

# ***Bacciger bacciger* (Trematoda, Fellodistomidae) infection in commercial clams *Donax trunculus* (Bivalvia, Donacidae) from the sandy beaches of the Western Mediterranean**

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**ABSTRACT:** Sporocysts of the Fellodistomidae trematode *Bacciger bacciger* were embedded in gonadal tissue of the bivalve *Donax trunculus* from the Mediterranean coast of Spain. The overall prevalence of infection was 8.4%, increasing with host size to 23% in *D. trunculus* from 35 to 36 mm in shell length. Individuals <19 mm long were not infected. No clear seasonality was recognized in prevalence of infection. The proportion of infected individuals of both sexes was similar (6.56% in males and 8.04% in females), although the highest prevalence was in clams of unknown sex (13.47%). The proportion of infected clams reduced to virtual castrates of unknown sex reached 28%. The tegument of the sporocyst and shed cercariae was studied by light and electron microscopy. Scanning electron microscopy revealed a smooth surface on the sporocyst tegument, the area of which was greater due to the presence of circumferential infolds and numerous pits. A birth pore on one side of the sporocyst, unciliated sensory organs and cup-shaped sensory-like structures were present on the tegument. The cercarial body had spines and unciliated sensory organs. The ventral sucker of the cercariae had 2 rings of unciliated sensory organs and tegumental spines.

**KEY WORDS:** *Bacciger bacciger* · *Donax trunculus* · Trematode infection · SEM observations · Western Mediterranean

## **INTRODUCTION**

The suspension-feeding wedge clam *Donax trunculus* Linnaeus, 1758 is a dominant macrofaunal species on shallow bottoms (from 0 to 2 m depth) along the Mediterranean coast. Its geographical distribution extends from the French Atlantic to the Senegal and the Mediterranean Sea. It inhabits high-energy environments with strong wave action and with numerous suspended particles. Although the wedge clam is important commercially in some Mediterranean countries (Spain, Italy), little is known of the pathogens and parasites which may adversely affect the health of these populations.

Trematode larvae are one of the most important parasites in clams of the family Donacidae (compiled in Lauckner 1983), although few species have been studied in detail (Ansell 1983). The cercaria of *Bacciger bacciger* (Rudolphi, 1819) (Fellodistomatidae) was first found in *Tapes decussatus* collected in Arcachon by Lespès (1857), who named it *Cercaria lata*. Later several authors reported sporocysts and cercariae which appear to be the same species in other hosts and localities (Table 1). Palombi (1934a) was finally able to relate this cercaria with the adult in the intestine of the fish *Atherina* spp.

*Bacciger bacciger* adults were originally discovered by Rudolphi (1819) in marine fish. The life cycle, according to Palombi (1934a), is as follows: cercariae, after escaping from sporocysts parasitising the bivalve's first intermediate host, penetrate and encyst

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Table 1. Reported bivalve species infected as a first host for *Bacciger bacciger* (from Lauckner 1983)

| Host species               | Locality                   | Source                                 |
|----------------------------|----------------------------|--|
| Family Veneridae           |                            |  |
| <i>Tapes decussatus</i>    | Arcachon (French Atlantic) | Lespès (1857), Jobert (1894)           |
|                            | Manche (French Atlantic)   | Dollfus (1925)                         |
| <i>Tapes philipinarum</i>  | Tokyo Bay                  | Fujita (1906, 1907), Kobayashi (1922)  |
| <i>Venerupis pullastra</i> | Arcachon                   | Jobert (1894)                          |
|                            | Wimereux (French Atlantic) | Pelseneer (1906)                       |
|                            | Manche                     | Dollfus (1925)                         |
| <i>Venerupis aurea</i>     | Naples (Tyrrhenian Sea)    | Palombi (1934a, b)                     |
| <i>Chamelea gallina</i>    | Black Sea                  | Dolqikh (1968)                         |
| Family Donacidae           |                            |  |
| <i>Donax vittatus</i>      | Calvados (French Atlantic) | Huet (1891)                            |
|                            | Crèche (French Atlantic)   | Giard (1897)                           |
|                            | Wimereux                   | Pelseneer (1906), Dollfus (1925)       |
|                            | Naples                     | Palombi (1934a, b)                     |
|                            | Boulogne-sur-mer           | Pelseneer (1896), Dollfus (1911, 1925) |
| <i>Donax trunculus</i>     | Valencia (Mediterranean)   | Present study                          |
| Family Pholadidae          |                            |  |
| <i>Barnea candida</i>      | Crèche                     | Giard (1897)                           |
|                            | Naples                     | Palombi (1934a, b)                     |

as metacercariae in the amphipoda *Erichthonius difformis* (Edw.), and, after *E. difformis* is eaten by fish *Atherina* spp., develop into adults in the alimentary tract.

Heavy sporocyst infiltration of *Bacciger bacciger* can cause complete castration and depletion of body reserves, with host soft tissues becoming flaccid (Lauckner 1983). On the French Atlantic coast and Italian Mediterranean coast the parasite caused large-scale fluctuations in the abundance of *Tapes* spp. and *Donax vittatus* populations.

Our study presents the first record of the donacid *Donax trunculus* as a host of the trematode *Bacciger bacciger* and the first record of this trematode in the westernmost part of the Mediterranean. Data on prevalence of infection by sex and season are included. Light microscopical observations of sporocysts and cercariae complete the descriptions of Palombi (1933a, b, 1934a, b, 1940). Additionally, the study describes characteristics of sporocysts and cercariae using scanning electron microscopy (SEM). Surface tegumentary features are compared with those reported by Matricón-Gondran (1965, 1966a, b, 1969, 1971a, b) using transmission electron microscopy (TEM) for the same species. Sensory structures are compared with those in larval stages of other digenetic trematode species.

## MATERIAL AND METHODS

**Field collection of clams.** The study was conducted in a natural wedge clam *Donax trunculus* bed in the sandy beaches of Cullera (39° 9' N, 0° 15' E), in the Gulf of Valencia (Spain), between June 1988 and May 1990. Samples of *D. trunculus* were collected at approxi-

mately monthly intervals from water shallower than 2 m. A dredge with a small mesh size (4 × 4 mm) was dragged from a fishing vessel. The sample size depended on the size composition of the population, encompassing the full size range available depending on season (from 11 to 40 mm anteroposterior length).

Live individuals of *Donax trunculus* were opened in the laboratory and examined for the trematode *Bacciger bacciger* under a dissecting microscope (Nikon SMZ-10). Sporocysts longer than 0.5 mm were detected. To test for differences in infection between male and female clams, sex was recorded. *D. trunculus* is a dioecious species and shows no external signs of sexual dimorphism apart from the appearance of the gonad. When the gonad is ripe, it occupies the whole visceral mass. Sex can be easily identified macroscopically when the gonad begins development as indicated by differences in colour, dark blue in females and creamy white in males. During the gonadal inactive stage (from October to January in the studied area, Ramón 1993) the sex of most of the clams cannot be determined microscopically.

**Light microscopy.** Live sporocysts and spontaneously shed cercariae were placed in Bouin's fixative between slide and coverslip under slight pressure, stained with aluminic carmine, mounted in Canada balsam, observed and measured with a Leitz Laborlux K microscope.

**SEM.** Live sporocysts and spontaneously shed cercariae were fixed in 2.5% (v/v) glutaraldehyde buffered with 0.1 M Sorensen phosphate (pH 7.2 to 7.4) for 3 h at 4°C. After 3 washes in this buffer, specimens were postfixed with buffered 1% OsO<sub>4</sub> for 1 h at 4°C and again washed in Sorensen phosphate buffer.

Samples were dehydrated through an ethanol series, passed through hexamethyldisilazane and air-dried. Dried specimens were mounted on colloidal silver covered stubs and sputter-coated with pure gold. Observations were made using a Hitachi S570 scanning electron microscope, operating at 15 kV.

## RESULTS

### Sporocysts

The daughter sporocysts of *Bacciger bacciger*, enclosing numerous cercariae at different stages of development (Fig. 1), infected gonadal tissues of *Donax trunculus*. Immature sporocysts were 2.56 mm long ( $\pm 0.74$  SD,  $n = 20$ ) and 0.36 mm wide ( $\pm 0.045$  SD,  $n = 20$ ). Mature sporocysts, harbouring fully developed cercariae, 3.16 ( $\pm 0.27$  SD,  $n = 20$ ) mm long, 0.37 ( $\pm 0.027$  SD,  $n = 20$ ) mm wide, were cylindrical with motile ends (Fig. 2). The surface was smooth and devoid of microvilli, and its area was markedly greater due to the presence of extensive circumferential infolds (Fig. 3a). Elevations were separated from one another by deep grooves. Numerous pits were present along the entire surface of the sporocysts (Fig. 3b). A birth pore was located on one side of the sporocyst (Fig. 4a, b), the opposite side being the more rounded. SEM observations corroborated the presence of the birth pore, also marked by tegumental surface changes: from the infolded surface to a microvillous-like one (Fig. 4a). No sensory organs were detected around the birth pore. Unciliate sensory receptors were observed scattered on the sporocyst surface (Fig. 5). Cup-shaped sensory-like structures were also present (Fig. 6).

### Cercariae

The fully developed cercaria was trichocercous, i.e. with setiferous tail; body ovoid, 329.7 ( $\pm 34.3$  SD,  $n = 10$ )  $\mu$ m long, 220.8 ( $\pm 18.1$  SD,  $n = 10$ )  $\mu$ m wide; anterior sucker 54.2 ( $\pm 4.0$  SD,  $n = 10$ )  $\mu$ m in diameter; ventral sucker 54.9 ( $\pm 2.6$  SD,  $n = 10$ )  $\mu$ m in diameter (Fig. 7). The entire surface of the cercaria was armed with sharp, single-pointed spines arranged in regular rows in the tegumentary cavities (Figs. 8 & 9). The ventral sucker was also armed. An internal ring of 12 unciliate sensory organs was observed on the ventral sucker, surrounded by another ring of unciliate sensory organs (Fig. 10). Scattered over the body were unciliate sensory organs, with a central protruding cilium (Fig. 11). The surface of the tail was aspinous, with numerous folds as shown by SEM. Twenty-seven pairs

of finlets, 125 ( $\pm 2.64$  SD,  $n = 10$ )  $\mu$ m long, were present, arranged laterally along the tail (Fig. 12). The finlet surface was smooth, with 8 longitudinal protruding rib-like supports. The rib-like supports were unequal in length: the outermost 2 were short, the middle 3 were longer, and the innermost 3 were longest (Fig. 13).

## Infection

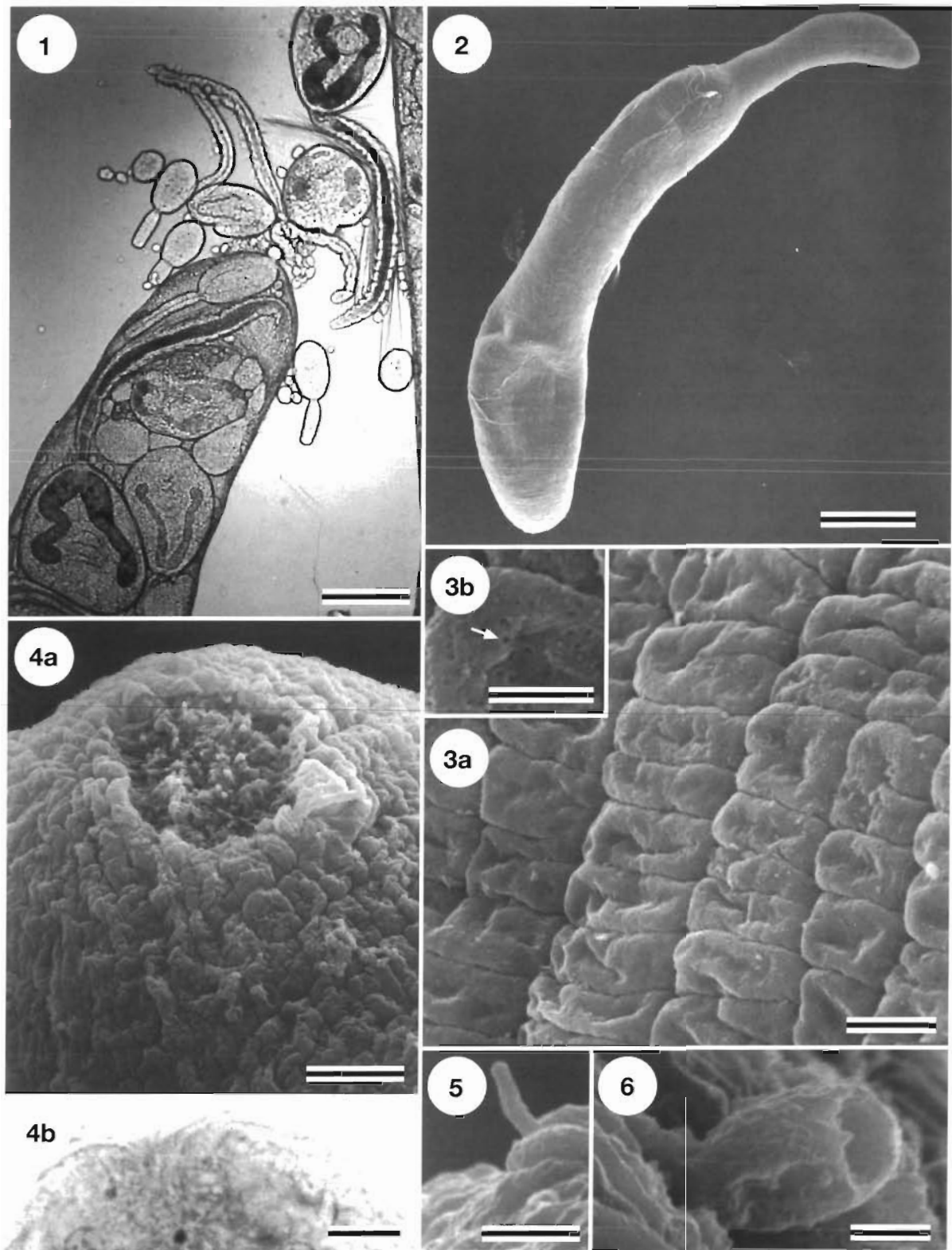
Examination of infected *Donax trunculus* showed that sporocysts were located only in gonadal tissues. Parasitized clams could easily be distinguished because of the contrast in colour between the blue female or creamy male gonad and the orange sporocysts. Sporocysts of *Bacciger bacciger* were found in 165 of 1963 specimens examined (8.4%). Infection levels ranged from a few sporocysts to heavily infected clams containing hundreds of daughter sporocysts with developing cercariae. Most of the clams with advanced stages of infection still retained gametes in the gonad, although their number was reduced and soft tissues were flaccid. Total destruction of gonadal tissue, i.e. gonadal tissue replaced totally by a dense mass of sporocysts, was observed in 47 clams (2.4% of the population).

The number of infected *Donax trunculus* versus the number of total clams by sex (male, female, unknown) and month is shown in Table 2. The prevalence of infection in males, females and clams of unknown sex, were 6.56, 8.04 and 13.47%, respectively. There were no significant differences in prevalence of infection between males and females ( $\chi^2 = 1.31$ ,  $0.5 < p < 0.25$ ); significant differences were found when comparing clams of known and unknown sex ( $\chi^2 = 14.12$ ,  $p < 0.001$ ).

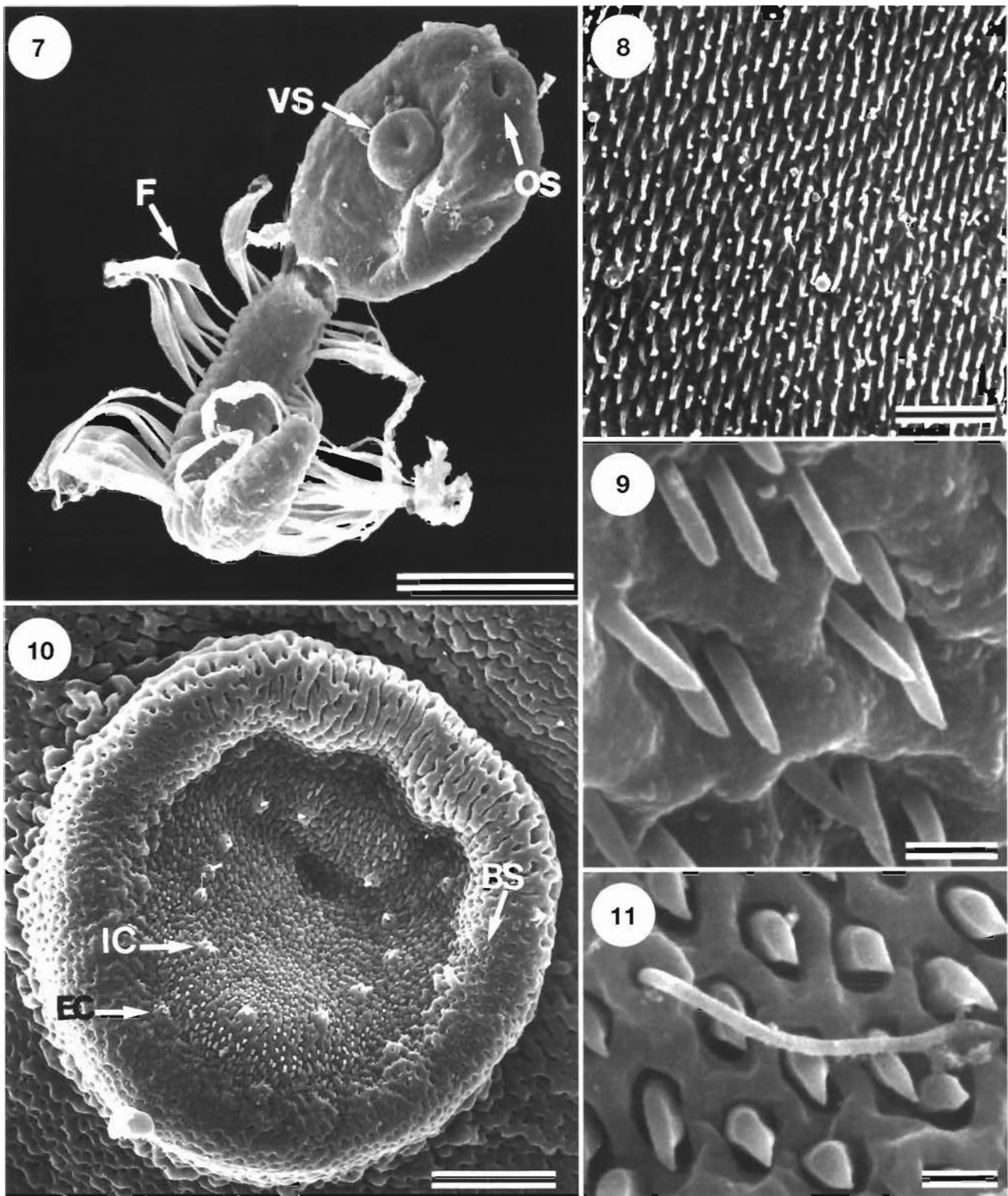
Prevalence of infection of *Donax trunculus* examined within each 2 mm size class is shown in Fig. 14. Individuals <19 mm long were not infected whereas clams >22 mm long were most likely to be infected (>4.5%), especially clams 33 to 36 mm long (15 to 23% of infected individuals). Low prevalence values in individuals >37 mm reflect small sample size (1 specimen of 37 mm and 2 of 40 mm length).

The number of infected clams was analyzed throughout the study. Temporal patterns of infection differed between years and showed no relation with temperature or salinity (Fig. 15). No clear seasonality was recognized in prevalence of infection, even when 3 length groups (<23 mm, 23–29 mm and 30–40 mm) were considered each month separately. The highest prevalence was in June 1988 (21.7%), decreasing during autumn, winter 1988 and spring 1989. In summer 1989 there was an increase which continued through autumn and winter 1989. The prevalence was higher in spring 1990 than in spring 1989.



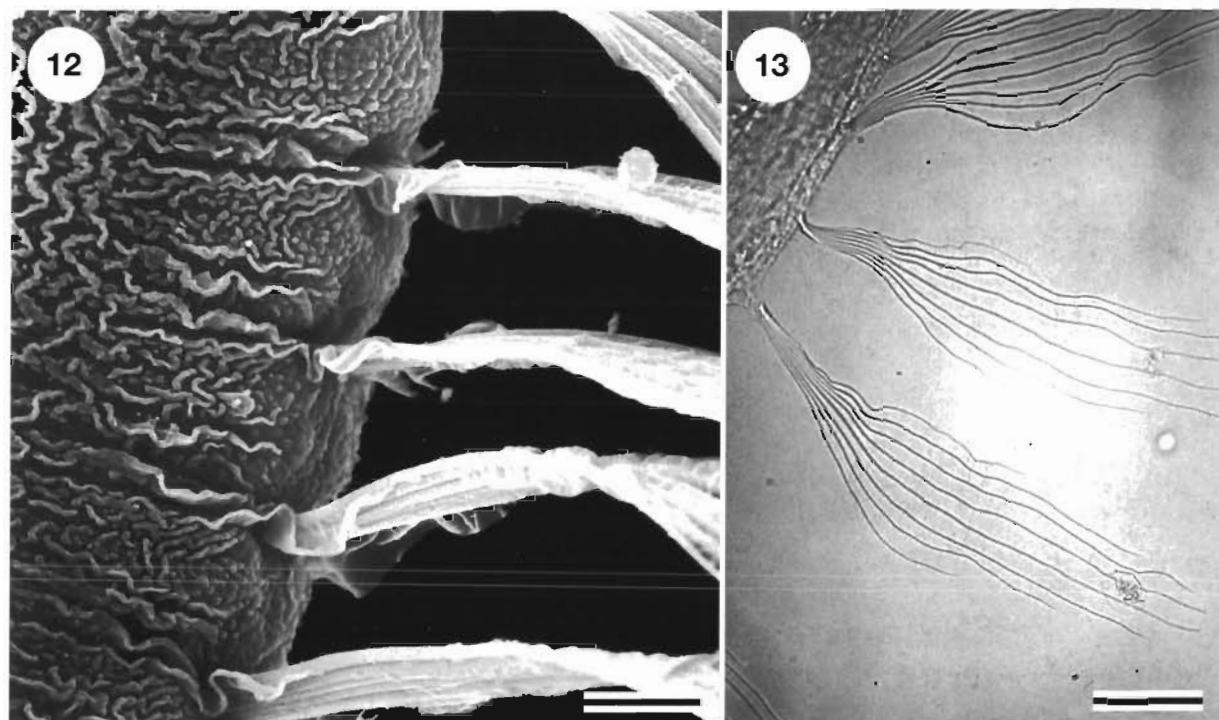


Figs. 1 to 6. *Bacciger bacciger*. Fig. 1 Sporocyst photomicrograph of *B. bacciger* enclosing cercariae. Scale bar = 300  $\mu$ m. Fig. 2. SEM photomicrograph of the sporocyst of *B. bacciger*. Scale bar = 200  $\mu$ m. Fig. 3. (a) Scanning ultrastructure of the tegument of the *B. bacciger* sporocyst. Scale bar = 3  $\mu$ m. (b) Detail of the numerous pits present (arrow). Scale bar = 1  $\mu$ m. Fig. 4. Apical view of the birth pore of the sporocyst. (a) SEM photomicrograph (Scale bar = 4  $\mu$ m). (b) Light micrograph (Scale bar = 10  $\mu$ m). Fig. 5. SEM photomicrograph of the uniciliate sensory receptor on the sporocyst surface. Scale bar = 1  $\mu$ m. Fig. 6. Presumed sensory structure of the sporocyst surface. SEM photomicrograph. Scale bar = 1  $\mu$ m



Figs. 7 to 11. *Bacciger bacciger*. Fig. 7. SEM photomicrograph of the setiferous cercaria of *B. bacciger*. OS: oral sucker; VS: ventral sucker; F: finlet. Scale bar = 100  $\mu$ m. Fig. 8. Scanning ultrastructure of the spinous tegument of the cercaria of *B. bacciger*. Scale bar = 3  $\mu$ m. Fig. 9. Detail of the spines covering the cercarial body. SEM photomicrograph. Scale bar = 1  $\mu$ m. Fig. 10. Scanning electron photomicrograph of the ventral sucker of the cercaria of *B. bacciger*. BS: body spines; IC: internal sensory receptor cilia; EC: external sensory receptor cilia. Scale bar = 10  $\mu$ m. Fig. 11. Scanning ultrastructure of the tegument of the cercarial body of *B. bacciger* showing the spines and the unciliate sensory organs. Scale bar = 1  $\mu$ m





Figs. 12 & 13. *Bacciger bacciger*. Fig. 12. Finlet protusions from the cercarial tail. SEM photomicrograph. Scale bar = 10  $\mu$ m. Fig. 13. Detail of the cercaria finlet showing the longitudinal rib-like supports. Light micrograph. Scale bar = 25  $\mu$ m

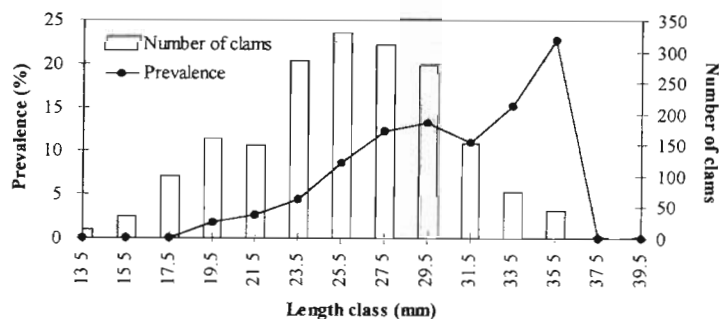


Fig. 14. Prevalence of *Bacciger bacciger* infections and number of clams examined by *Donax trunculus* size class

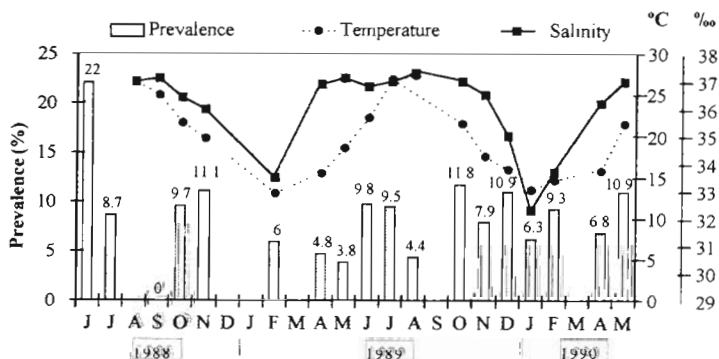


Fig. 15. Prevalence of *Bacciger bacciger* infections in *D. trunculus* by month and year. Water temperature and salinity are also indicated

## DISCUSSION

Sporocysts and cercariae obtained from the gonads of the wedge clam *Donax trunculus* were identified by morphological examination as *Bacciger bacciger*. This study records for the first time the donacid *D. trunculus* as a host of *B. bacciger*. Although Pelseneer (1896) and Giard (1897) mentioned the presence of *B. bacciger* in this bivalve species, later studies (Dollfus 1925, Palombi 1933a,b, 1934a,b and Lauckner 1983) referred to the host mentioned by Pelseneer and Giard as *Donax vittatus* Da Costa (= *D. trunculus* L.). This trematode larva is reported for the first time in the most western part of the Mediterranean. Previous records of *B. bacciger* in several hosts and localities are summarized in Table 1.

The light and SEM microscopic observations of the sporocysts and mature cercariae of *Bacciger bacciger* corroborate the metric and morpho-anatomical features reported by Palombi (1934a, b). Some new characters are described here, including the presence of a birth pore located at the most motile protruding edge of the sporocyst, unciliate sensory organs and cup shaped sensory-like structures on the

Table 2. Prevalence of *Bacciger bacciger* in the gonadal tissues of *Donax trunculus* by month and sex

|          | Male clams              |                   | Female clams            |                   | Unknown sex             |                   |
|----------|-------------------------|-------------------|-------------------------|-------------------|-------------------------|-------------------|
|          | Infected/total<br>(no.) | Prevalence<br>(%) | Infected/total<br>(no.) | Prevalence<br>(%) | Infected/total<br>(no.) | Prevalence<br>(%) |
| Jun 1988 | 5/51                    | 9.80              | 8/61                    | 13.11             | 15/15                   | 100               |
| Jul 1988 | 16/155                  | 10.32             | 8/122                   | 6.56              | 0/0                     | 0                 |
| Sep 1988 | 0/10                    | 0                 | 0/12                    | 0                 | 0/4                     | 0                 |
| Oct 1988 | 0/12                    | 0                 | 2/10                    | 20                | 1/9                     | 11.11             |
| Nov 1988 | 0/0                     | 0                 | 0/0                     | 0                 | 2/18                    | 11.11             |
| Feb 1989 | 0/31                    | 0                 | 3/35                    | 8.57              | 1/1                     | 100               |
| Apr 1989 | 3/80                    | 3.75              | 5/87                    | 5.75              | 0/0                     | 0                 |
| May 1989 | 0/69                    | 0                 | 5/61                    | 8.20              | 0/0                     | 0                 |
| Jun 1989 | 5/66                    | 7.57              | 7/57                    | 12.28             | 0/0                     | 0                 |
| Jul 1989 | 9/78                    | 11.54             | 6/80                    | 7.50              | 0/0                     | 0                 |
| Aug 1989 | 0/91                    | 0                 | 8/90                    | 8.89              | 0/0                     | 0                 |
| Oct 1989 | 0/2                     | 0                 | 0/2                     | 0                 | 2/13                    | 15.38             |
| Nov 1989 | 1/4                     | 25                | 2/50                    | 4                 | 2/9                     | 22.22             |
| Dec 1989 | 0/0                     | 0                 | 0/0                     | 0                 | 13/119                  | 10.92             |
| Jan 1990 | 0/0                     | 0                 | 0/0                     | 0                 | 10/160                  | 6.25              |
| Feb 1990 | 5/60                    | 8.33              | 6/58                    | 10.34             | 0/0                     | 0                 |
| Apr 1990 | 5/58                    | 8.62              | 3/59                    | 5.08              | 0/0                     | 0                 |
| May 1990 | 3/26                    | 11.54             | 3/37                    | 8.11              | 1/1                     | 100               |
| Total    | 52/793                  | 6.56              | 66/821                  | 8.04              | 47/349                  | 13.47             |

sporocyst tegument surface, and spines and unciliate sensory organs in the ventral sucker of the cercariae.

Morphologic features of the surface of the sporocysts of *Bacciger bacciger* largely agree with TEM observations by Matricón-Gondran (1969), who described long, tubular invaginations of the external tegumentary membrane. The numerous pits detected by SEM on the sporocyst surface in the present study closely correspond to the entrance of the invaginations mentioned. Functionally, the sporocyst tegument would allow for the absorption of nutrients from the host (Bibby & Rees 1971, Matricón-Gondran 1971b) and tubular invaginations greatly increase the absorptive surface area. The morphologic aspect of unciliate sensory receptors here described by SEM as scattered on the surface of *B. bacciger* sporocysts, are compatible with the fine structure proposed by Matricón-Gondran (1971b) for single ciliate receptors in sporocysts of the same species. The number and precise arrangement of sensory receptors have not been determined here or in other SEM studies of daughter sporocysts. Nevertheless, concentration of ciliate sensory papillae around the birth pore was noted in cyathocotylid *Cercaria kuwaitae* II daughter sporocysts, infecting the prosobranch *Cerithidea cingulata*, by Abdul-Salam & Sreelatha (1993). Absence has been reported by Busta & Nasincova (1988) in the plagiiorchiid *Opisthoglyphe ranae*, infecting water snails *Lymnaea stagnalis*, and by Abdul-Salam & Sreelatha (1995) in the *Cercaria kuwaitae* VI (Haplosporididae) daughter sporocysts. This diversity contrasts with the daughter rediae in digenetic trematodes, in whose anterior region abundant ciliate and dome-shaped papillae surround-

ing the mouth are a constant feature. This characteristic has been associated with functions as chemo- or tangoreceptors, presumably facilitating feeding and orientation during redial migration through host tissues (Rees 1980, Dunn et al. 1992, Krejci & Fried 1994).

The cup-shaped sensory-like structures described in this study on the sporocyst surface of *Bacciger bacciger* were not reported in this species by Matricón-Gondran (1971b) using TEM. Their sensory-like condition has been postulated considering their morphological compatibility with sheathed sensory receptors found by TEM and SEM on larval stage surfaces of digenetic trematodes. Czubaj & Niewiadomska (1991), working on TEM with daughter sporocysts of *Diplostomum pseudospathaceum*, which infects the snail *Lymnaea stagnalis*, have described 2 types of sensory ending with a short cilium and high tegumentary collar. Larval stages other than sporocysts have also been considered in our interpretation. Sheathed sensory receptors have been seen, by TEM, in *Schistosoma mansoni* cercariae infecting *Australorbis glabratus*. The tegument surrounding each organ forms a tubular sheath which encloses a cilium except at its apex (Robson & Erasmus 1970, Nuttman 1971, Ebrahimzadeh 1974). Pariselle & Matricón-Gondran (1985) reported, using SEM and TEM, receptors with a smooth tegumentary collar sheathing a cilium in the cercaria of *Nicola gallica* (Coitocaecidae) infecting *Theodoxia fluviatilis*. Similar unciliate receptors possessing a tegumentary collar extended in the form of a shorter or longer cylinder occur in the cercariae of *Hasstilesia ovis*, *Brachylaimus aequans* and *Eurytrema pancreaticum* as reported by Zdarska & Soboleva (1982), Zdarska (1983) and

Zdarska et al. (1983), respectively. In a recent TEM study, Czubaj & Niewiadomska (1996) recorded up to 13 types of sensory endings in *D. pseudospathaceum* cercariae which are different ultrastructurally, 5 of which possess a short cilium surrounded by a tight high tegumentary collar. SEM of metacercaria of *Brachylaima fuscatus*, infecting the terrestrial snail *Ponsadenia duplocincta*, has papillae with finger-like projections, sometimes with a short cilium visible (Zdarska 1994).

Cilia have not been observed in the cup-like structures of *Bacciger bacciger* sporocysts, but its presence inside the cup structure cannot be ruled out. Few studies have been made of sensory receptors in larval digenetic trematodes using TEM and SEM simultaneously to correlate exactly the fine structure and external features of each type of receptor. SEM figures of unciliated sheathed receptors with a smooth tegumentary collar from Pariselle & Matricón-Gondran (1985) did not show evidence of the central cilium, clearly marked in respective TEM figures. Likewise, sensory receptors possessing a short cilium sheathed by a tegumentary collar which have been described by TEM by other authors could in a SEM have an appearance close to the cup-like structures described in *B. bacciger*.

The spinous character of the ventral sucker of the cercariae of *Bacciger bacciger* appears well established by SEM, although it was not reported in previous studies on this species. The presence of spines in the ventral sucker of the cercariae is not a general occurrence in digenetic trematodes. Nevertheless, Yamaguti (1975) reports 3 cercariae belonging to Fello-distomidae family (*Cercaria inbecilla*, *C. fragosa* and *C. pusilla*) whose acetabula contain minute spines in their cavity. Cercariae belonging to other families such as Plagiorchiidae, reported by Busta & Nasincova (1988), and Diplostomidae by Bibby & Rees (1971) have spines on the ventral sucker. These authors claim that this character would facilitate the initial attachment of the cercaria to the second intermediate host.

The 2 rings of unciliated sensory organs located on the ventral sucker of the cercariae of *Bacciger bacciger* may have a chemo- or tangoreceptor character (Matricón-Gondran 1971b). Within fello-distomid cercariae, an examination of *Cercaria fragosa* by light microscopy reveals 6 papillae on the acetabulum (Yamaguti 1975). Sensory papillae arranged in concentric circles on the ventral sucker have been reported in a variety of cercariae studied by SEM (see above-mentioned authors). Their morphological features, number and distribution are considered useful as taxonomic data (Smyth & Halton 1983).

SEM observations of the cercarial tail finlet confirm its composite character, the rib-like supports acting as a skeleton.

None of the previous studies on *Bacciger bacciger* reported the prevalence of sporocyst infection in relation to host size. The increase in the prevalence of *B. bacciger* with increasing size of *Donax trunculus* could be caused by one or a combination of the following factors (Heasman et al. 1996): (1) a cumulative effect as larger, older clams have been exposed longer to the chance of miracidial infection; (2) the increased chance of miracidial contact because larger clams filter greater volumes of water; or (3) decreasing resistance to infection with advanced age. The increase of prevalence with host size has been reported previously in other trematodes, including *Proctoeces maculatus* (Lang & Dennis 1976), *Bucephalus* spp. (Loesch 1957, Heasman et al. 1996) and *Gymnophalus* spp. (Loesch 1957). The effect of gigantism in infected clams cannot be excluded.

The absence of sporocyst infection in clams <19 mm suggests that individuals attained this size before the invasive stage appeared, although clams of this size were found throughout the year in the population (Ramón 1993). However, the presence of sporocysts may depend on the sexual maturity of the bivalve (Uzmann 1953); *Donax trunculus* becomes reproductively active at a size of 15 to 16 mm (Ramón 1993).

Studies on the fluctuations in the prevalence of sporocysts in the genus *Bacciger* are scarce. Bae et al. (1977) reported the highest prevalence of infection in *Meretrix lusoria* by *B. harengulae* in July, and the lowest in March. Palombi (1934a, b, 1940) mentioned that the developmental cycle of *B. bacciger* is completed in 1 yr, with larval stages occurring during winter and adult stages during spring. The maximum rates of parasitism by sporocysts in *Tapes decussatus* occurred in March to May in Fusaro, reaching 45 to 65%, while in the Gulf of Naples the maximum was recorded in December to February (around 8%). In both areas the maximum prevalence in the bivalve preceded the maximum prevalence in *Atherina* spp. by 1 to 2 mo. In contrast, in our study, *B. bacciger* did not show clear seasonality in prevalence of infection of *D. trunculus*. Infection seasonality in trematode larvae is not common. Lang & Dennis (1976) mentioned that *Proctoeces maculatus* sporocysts exhibited seasonal variation in the incidence of infection, infection being more common in late summer. In contrast, Heasman et al. (1996) found no consistent annual pattern in an overview of 5 continuous years of bucephalid sporocysts in *Pecten fumatus*. Additionally, Taskinen et al. (1994) did not find clear seasonality in prevalence of *Rhipidocotyle campanula* and *R. fennica* sporocysts infecting the bivalve *Anodonta piscinalis*.

Infected *Donax trunculus* of unknown sex showed the highest prevalence values. These clams were found not only during the resting gonadal stage period (from



October to January), but also in June 1988 (Table 2). The presence of adult individuals whose gonads harbored sporocysts of *Bacciger bacciger* but not gametes in a period of sexual maturity suggests that larval trematodes can reduce clam reproduction by castration. Indeed, Dupouy & Martinez (1973) found parasitic castration in *Mytilus galloprovincialis* when miracidia of *Proctoeces maculatus* invaded during the resting phase. The sporocyst utilized the storage substances (glycogen) of the intertubular tissue, which led to arrest of the gametogenic cycle. Wardle (1988) mentioned that sporocysts of the bucephalid larva *Cercaria pleuromerae* infected the gonads of the clam *Pleuromeris armilla*, apparently preventing gametogenesis in the host. In our study we observed the presence of gametes in most of the parasitized individuals. This suggests that gametogenesis was at an advanced stage when these individuals were infected.

Many of the trematode parasites found in the genus *Donax* occur in the visceral mass, and cause castration of infected bivalves (Pelseneer 1896, Loesch 1957, Wade 1967). In other species of bivalves infected by *Bacciger bacciger* the foot and the visceral mass are completely filled with sporocysts, which causes complete castration in heavily infected individuals. They can infect the liver and all the visceral mass in heavy infections, with individuals assuming a flaccid consistency (Palombi 1934a). The gonad is the first organ to be infected and may be destroyed completely. *B. bacciger* infections can cause other negative effects on the hosts. Palombi (1934a) suggested that during the gonadal maturation period there was an increase in mortality because, instead of burrowing, infected clams frequently lie exposed to predators on the surface of the sediment.

The infection by *Bacciger bacciger* reported here caused parasitic castration in 2.4% of the *Donax trunculus* population; it did not reduce burrowing. There were no sporocysts in the foot, which is used as an anchor during burrowing. We did not observe large accumulations of newly killed clams or empty shells in the dredge catches, which could be a sign of mass mortality. The prevalences of Fellodistomidae infections reported previously vary from 0.5 to 65%. The low prevalence of infection (8.4%) of *B. bacciger* in *D. trunculus* and low levels of parasitic castration suggest that the development of this clam population in the Gulf of Valencia was not significantly affected by infection.

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