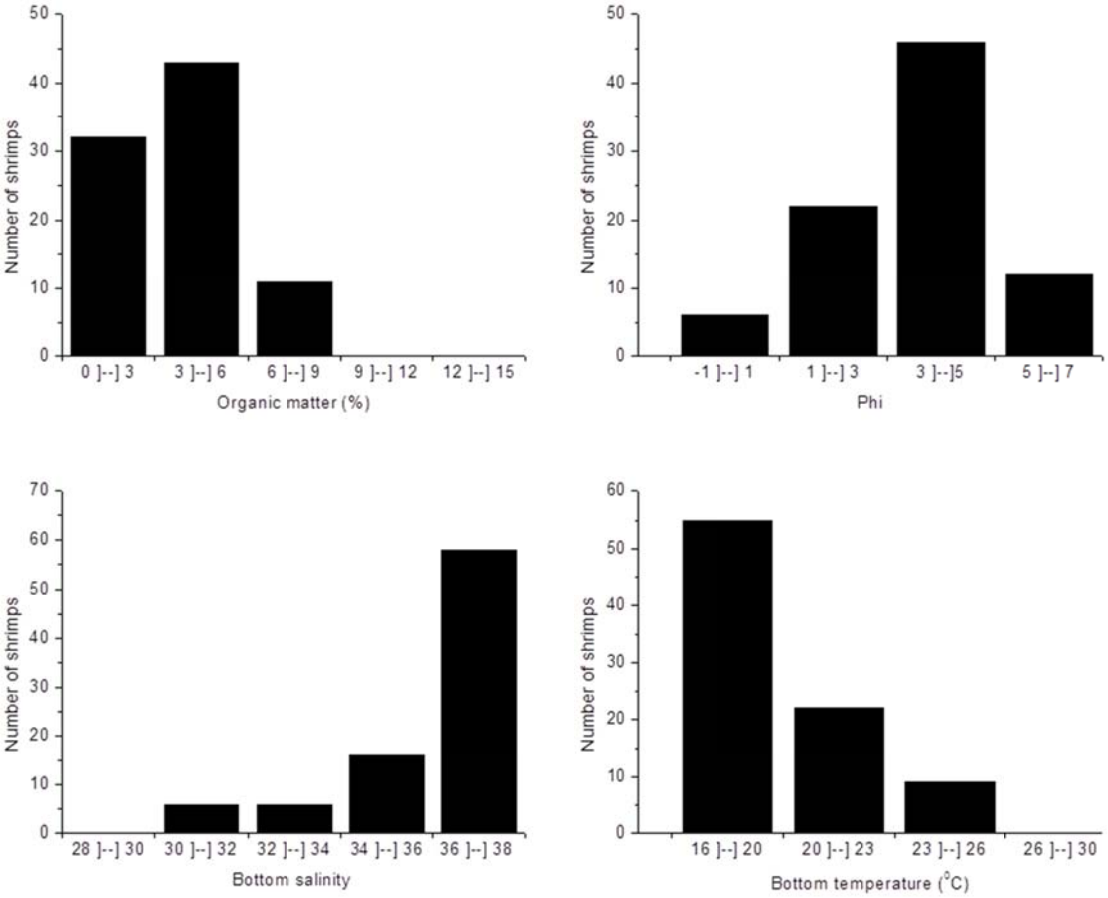

Figure 10. *Sicyonia typica* (Boeck, 1864). Distribution of abundance of shrimps in each class of environmental factor recorded from January to December 2000 at Ubatuba.

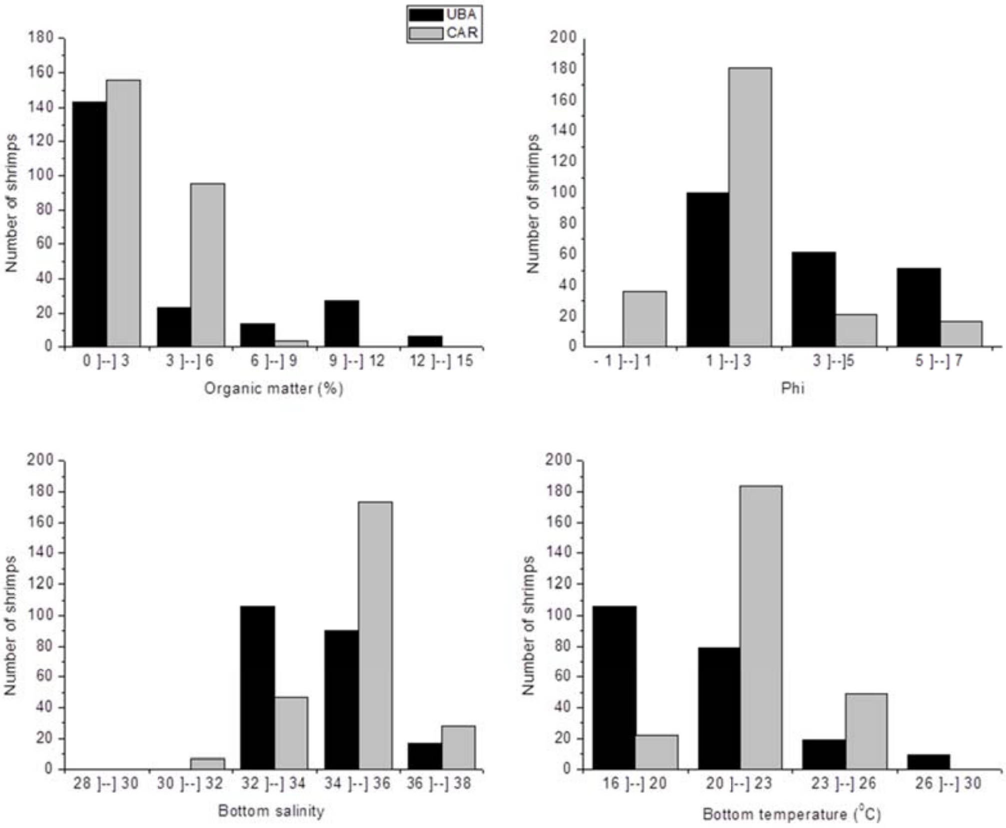

Figure 11. *Sicyonia typica* (Boeck, 1864). Distribution of the number of shrimps in each class of environmental factor recorded from 2001 to 2003 at Ubatuba and Caraguatatuba areas. Dark bars (UBA) = Ubatuba; Gray bars (CAR) = Caraguatatuba.

DISCUSSION

According to various authors (Boschi, 1963; Dall *et al.* 1990; Nakagaki *et al.* 1995; Fransozo *et al.* 2004), the spatial and temporal distributions of penaeoidean shrimps are strongly modulated by the action and variation of environmental factors. In the present study, bottom temperature, bottom salinity and sediment texture can be considered as key factors underlying the ecological distribution of *S. typica* in the two areas investigated at the north coast of São Paulo state. This can be evidenced by the high abundance of this species in sites characterized by low and intermediate temperature, high salinity and substrates with fine grain sizes.

Species of the genus *Sicyonia* can inhabit on a variety of substrates under the continental shelf or down to the continental slope (D'Incao, 1995). Kennedy *et al.* (1977), studying a population of *S. brevirostris*, found that that species prefers sediments with fine to medium grained, corroborating the results obtained for *S. typica* in the present study. In the Ubatuba, during the period of 1998/1999, the positive association of the shrimp with organic matter content (%) reflected the presence of mud in the substrate, which is a consequence of the small size of grains that retains great quantities of dissolved organic matter. Castilho *et al.* (2008) obtained similar results for *S. dorsalis* investigated in that same area. In a study of energy gradient of bays in Ubatuba region, Mahiques *et al.* (1998) found that the sediments contain mainly silt and very fine sand distribution, which is consistent with our results.

The spatial distribution is closely related to the sediment texture for the majority of penaeoidean species. They have the habit of burrow into the soft bottom substratum (looking for protection against predators) (Castilho *et al.* 2008) and they could ingest some of it (Lemonnier *et al.* 2004), but this behavior does not influence with breathing activity (Costa & Fransozo, 2004). At Ubatuba there are large quantities of fine sediment grains because of the low circulation of water, and the grains are becoming larger offshore due to the action of marine currents (Tables II and III). At Caraguatatuba, according to Furtado & Mahiques (1990) and Pires-Vanin *et al.* (1993), there is more quantity of fine sediments as far as 35 m of depth due to physical barriers such as some islands, which prevent the transport of fine sediments. Other penaeoideans as *Rimapenaeus constrictus* (see Costa & Fransozo, 2004) and *Fenneropenaeus indicus* do not burrow on very soft sediments because they are unable of controlling the water circulation on branchial chamber, whilst for *S. typica* does not seem to be a problem (Brandford, 1981; Penn, 1984). However, there are cases in which the sediment characteristics and organic matter do not affect the abundance of a shrimp species, as the case of the caridean *Nematopalaemon schimtti* that occurs in the same region of this study (Fransozo *et al.* 2009).

Temperature is directly related to movement, feeding, growth and survival of penaeoids (Dall *et al.* 1990). Most most of specimes of *S. typica* were collected in the deepest areas of Ubatuba and Caraguatatuba , with relatively high bottom salinity and low temperature, where the sediments were composed by very fine sand and low or high organic matter content. With this pattern of spatial distribution, we can conclude that *S. typica* shows a life cycle of type III, according to Dall *et al.* (1990), in which individuals of the populations are restricted to true marine environments, usually migrating from inshore to offshore areas over their ontogeny. Considering the first three years of the study, only in the first one there were a large number of individuals on summer at Ubatuba, being winter the season of a high number of individuals in 1998, 1999 and 2000, when they were recorded the lowest values of bottom temperatures. The campaign of 2001/2003 at Ubatuba and Caraguatatuba areas showed a high number of individuals in the Caraguatatuba during autumn in 2001 and 2002; but in winter, Ubatuba had a high number of shrimps only in 2001. We can propose that if there is a migration of *S. typica* northward, this movement is not annual. For *S. dorsalis*, a species that coexist in the exactly same region of *S. typica*, there is a migration from south to north, mostly influenced by the intrusion of SACW every year, changing the bottom conditions of the environment (Castilho *et al.*, 2008). As the study region is strongly influenced by three water currents: SACW, South Atlantic Central Water, with low temperature and salinity ($T < 20^0C$; $S < 36‰$), CW, Coastal Water, with high temperature and low salinity ($T > 20^0C$; $S < 36‰$) and TW, Tropical Water, with high temperature and high salinity ($T > 20^0C$; $S > 36‰$) (Castro-Filho *et al.* 1987), Pires (1992) observed that the influence of SACW, mainly during summer months, is critical for the distribution of any decapod species in Ubatuba, which was not verified for *S. typica*, at least in the first three years of samples (tables X and XI). In the last campaign of samplings (2001/2003), the obtained results indicated for the two regions (UBA and CAR) that on spring the mean bottom temperatures reached about 17 ^{0}C in the deeper stations as a consequence of the SACW entrance. This transport of water masses certainly shifted the physicals conditions of the substrate and influenced the distribution of *S. typica*. During the summer of 1998 and 2001, the abundance of *S. typica* was higher than the other years, and this fact can be attributed to the intrusion of SACW, always below 20 ^{0}C, from deeper areas to shallower coastal zones (Castro-Filho *et al.*, 1987).

Other authors have reported the action of SACW affecting the dynamic of abundance of decapod species as *Xiphopenaeus kroyeri* (Heller, 1862), studied by Nakagaki & Negreiros-Fransozo (1998), Castro *et al.* (2005) and Costa *et al.* (2007); *Artemesia longinaris* Bate, 1888 (Fransozo *et al.*, 2004) and Costa *et al.* (2005); *Rimapenaeus constrictus* (Stimpson, 1874) (Costa & Fransozo, 2004); *Pleoticus muelleri* (Bate, 1888) (Costa *et al.*, 2004); *Exhippolysmata oplophoroides* (Holthuis, 1948) by Fransozo *et al.* (2005) and *Litopenaeus schmitti* (Burkenroad, 1936) by Fransozo (2011).

The association of bottom salinity with the abundance of shrimps was not verified in the first two years (1998/1999), but it was positive during 2000 and negative in the next period (2001/2003), which can be considered an interestingly result. Other species of *Sicyonia* showed the capacity of living in a variety of salinities conditions as *S. brevirostris* studied by Kennedy *et al.*, (1977) and *S. dorsalis* by Castilho *et al.*(2008). With the data obtained in the present study, it is not possible to distinguish a preferred area with a specific salinity where the occurrence of *S. typica* is higher. We found individuals in sites with salinities varying from under 32 ‰, to areas with salinity above 36 ‰, characteristics of a euryhaline species. Castilho *et al.* (2008) also found for *S. dorsalis* that the bottom salinity was not significant associated with shrimp abundance, otherwise other factors as temperature and sediment texture.

Beyond of the majority shrimps being collected in deeper sites of Ubatuba and Caraguatatuba areas during the campaign of 1998/1999, a high number of shrimp was sampled at station VI, which we called as sheltered site. Therefore, *S. typica* demonstrated a great degree of attraction for sheltered habitats. It is a relevant result, since the sheltered part of Ubatuba bay can provide important sites for *S. typica* spawning or searching food. Costa & Fransozo (2004), studying *R. constrictus,* and Castilho *et al.* (2008), *S. dorsalis,* found a similar behavior that agrees with this hypothesis.

It was not verified a significant difference in abundance between the Ubatuba and Caraguatatuba areas during the period of 2001/2003 (table IX). Probably, the movements of the *S. typica*, population are not predictable that we can establish a pattern. This rock shrimp seems to have a complex nature of movements and, in the present study we, maybe, have not chosen the appropriate scales to verify a pattern of migration. Highly mobile species, as some decapod crustaceans, exhibit movement patterns that sometimes are thought to be critical for the maintenance of populations in an area (Acosta, 1999; Pittman & McAlpine, 2001). Certainly, *S. typica* performs movements for home range activity and movements associated with ontogenetic shifts, spawning migrations and planktonic eggs and larvae, as many species of penaeoids shrimps, but, with the results presented here it was not possible identify a trend in population movements, probably due to the scale selection used.

The abundance proportion of *S. typica* found here in the north coast of São Paulo state differs from the abundance proportion of its congeneric and sympatric species *S. dorsalis,* studied by Castilho *et al.* (2008). It is probable that *S. dorsalis* found better conditions to occur in the sampled area. According to D'Incao (1995), *S. typica* occurs at depths from shallow waters to 101 m in the Brazilian waters, whereas *S. dorsalis* have the highest abundance at 80 m of depth. It seems that both species are more common at deeper areas than of those sampled in the present study. As both species are considered product of "bycatch", only a research in which *Sicyonia* spp. will be the target species could explain better its pattern of distribution along the continental shelf and slope.

To our knowledge, we have provided the first estimates of *S. typica* abundance in the north coast of São Paulo state. The spatial and temporal distribution of its species seems to be closely related to physical environment features as water temperature, salinity and properties of the sediments. However, other factors (i.e. food resources, competition, predation, physiology, diseases, and toxic substances, among others) may be modulating the general biology of this penaeoid shrimp, including its distribution pattern. Unfortunately, other parameters as food type, pH of sediment and vegetation cover were not measured in the present study. Then, although the measured factors can provide a convincing explanation about the species' ecological distribution, more information could reveal important causes of its distribution pattern.

We propose experimental studies with *S. typica* evolving inter and intra-specific relationships with physical and chemical characteristics of the environment to clarify the principal (or the group of) factors that really influences its distribution. Indeed, samplings in depth far away the 45 m, where we think that there are a higher abundance of *S. typica*.

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CAPÍTULO 3

POPULATION STRUCTURE AND GROWTH OF THE ROCK SHRIMP *SICYONIA TYPICA* (BOECK, 1864) (DECAPODA, PENAEOIDEA) IN THE NORTHERN COAST OF SÃO PAULO STATE, BRAZIL

ABSTRACT

The rock shrimp *Sicyonia typica* (Boeck, 1864) is one of the species rejected in the shrimp fishery of the southeast coast of Brazil. The objective of the present study was to investigate the population structure and growth of this species. The population patterns were examined from data collected monthly by bottom trawl surveys at 8 stations in Caraguatatuba and Ubatuba regions from July 2001 to June 2003. Population parameters from histograms of frequency distributions by carapace size classes and size (carapace length = CL) at onset of the sexual maturity were analyzed. The degree of gonadal development was also assessed. The shrimps mean size of CL were similar for both regions (CL = 11.62 mm Ubatuba region; CL = 11.94 Caraguatatuba region). Females attained larger sizes than males suggesting a sexual dimorphism related to body size. This study also revealed a female-biased sex ratio (1: 0.61). Reproductive females were more abundant during winter months and the recruitment seems to occur 2-3 months after the spawning season, around October. A trend indicates that the population follows a tropical/subtropical reproductive pattern, with breeding activity almost throughout the year but with a peak of reproduction in a certain period (winter months). The von Bertalanffy growth parameters were estimated only for females (CL_∞ = 17.29; K = 0.0125; t_0 = - 0.167 and longevity = 1.01 year) and they were similar with other *Sicyonia* shrimps species. Further studies should be accomplished on growth parameters of males to clarify the overall population structure and growth.

KEYWORDS: von Bertalanffy growth function, sex-ratio, reproductive females, trawl fishing.

RESUMO

O camarão pedra *Sicyonia typica* (Boeck, 1864) é uma das espécies que é descartada como um subproduto da pesca do camarão na costa sudeste do Brasil. O objetivo do presente estudo foi investigar a estrutura e o crescimento da população desta espécie. Os padrões populacionais foram examinados a partir de dados coletados mensalmente por arrastos de fundo em 8 estações de coleta na região de Ubatuba e Caraguatatuba, de Junho de 2001 até Julho de 2003. Os parâmetros populacionais obtidos a partir das distribuições de frequência por classes de tamanho de carapaça (CL = comprimento da carapaça) e o tamanho no qual atingem a maturidade sexual foram analisadas. O grau de desenvolvimento gonadal também foi verificado. O tamanho médio de CL foi similar para ambas as regiões (CL = 11,62 mm região de Ubatuba; CL = 11,94 região de Caraguatatuba). Fêmeas atingiram tamanhos maiores que machos sugerindo um dimorfismo sexual relacionado ao tamanho corpóreo. Este estudo também revelou uma razão sexual desviada para as fêmeas (1: 0,61). Fêmeas reprodutivas foram mais abundantes durante os meses de inverno e o recrutamento parece acontecer de 2-3 meses depois da estação de desova, por volta de Outubro. Uma tendência indica que a população segue um padrão de reprodução característico de regiões tropicais/subtropicais, com atividade reprodutiva quase que constante ao longo do ano, mas com um pico reprodutivo em certo período (meses de inverno). Os parâmetros de crescimento de von Bertalanffy foram estimados apenas para as fêmeas (CL_∞ = 17,29; K = 0,0125; t_0 = - 0,167 e longevidade = 1,01 ano) e foram similares aos de outras espécies de camarões do gênero *Sicyonia*. Estudos adicionais sobre parâmetros de crescimento dos machos desta espécie deverão ser realizados para esclarecer de modo completo a estrutura e crescimento desta população.

PALAVRAS-CHAVE: função de crescimento de von Bertalanffy, razão sexual, fêmeas reprodutivas e pesca de arrasto.

INTRODUCTION

The penaeoids shrimps are the most important economic resource in the world’s crustacean fishery industry accounting for more than half of the gross of shrimp production and comprise an important component of tropical fisheries, from both economical and social standpoints (Aragón-Noriega & García-Juárez, 2007; Hossain & Ohtomi, 2008). However, the shrimp fishery is responsible for the largest bycatch among all fishing gears in the world (Keunecke *et al.* 2007). The rocky shrimp *Sicyonia typica* is an epibenthic decapod crustacean with a wide geographic distribution which covers the western Atlantic from the east USA to the south of Brazil (D’Incao, 1995). It is not a species with a commercial interest for the trawl fishery in Brazil, but is accidentally captured and rejected during this practice. Its life history is poorly known and published information on this species in western Atlantic Ocean is very scarce.

Marine invertebrate populations are characterized by dynamic properties which are, in fact, evolutionary answers to environmental changes (Silva *et al.* 2007). For *S. typica* there are biological aspects that must be studied on order to improve our knowledge about its life cycle. One of the main goals in the study of biology of benthic crustaceans is to describe trends in population structure and growth (Castilho *et al.*, 2007). Studies on population structures provide an instantaneous vision at certain point in time, due to birth, death and individual migrations (Ricklefs, 1996). Among carcinologists, a common way to describe the structure of a certain population is the use of size classes’ graphs or age frequency distributions, which can provide a value of animal growth, period and intensity of spawning and recruitment as well as possible seasonal variations (Pianka, 1983; Leme & Negreiros-Fransozo, 1998; Yamaguchi, 2001; Silva *et al.*, 2007).

The sex ratio is also a feature that reflects the balance of a population. In general, a proportion of 1:1 is expected (Fisher, 1930) once an individual progeny of male or female has an equal opportunity to be generated (Wilson & Pianka, 1963). After birth, several factors (i.e. biotic and environmental characteristics) can affect this relationship and bias the occurrence of one sex (Litulo, 2005).

Another critical aspect of a population that can reveal its interaction with the environment is the beginning of the reproductive phase, which represents a critical event in the individual's life history (Silva *et al.*, 2007). For decapod crustaceans and other animal groups, the size of morphological maturity can be based on the analyses of biometric relations, observation of gonad maturation or the proportion of 50 % sexually mature (Crocos *et al.*, 2001; Cha *et al.*, 2004; Silva *et al.*, 2007). This information is essential to classify the individuals of each sex of a population in demographic size groups and evaluate, for example, variations in the spatial and temporal distribution of spawning activity (Crocos *et al.*, 2001). It is also possible to consider the age structure of the shrimp stock and spawning stock recruitment, and estimate the size of the effective spawning stock.

The energy budget of an individual is used in amounts directed to the body biomass, in the juvenile phase, and to the body mass and reproductive features in the adult phase (Fonteles-Filho, 2011). In exploited populations is important to determine the individual size variation in function of age (growth function) and this kind of study has been approached in the literature (Chu *et al.*, 1993; D'Incao & Fonseca, 1999; Peréz-Castañeda & Defeo, 2005). According to Fonseca & D'Incao (2003), the asymptotic length of the von Bertalanffy growth curve has biological significance and it is proposed to validate the crustacean growth curves by longevity estimates. The growth parameters are then estimated by modal progression analysis. The achievement of biological parameters through the growth model of von Bertalanffy (1938) can provide mortality rates in a population and the relationship between size and age of the individuals, helping to get a sustainable harvest of crustacean species (Keunecke *et al.*, 2008).

As shrimps respond quickly to environmental changes and have a relative short life cycle (~2 years), they constitute an excellent model to study variations in growth, mortality, recruitment, catch ability and reproductive cycle (Lopéz-Martinez *et al.* 2005). These variations must be considered in the fishery models employed to evaluate this resource and one could consider the variation as being a result of evolutionary forces and/or a more immediate plastic response to environmental factors (Begon *et al.*, 2006).

With the decline in landings of commonly exploited crustacean species as the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez-Farfante, 1967), the white shrimp *Litopenaeus schmitti* (Burkenroad, 1938) and the “seabob” shrimp *Xiphopenaeus kroyeri* Heller (1862) along the coast of São Paulo state, other penaeoids with a potential for fishing are now focus of populational researches, as the case of *Artemesia longinaris* Bate, 1888, and other species of the genus *Sicyonia*.

Growth parameters differ between species but they may also vary from populations within the same species. In other words, growth parameters can take different values in different parts of its range of occurrence (Sparre & Venema, 1992). Therefore, the aim of this study was to determine the structure, growth and longevity of the *S. typica* population, to describe the sex ratio and to analyze the distribution of the reproductive females and recruit juveniles in two regions (Ubatuba and Caraguatatuba) from the northern coast of São Paulo, Brazil, verifying possible differences between these two regions. Some environmental factors such as salinity, bottom temperature, sediment texture and organic matter were measured and analyzed in relation to the abundance of the reproductive females and recruit juveniles at both localities.

MATERIAL AND METHODS

The fieldwork took place at two locations (UB – Ubatuba and CA - Caraguatatuba) of the northern coast of São Paulo state (Brazil). Monthly samples were taken from July 2001 to June 2003 in each location (UB: 23^0 26’ 27’’- 45^0 03’ 18’’; CA: 23^0 36’ 09’’- 45^0 20’ 25’’). Located along the northern coastline of São Paulo state, the region is an important area for crustacean research because of its high decapod fishing effort. Seven stations were sampled in each location that covered a depth range of 5 to 35 m (Figure 1). A shrimp-fishing boat equipped with two double-rig nets (mesh size 20 mm and 15 mm in the cod end) was used at a towing speed of 1.5 knots (sufficient to prevent significant escape from the nets) for trawling, which lasted for 30 minutes in each transect.

Salinity, temperature, depth and sediment characteristics were measured at each station. A detailed description of the sampling methods and an analysis of environmental parameters during the study period are available elsewhere.

The samples were preserved in 70 % ethanol for storage. Specimens were identified to species following morphological criteria provided by Pérez-Farfante & Kensley (1997), sexed and measured in the laboratory. Size of *S. typica* was recorded as carapace length (CL), measured as the linear distance from the postorbital margin to the median posterior edge of the carapace to the nearest 1 mm. Length-frequency distributions were based in CL and were constructed using 1 – mm intervals of this variable (CL).

Adult females were determined visually by macroscopic observation of the degree of ovarian development (color and volume occupied by the gonads). Ovaries were categorized as immature when were thin, from transparent strands to thicker strands. The reproductive stage of males was assessed by examining the shape of the petasma, which is fused in adult individuals (Boschi & Scelzo, 1977). Size at sexual maturity (CL_{50}), corresponding to a proportion of 50 % sexually mature, was also calculated. The relative frequency (%) of adult females and males in each size class were plotted and the logistic function:

$y = 1/1 + e^{r(CL - CL50)}$ was fitted to data.

The proportion of males to females was tested by the χ^2 test (Zar, 1999). The mean carapace length of individuals in each month was compared between the male and female, by means of Student's *t*-test. Normality was checked with the Shapiro-Wilk test (Zar, 1999). Shrimps were classified into four groups: (1) recruits, with CL ≤ 9.9 mm; (2) non reproductive females, with CL > 9.9 mm, but not developed gonads; (3) reproductive females, with CL > 9.9 mm and developed gonads and (4) adult males, with CL > 9.9 mm. The juvenile shrimps and adult reproductive females (demographic groups) whose were significant related spatial-temporally with the abiotic factors were showed and positioned geographically using the software ‘Surfer’ (8.0 version, Golden software, California). Also, the proportion of reproductive females was plotted with the abiotic parameters in order to identify any pattern of spatial distribution related to depth.

The analyses of population growth was performed for both sexes separately and the modes were calculated using the software ‘Peakfit’ 4.0 that adjusts the observed frequencies to the normal curves, in a way that the mean values and the adjusted modes will be the same ones.

Growth was estimated through modal progression analyses (MPA), using a length-class interval of 1 mm of CL to obtain histograms. The growth pattern of the population was described, separately for males and females, using the modified von Bertalanffy growth function (Pauly & Gaschutz, 1979):

$$L_t = L_\infty \left[1 - e^{-k\,(t - t0)} \right],$$

where L_∞ is the asymptotic length, K is the intrinsic growth rate and t_0 is the age at which the length of shrimps is 0. The criteria used to validate a cohort were the biological coherence with life cycle of species (coherent estimate of longevity based on the duration of a cohort in time and values suggested in the literature) and statistical significance of the adjustment to VBGM ($F_{calculated} > F_{critical}$).

Longevity was estimated for each curve by inverted VBGM with the modification suggested by D’Incao & Fonseca (1999), considering $t_0 = 0$ and $TLi/L_\infty = 0.99$. The equation of longevity is given by: $longevity_{max} = 0 - (1/\,k)\ Ln\ [1 - (TL_i/TL_\infty)]$. The maximum longevity was considered as a function of the annual growth coefficient (k).

Any differences in the size-frequency distributions of the population between the two sampling years, sexes and locations were determined by the Kolmogorov-Smirnov two sample test (Sokal & Rohlf, 1995) using STATISTICA Ver. 6.0.

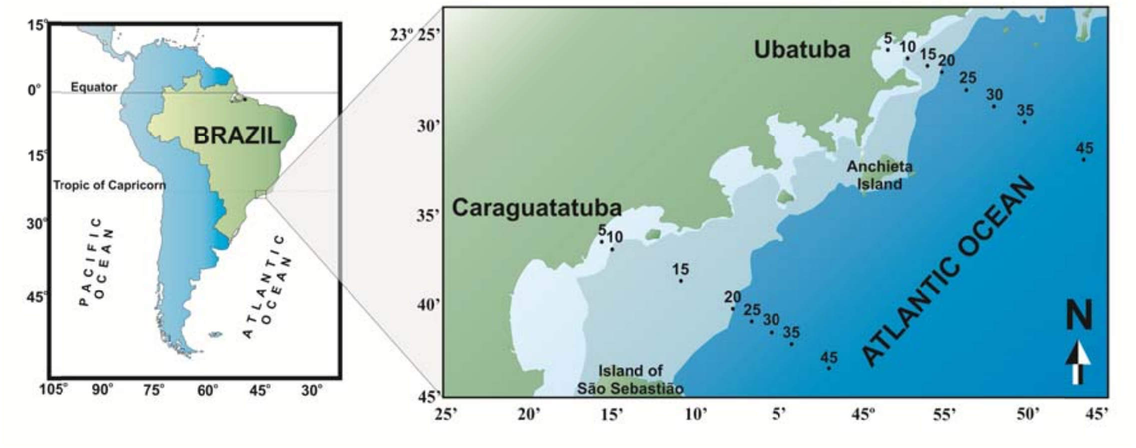


Figure 1. Study locations with the indication of the sampling stations at Caraguatatuba and Ubatuba, São Paulo littoral.

RESULTS

A total of 399 shrimps were sampled in the studied period (230 at Caraguatatuba region and 169 at Ubatuba region). The sampled population consisted mainly of females on both regions. Females have attained a larger mean size of CL than males in the two regions (table I), indicating sexual dimorphism of size (Student's *t*-test, $t = 6.90$; $P < 0.01$). The size frequency distribution of CL showed that the number of males and females decreased in the high and low classes (fig. 2). In both males and females, size frequency distribution differed from normality (Kolmogorov Smirnov test, $D_{males} = 0.19$, $P < 0.05$; $D_{females} = 0.17$, $P < 0.05$). The mean size of shrimps not differed statistically between Ubatuba and Caraguatatuba (Student's *t*-test, $t = -1.45$; $P > 0.14$).

When the bottom temperature and salinity were plotted together, it was clear the dynamics of water masses in the area for the period studied (fig. 3). The estimated size at onset of the sexual maturity was markedly different between sexes and the proportion of adult females and males increased logistically with carapace length (fig. 4). The size at onset of the sexual maturity for males was $CL_{50\%} = 10.1$, whereas for females was estimated in $CL_{50\%} =$

12.2. The overall size frequency distributions of *S. typica* of both sexes were significantly different (Kolmogorov-Smirnov two sample test; $d_{máx} = 0.27$, $p < 0.01$).

Size distributions of size groups and of proportion of reproductive females are shown in figs. 5 and 6, respectively. Large females were most abundant during winter (June to August), whereas large males were most common during spring (November and December). Small individuals (CL ≤ 9.9 mm) began to recruit after July. Few reproductive females have occurred during September and October. In general, the proportion of reproductive females was higher during late spring and summer.

During the two years of samplings, it was obtained a total of 152 males and 247 females and a sex ratio of 0.61:1 (M:F) for the population studied. There were significant differences in the sex ratio related with depths ($\chi^2 = 7.48$, $P < 0.01$), size classes of CL ($\chi^2 = 9.20$, $P < 0.01$) and bimonthly throughout the sampling period ($\chi^2 = 9.26$, $P < 0.01$) (fig. 7).

Only the females were used to length –frequency analysis due to the low number of modes of the males. Females showed one modal size group per year. This mode could be followed from July 2001 through October 2001, when this group grew about 16.0 mm CL. We could obtain 6 cohorts for females. The length frequency distribution of females and the cohorts is presented in figure 8. The growth pattern of females is shown in figure 9. The growth curve calculated for females of *S. typica* resulted in an estimative of CL_∞ =17.29 mm, K = -0.0125 and T_0 = -0.17 days. The maximum age calculated for females was 1.01 year.

The spatial variation of recruits, reproductive females and adult males in the two regions can be observed in the figure 10. A large number of recruits and reproductive females were found at depths of 35 and 45 m preferentially. The spatial variation of the abiotic factors measured in Ubatuba and Caraguatatuba regions is presented in figure 11. The sediment was mainly composed with sand and very fine sand at high depths (20 to 45 m), and silt and clay at the shallows stations.

Figures 12 and 13 presents the spatial variation of the proportion of reproductive females related to the abiotic factors. In Ubatuba region, for all parameters, it can be observed a decrease of shrimps associated with temperature, salinity, organic matter and the proportion of silt and clay. For Caraguatatuba this pattern could not be observed.

Table I. *Sicyonia* typica (Boeck, 1864). Number of individuals and mean size of CL (mm) of both sexes at Ubatuba and Caraguatatuba regions. M = males; F = females.

Region	N	Size of CL (mm) (mean± s.d.)	Minimum size of CL (mm)	Maximum size of CL (mm)
Ubatuba	169	11.62 ± 2.24	7.5	18.70
M (♂)	54	10.67 ± 1.58	8.10	14.0
F (♀)	115	12.06 ± 2.36	7.5	18.70
Caraguatatuba	230	11.94 ± 2.56	5.3	19.80
M (♂)	98	10.77 ± 1.52	8.1	13.50
F (♀)	132	12.76 ± 2.80	5.3	19.80

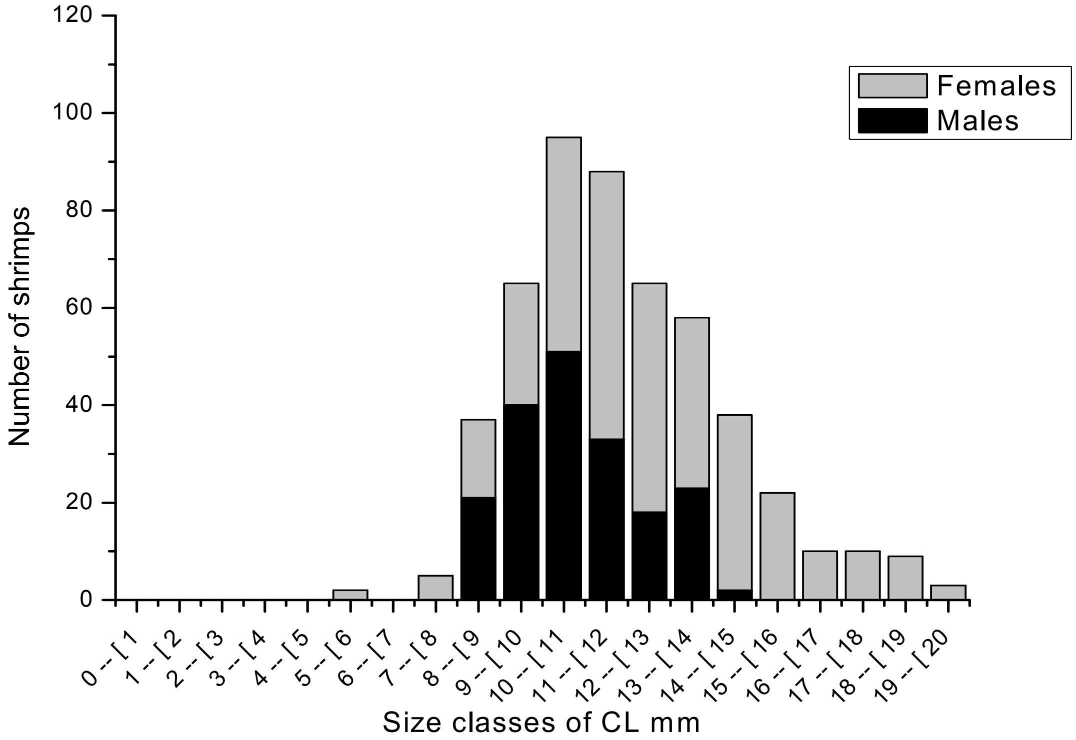


Figure 2. *Sicyonia typica* (Boeck, 1864). Number of individuals by size frequency distribution for Ubatuba and Caraguatatuba regions. Bars indicates the mean number of shrimps in each size classes.

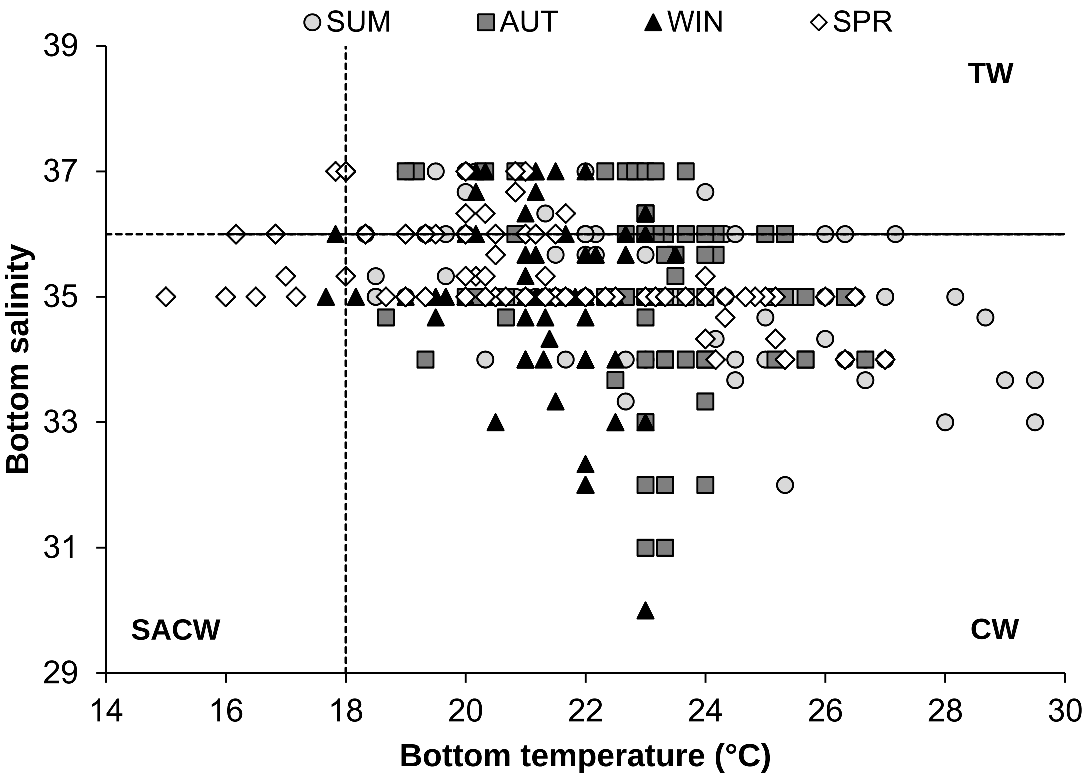


Figure 3. Values of bottom temperature (^{0}C) and bottom salinity (‰) in the study area, during the sampling period. SUM = summer; AUT = autumn; WIN = winter and SPR = spring.

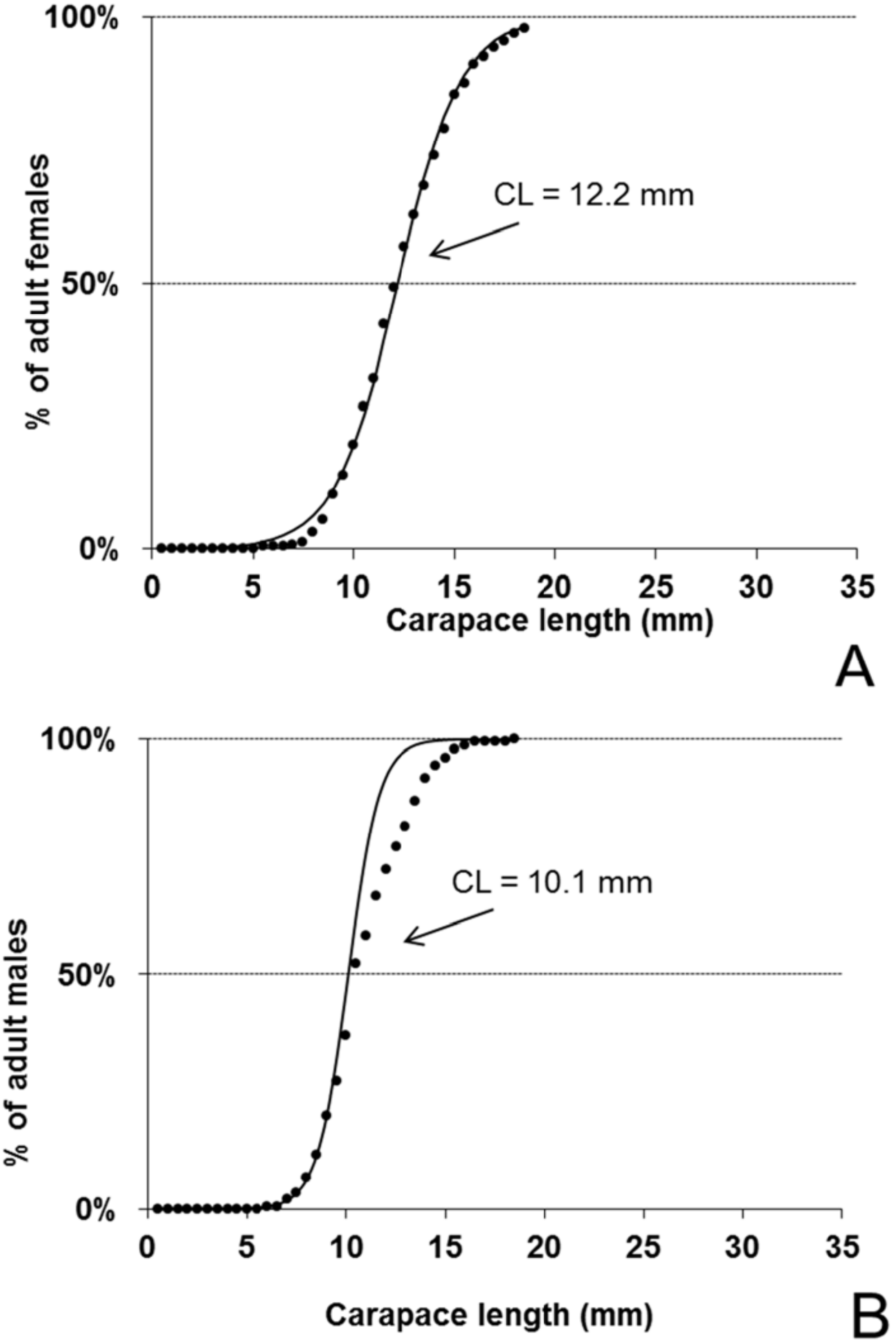


Figure 4. *Sicyonia typica* (Boeck, 1864). Size at onset of the sexual maturity based on the $CL_{50\%}$ of females (A) and males (B) sampled in the northern coast of São Paulo state.

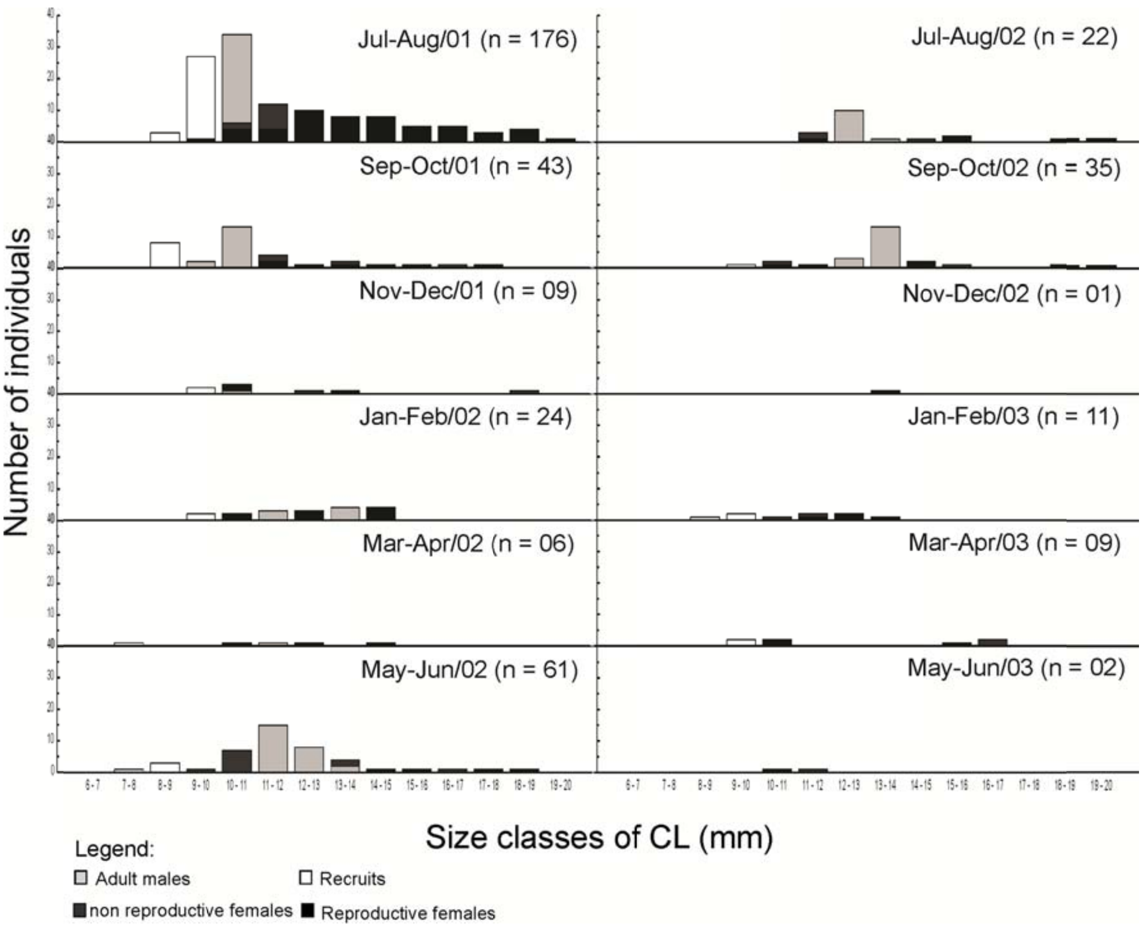


Figure 5. *Sicyonia typica* (Boeck, 1864). Size frequency distributions of recruits, non reproductive females, reproductive females and adult males sampled bimonthly.

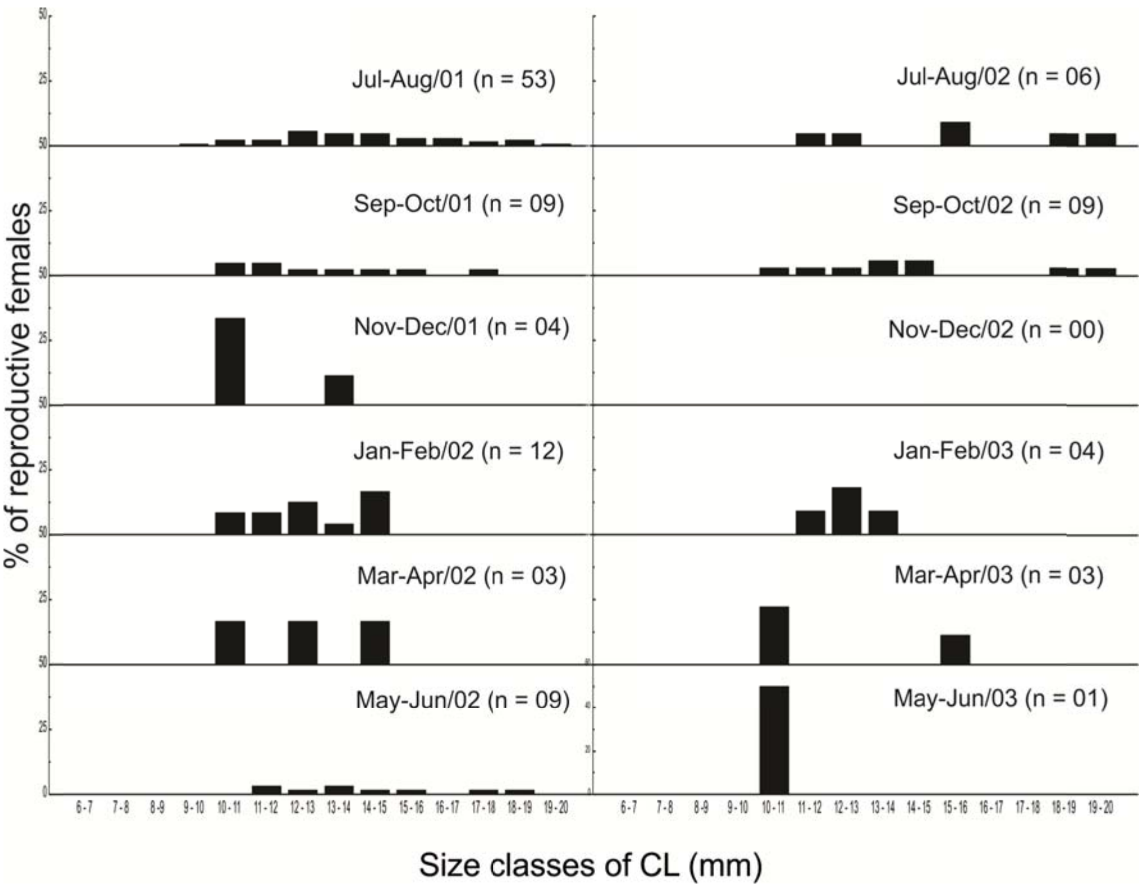


Figure 6. *Sicyonia typica* (Boeck, 1864). Size frequency distributions of the proportion of reproductive females sampled bimonthly at Caraguatatuba and Ubatuba regions.

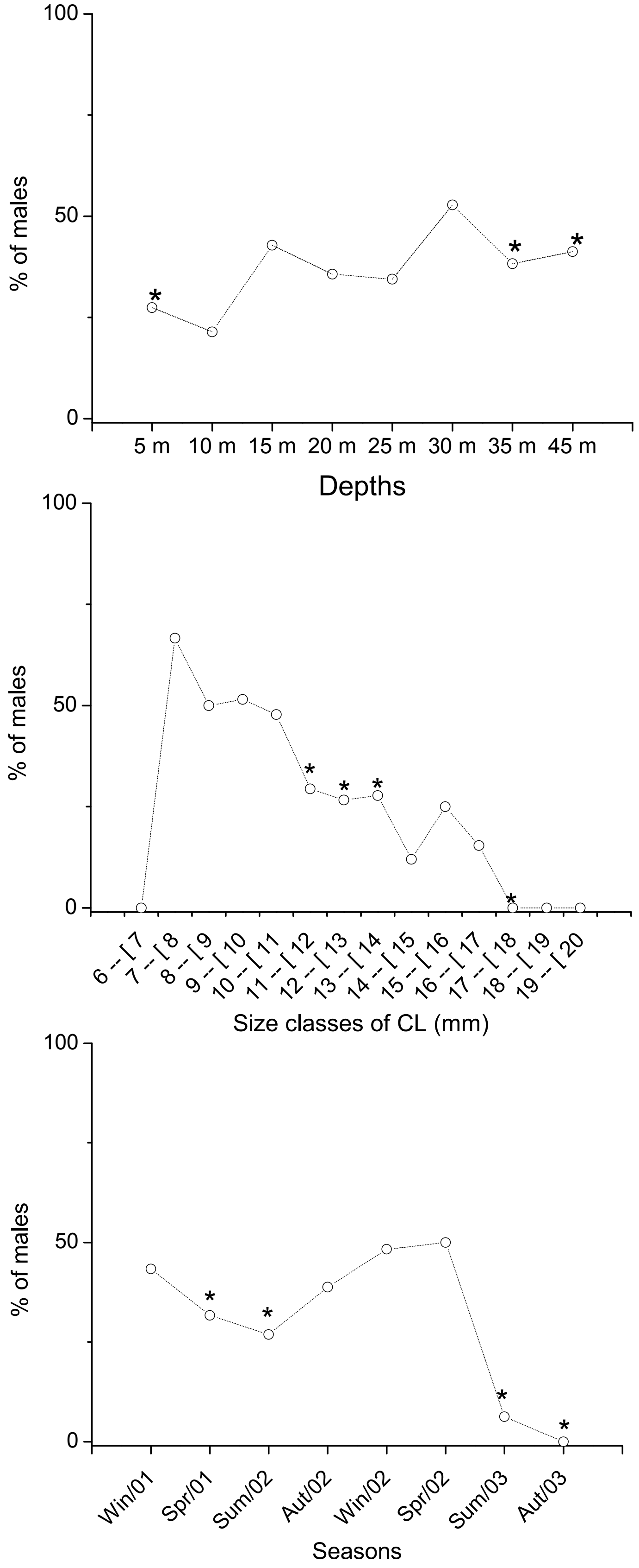


Figure 7. *Sicyonia typica* (Boeck, 1864). The sex ratio of the population related to depths, seasons and size clesses of CL. Asterisks (*) indicates significant difference, p = 0.05.

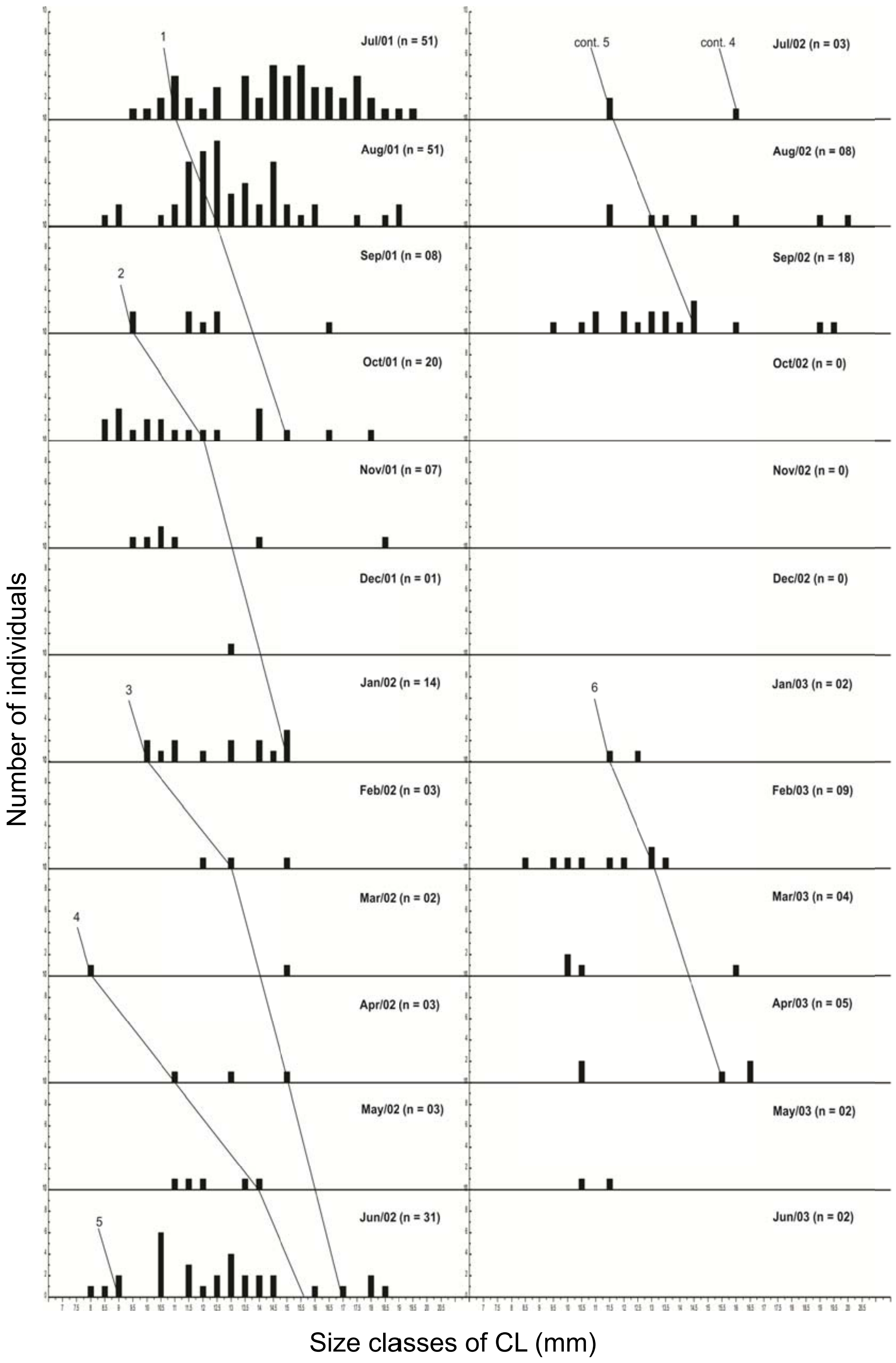


Figure 8. *Sicyonia typica* (Boeck, 1864). Modal progression analysis (MPA) of female cohorts. Bold lines are the cohorts linked along the period of study used to describe the individual growth.

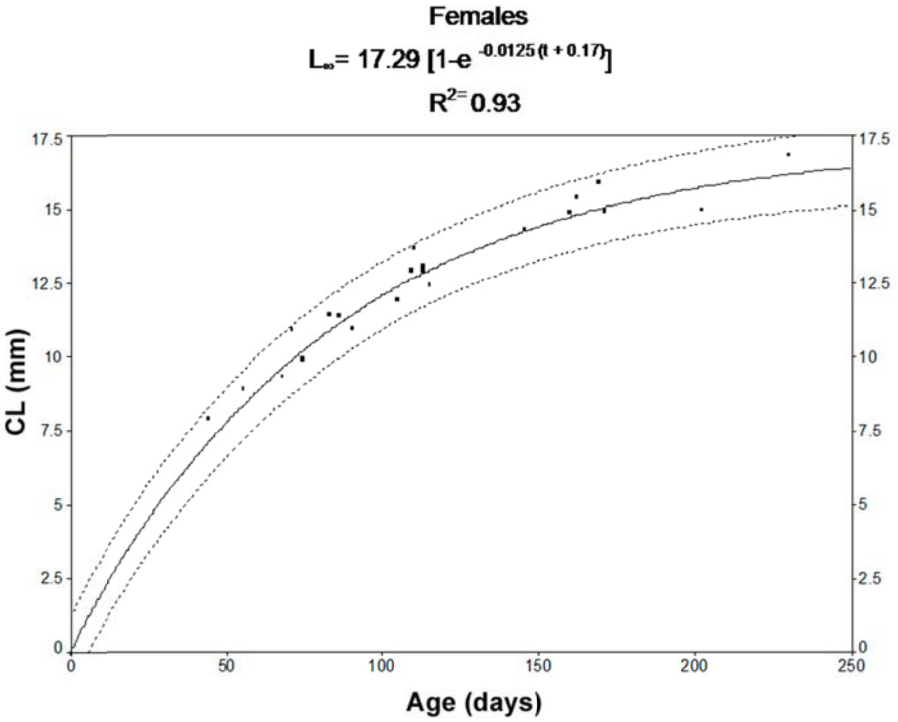


Figure 9. *Sicyonia typica* (Boeck, 1864). Growth curve and VBGM estimated for females.

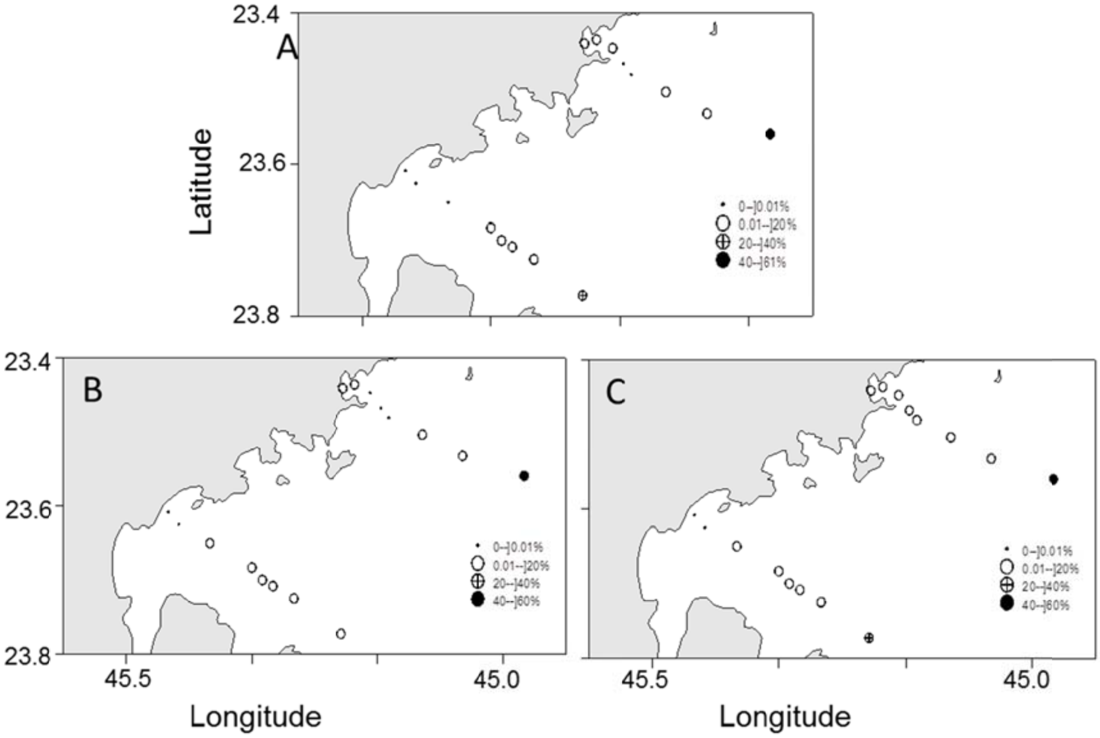


Figure 10. *Sicyonia typica* (Boeck, 1864). Variation of the number of adult males (A), recruits (B) and reproductive females (C) at Caraguatatuba (stations in the low part) and Ubatuba (stations in the north part) regions.

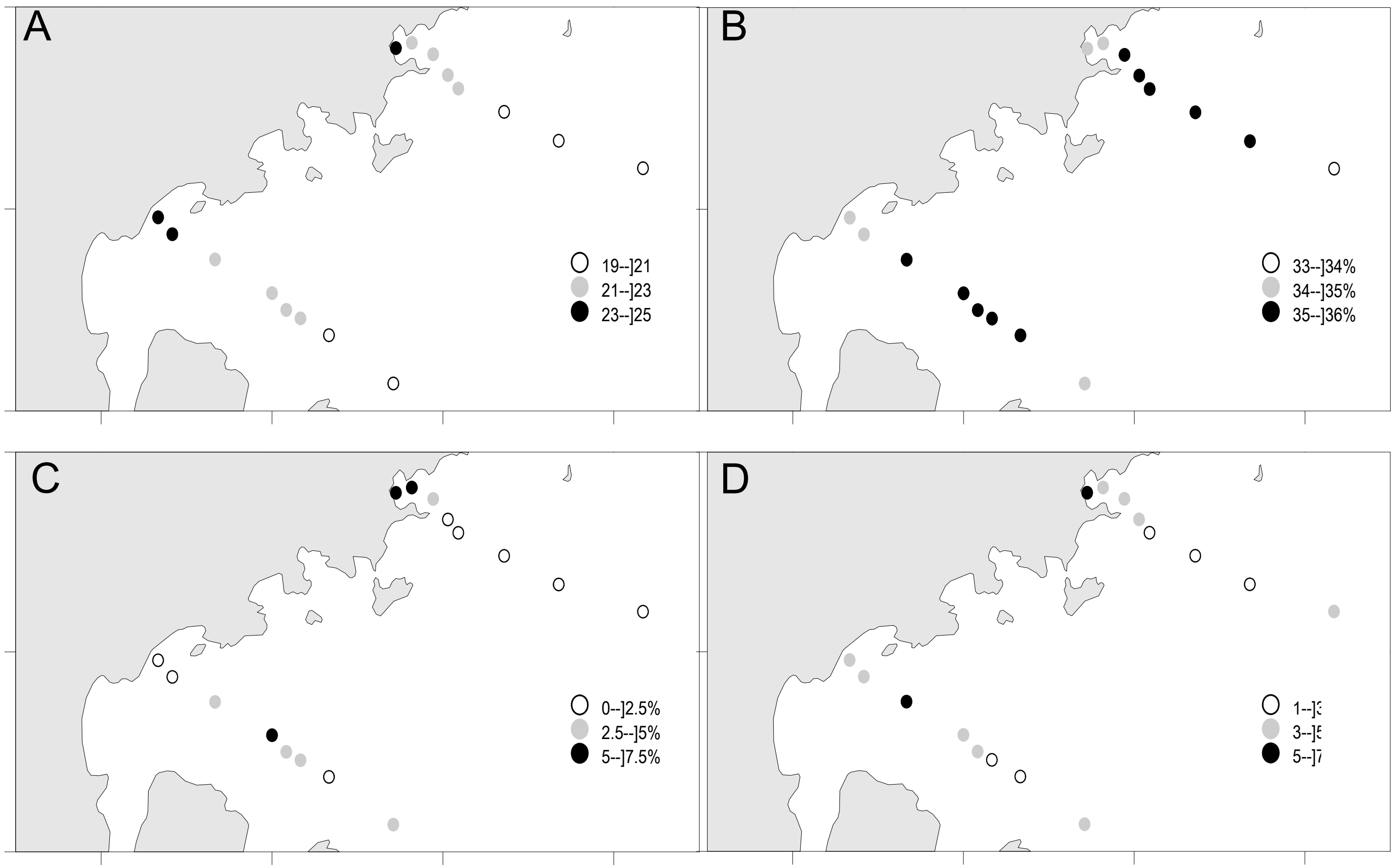


Figure 11. Variation of the mean value of bottom temperature (^{0}C) (A), bottom salinity (‰)(B), % of sediment organic matter (C) and phi (D) at Caraguatatuba (stations in the low part) and Ubatuba (stations in the north part) regions.

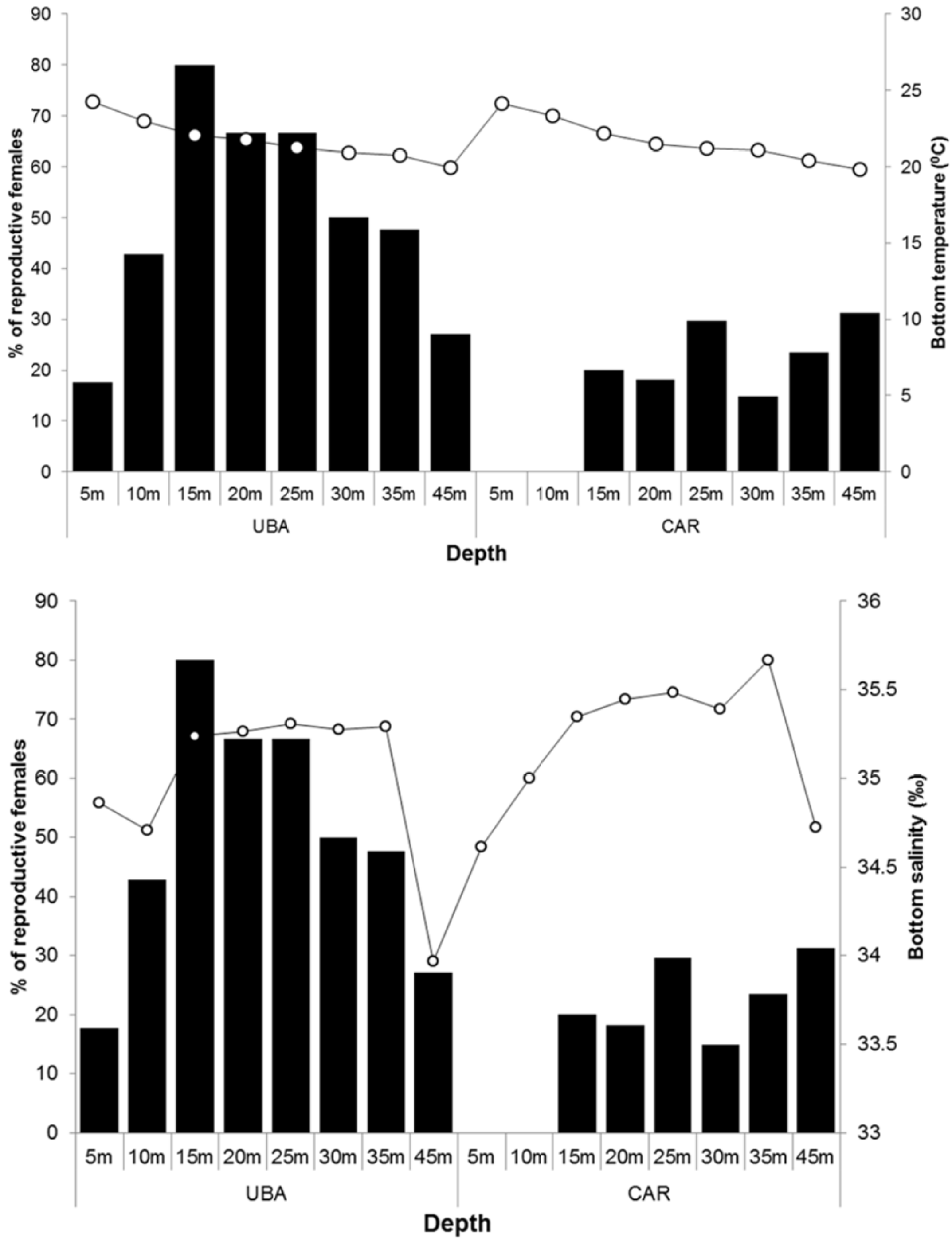
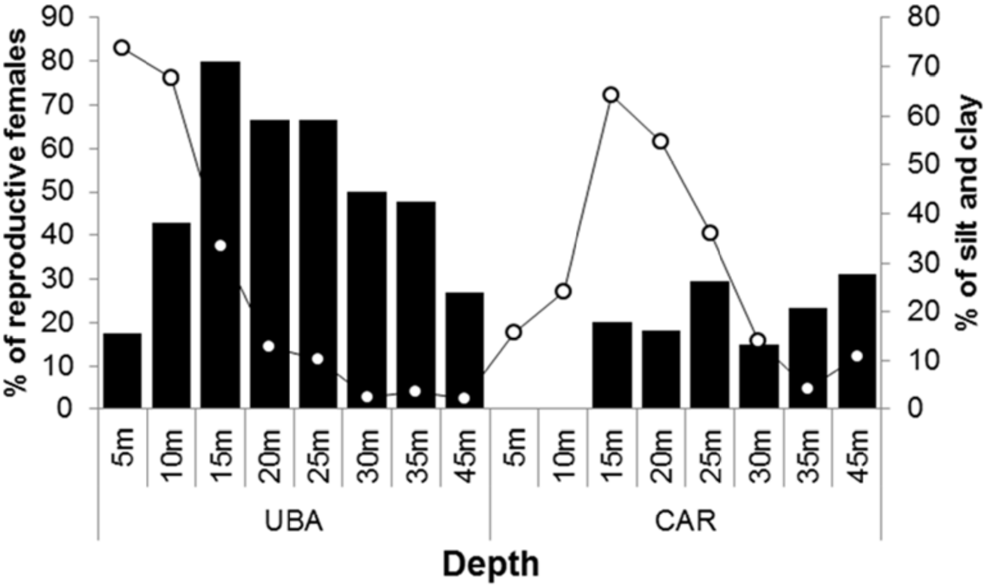


Figure 12. *Sicyonia typica* (Boeck, 1864). Proportion of reproductive females in each depth related with bottom temperature and salinity.



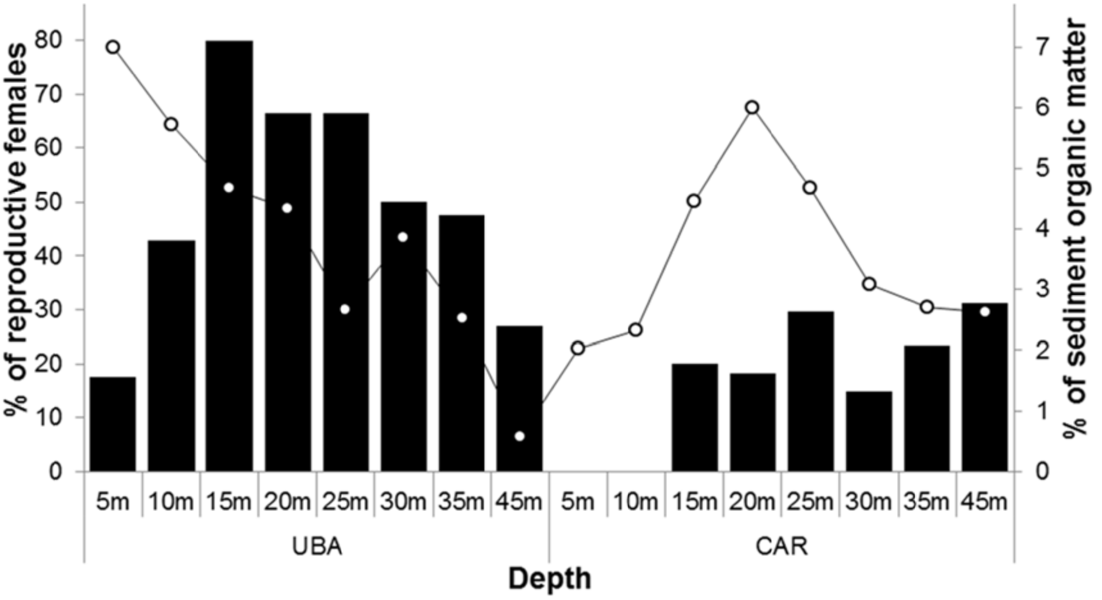


Figure 13. *Sicyonia typica* (Boeck, 1864). Proportion of reproductive females in each depth related with % of sediment organic matter and % of silt and clay.

DISCUSSION

Information regarding on any biological aspect of *Sicyonia typica* from Brazilian waters are quite insufficient and the present work is the first contribution to the knowledge of the population structure and growth of the rock shrimp *S. typica* complementing the other data available on the species (D'Incao, 1995a; D'Incao, 1995b). Then, no historical information is available on rock shrimp *S. typica* in the north coast of São Paulo, mainly because fishers have not exploited it up to date. Samplings of rock shrimp were higher in Caraguatatuba than Ubatuba region (table I) and a reason to this may be the increase in the number of fishing vessels in Ubatuba region what could increase the catches of penaeoid shrimps, including *S. typica*.

According to Rodrigues & D'Incao (2008), for penaeids, the populations tends to present a normal distribution of size, with a high abundance of individuals in the intermediate classes and a decrease in the number of individuals in the large and small sizes, following a Gauss curve. The low quantity of individuals in the large classes of size must be related to the higher mortality rate of larger individuals.

The analysis of length frequency data is a reliable way of obtains shrimp population parameters (Pauly, 1987). This study showed an apparent shift in modal length with time in females during the two years. Shrimp recruited in July-August continued to grow through to the following summer and took part in spawning in next September-October. After spawning, they probably die, which suggests a one-year life span of *S. typica* after recruitment. This spawning pattern was also found for *S. dorsalis* that coexists with *S. typica* in the area (Castilho *et al.*, 2008). This study indicated that *S. typica* has only one major recruitment event per year (September-October). Recruits have entered in adult catches as a clearly distinguishable cohort in October, of 2001 and 2002. So, *S. typica* was synchronized with spawning with a time-lag of 2-3 months. The duration of this time-lag depends upon several factors such as time of spawning, environmental and hydrological conditions, which can result in a poor relationship between the number of recruits and the size of spawning stock in penaeoids (Garcia & LeReste, 1981; King, 1995; Cha *et al.*, 2004).

Usually, tropical shrimp species should have continuous reproduction because the relatively stable and elevated water temperatures in this region allow year-round breeding (Sastry, 1983). However, it is common that females do spawn in identifiable breeding seasons, even in tropics, and penaeoids usually have two peaks of reproduction per year (Pauly, 1984). The species *S. typica* seems to reproduces year-round but with more intensity during winter months. Thus, we can infer that in 2001 and 2002, the winter spawning was the most important to the local stock maintenance. A lot of previous studies have indicated that temperature is an important factor regulating reproduction and for penaeoid shrimps, the spawning periodicity is usually centered in the warmer months (Crocos,1987; Beukema, 1992; Bauer & Vega, 1992; Costa & Franzoso, 2004). For other species of *Sicyonia*, such as *S. brevirostris* and *S. ingentis*, the populations from the west coast of USA (26-28^0 N, Cobb *et al.*, 1973) and east coast of Florida (28^0 N, Kennedy *et al.*, 1977) presented the peak of intensity reproduction from late fall to winter, corroborating our results. In the studied area, the upwelling current of the South Atlantic Central Water (SACW) is responsible for the decline of coastal water temperature during summer, among other shifts on bottom water characteristics (Castro-Filho *et al.*, 1987). The figure 3 shows that the SACW was detected in this study during the spring and summer, which can explain the lack of significant association between relative frequencies of reproductive females with bottom-water temperature.

The size at onset of the sexual maturity is of special interest in fisheries management and is widely used as an indicator for minimum permissible capture size (Fonteles-Filho, 1989; Lucifora *et al.* 1999). There is available information on size at onset of the sexual maturity of shrimps from plot of percentage of mature individuals against length class in the several studies (Nakagaki & Negreiros-Fransozo, 1998; Costa & Fransozo, 2004; Chilari *et al.*, 2005; Castilho *et al.*, 2007) and, despite some authors (Garcia, 1985; Hossain & Ohtomi, 2008) have been questioned its sustainability, this method can be considered of high accuracy. The sexual dimorphism in size was verified in *S.*

typica with females attaining larger body sizes for age than do males (table I). This may indicate a reduction in the male's energy investment in growth and a decrease in their risk of predation (Yamada *et al.* 2007). Therefore, the large body sizes of females of *S. typica* may be an adaptation to increase egg production. The relationship between the growth and sexual maturity of males *S. typica* remains unknown and needs to be examined in the future.

Previous studies have suggested that the characteristics of water masses and substrate are factors that influence other species of the genus *Sicyonia* (Castliho *et al.* 2007; Castilho *et al.* 2008) in the area. Water temperature and salinity might play important role in determining the ecological distribution of individuals, as well as in its development (Costa *et al.*, 2005; Semensato & DiBeneditto, 2008). For *Artemesia longinaris*, for example, molting varies with temperature changes and in high temperatures (> 20^0C) the inter-molting period is shorter and the growth is faster, whereas the opposite is observed in low temperatures (< 14^0C) (Petriella & Bridi, 1992). Crustaceans do not molt when the temperature of the environment is low because it slows down their metabolism, which slows considerably when the temperature drops below a specific threshold, although they remain living (Conan, 1985). This pattern also can occur with *S. typica*, and low conditions of salinity might reduce the shrimp growth rate. However, Anderson *et al.* (1985), found for *S. ingentis* a higher intensity of molt activity during winter months in the coast of California, and the temperature seems to be not a critical factor for the growth of those shrimps.

The great fishery effort in Ubatuba region probably affects the species, as observed by Somers *et al.* (1987) for *Penaeus esculentus* Haswell in Australia, who suggested a continuous recruitment and/or the existence of a size-dependent source of mortality. In this study, the comparison of shrimps size between Caraguatatuba and Ubatuba regions reveals no differences in the population distribution that probably reflects in the recruitment and migration process.

The spatial distribution of the size groups (recruits, non-reproductive females, reproductive females and adult males) is quite complex but normally the species aggregate in relatively deep water of the slope. The shrimps do not occur uniformly distributed in the sampling area; unlike they are found concentrated at specific zones, preferentially at deeper waters during its life cycle, due to migratory of trophic movements. The most of reproductive females and recruits were sampled at 35 and 45 m both at Ubatuba and Caraguatatuba regions, which can indicates that spawning occurs exactly in this zone of the slope. This information can confirm the classification of the life cycle of *S. typica*, according to Dall *et al.* (1990), into a life cycle entirely in the open sea, with breeding and nursery area at offshore waters.

Penaeoid shrimps show a size sexual dimorphism where females are greater than males (Hartnoll, 1982). According to Boschi (1969), size sexual dimorphism is a general rule for penaeids. The male carapace commonly grew in a different way than of the females because such process is associated to reproduction (Santos & Ivo, 2000). This fact was observed for other shrimps that occurs in the same fishing area: *Rimapenaeus constrictus* (Stimpson, 1874), *Xiphopenaeus kroyeri* (Heller, 1862) and *Artemesia longinaris* Bate, 1888 (Costa & Fransozo 2004; Castro et al. 2005; Castilho et al. 2007).

For dioecious invertebrates, the populations are usually composed by approximately the same number of males and females (Pianka, 1983). However, Wenner (1972) found deviations in the sexual proportion for several crustacean species due to many factors as differential sexual growth, reproductive migrations, sexual reversion or a higher feeding activity in one of the sexes. The temporal sex ratio variation can be related to a seasonal reproductive pattern in *S. typica*, in which the proportion of males is the same of females (winter and summer/02, sex ratio = 1:1) before the spawning period, when the eggs fertilization takes place. This peak coincides with the most reproductive activity.

Many factors in the marine environment act to reduce the survivability of individuals in a population (King, 1984). We can cite adverse conditions, lack of food, competition, and, perhaps most important of all, predation (Niamaimandi *et al.*, 2007). The natural mortality rates varies from year to year, because environmental factors and especially relative abundance predators in an area.

Unfortunately, the predation rate on *S. typica* in the studied area was not verified in this study and it does not allow us to make any conclusion of the reason of the mean longevity of this species.

The values of growth parameters obtained here are the first for this species. The results showed that estimates of growth parameters (CL_{∞}, K and t_0) for *S. typica* are in agreement with the short longevity of the penaeid species (1.01 year in this study) (Pauly *et al.*, 1984; Cha *et al.*, 2002; Dumont, 2003). Estimates are consistent with the values reported in other studies for the same genus (table II) and are in the reported range for other penaeoids (D'Incao & Fonseca, 1999). The von Bertalanffy growth model fitted the data of females *S. typica* of the population from north coast of São Paulo state well, as indicate from the score function. The *K* value (0.0125 for females) corresponding to the best estimate of CL_{∞} (17.29 for females) is similar to those estimated by Bauer (1992). Unfortunately, we could not calculate the growth parameters for the males of the population due to the very low number of modes identified in the population. Then, it was not possible to verify differences or similarities in the growth rate between the two sexes of *S. typica*.

In the north coast of São Paulo state, growth of females (and probably males) *S. typica* was far more rapid during the first three months of its life (fig. 9). According to Karani *et al.* 2005, the diet of juvenile of a penaeid shrimp was different of that of adults and this was probably attributed to corresponding differences in the composition of the benthic assemblages of the open sea, as well as developmental differences that affect their feeding behavior, with feeding activity of juveniles apparently higher than that of adults, resulting to a higher growth rate. The fast growth of females (and males) in the first period of life is considered a pattern among penaeids, whose have the typical pattern of sigmoidal growth form, with a less growth in the second part of the life cycle (Garcia & LeReste, 1981; Dall *et al.*, 1990), and this result was expected for *S. typica*.

To clarify the life cycle of *S. typica*, further investigations must be made to obtain the substantial evidence supporting such reproductive aspects, mainly focusing the male's individuals. However, the results presented here should be taken into account for the assessment and management of this resource. It is especially relevant for this species, which we believe that can be exploited in the future in the area, that these results will be considered in the discussions regarding to adopt management measures for the improvement of the state of the resource. Further studies with *S. typica* aiming to detail the gonad morphology and histology, and the larval development will be helpful to improve the understanding of the life cycle of this species.

Tabela II. Relationship between size (carapace length) and longevity of females in *Sicyonia* species.

Species	Size range of adult female (mm CL)	Longevity (months)	Author
S. parri	3 - 9	6 – 8	Bauer (1992)
S. laevigata	3 - 9	6 – 8	Bauer (1992)
S. brevirostris	17 – 35	20 – 22	Bauer (1992)
S. ingentis	24 - 45	≥ 22?	Bauer (1992)
S. typica	5.3 – 19.8	12-13	Present study

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CONSIDERAÇÕES FINAIS

As informações sobre a biologia da espécie *Sicyonia typica* apresentadas neste trabalho certamente aumentam o conhecimento científico sobre a família de camarões Sicyoniidae. Os resultados obtidos pelo esforço de amostragem ao longo de 5,5 anos de coletas no litoral norte do estado de São Paulo permitiram verificar que esta espécie apresenta, assim como inúmeras outras espécies de invertebrados marinhos com desenvolvimento larval planctônico e que vivem próximo aos trópicos, reprodução contínua ao longo do ano com um pico principal de desova. Verificou-se que há um maior número de fêmeas reprodutivas nesta região durante os meses que antecedem o verão. Durante o verão as larvas e juvenis estão sujeitas, portanto, a condições ambientais que favorecem seu desenvolvimento devido à entrada da ACAS (Águas Centrais do Atlântico Sul) que atua como uma espécie de fertilizador das águas promovendo alta produção primária de fitoplâncton.

De modo geral, muitos aspectos da população estudada aqui se assemelham a outras populações de espécies de peneóideos que vivem na região tropical/subtropical do Atlântico como fêmeas atingindo maiores tamanhos corporais que machos, uma razão sexual desviada para as fêmeas e possíveis migrações ocorrendo conforme variações ambientais. Observou-se também neste estudo que variáveis ambientais como temperatura, salinidade e características do sedimento são importantes fatores controladores da distribuição de *S. typica*.

Espécies animais que são capturadas como fauna acompanhante da pesca do camarão e pescado comumente são negligenciadas por não apresentarem valor econômico de mercado. No entanto, estas mesmas espécies podem no futuro despertar interesse e prestígio com o declínio das populações atualmente exploradas. Dessa forma, é de fundamental importância se obter o conhecimento científico de espécies de camarões que são capturadas e rejeitadas durante a pesca do camarão marinho, pois as mesmas também podem sofrer pressão de extinção com o processo pesqueiro.

Os resultados apresentados neste estudo pioneiro com a espécie *S. typica* sobre reprodução, distribuição e estrutura populacional contribuem para discussões futuras sobre hipóteses filogenéticas a respeito dos camarões Penaeoidea viventes no Atlântico sul. Padrões reprodutivos podem ser identificados e comparados com outras espécies próximas ou distantes filogeneticamente e desta forma a história evolutiva deste grupo de Decapoda pode ser esclarecida.

Para a espécie *S. typica* em particular, serão necessários futuros estudos que abordem outros aspectos da biologia e ecologia e que, principalmente, foquem os esforços amostrais nesta espécie. Talvez se o alvo principal das coletas fosse o camarão-pedra, provavelmente a escala amostral seria diferente e outras informações seriam obtidas. Por outro lado, as coletas focaram espécies comercialmente importantes e pode-se desta forma verificar a associação do camarão-pedra com outros camarões economicamente importantes.

Além do avanço no conhecimento científico sobre a biologia e os processos dinâmicos da população de *S. typica* da região estudada, este estudo servirá como base para futuras pesquisas com as outras espécies de *Sicyonia* que ocorrem na costa sul do Brasil. Quanto mais informação biológica sobre uma espécie animal importante ecologicamente e praticamente desconhecida existir, saberemos como esta espécie se relaciona com outros organismos e seu ambiente. Este tipo de conhecimento é fundamental para direcionar planos de conservação e manejo de estoques naturais.

Por fim, este estudo constitui-se apenas em um esforço inicial na tentativa de se compreender a ecologia de *S. typica* e da família Sicyoniidae como um todo. Diversos outros trabalhos com esta espécie ainda são necessários para complementar o conhecimento sobre a mesma. Por exemplo, estudos experimentais com indivíduos juvenis e adultos sobre preferências alimentares, predação e fisiologia certamente ajudarão a entender a biologia desta espécie.

Após o estudo, os espécimes coletados foram depositados na coleção zoológica de referência no Departamento de Zoologia, Instituto de Biociências de Botucatu da Universidade Estadual Paulista - UNESP.