Seasonal occurrence of balanomorph barnacle nauplius larvae in the region of the Antarctic Peninsula

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Abstract

Plankton samples taken along the west coast of the Antarctic Peninsula and in Bransfield Strait show widespread occurrence of *Bathylasma corolliforme* nauplius larvae during the austral spring, mid-October to the third week of December. During autumn, between the first week of May and early June there was a complete absence of balanomorph nauplii. This evidence shows periodicity in reproduction. There is a seemingly close correlation between the presence of these nauplii and the published data on phytoplankton biomass and seawater surface temperature.

Key words: Antarctic acorn barnacle, reproductive periodicity

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1. Introduction

Periodicity of reproduction in marine benthic invertebrates differs among species and geographic regions. Along the northeast coast of North America the intertidal balanomorph or "acorn" barnacle *Semibalanus balanoides* reproduces during December. In contrast, time of spawning and the occurrence of nauplius larvae of *Balanus amphitrite* varies according to latitude. In north temperate regions it spawns during spring and summer, wheras at tropical latitudes reproduction occurs throughout the year.

The only species of balanomorph barnacle reported from Antarctic and Subantarctic waters is *Bathylasma corolliforme* (Hoek, 1883). It is known to occur typically at depths exceeding 100 meters (Dayton et al., 1892) and is widely distributed geographically throughout Antarctic and Subantarctic waters including McMurdo Bay, the Antarctic Peninsula, Weddell Sea, South Sandwich Islands, south Georgia and the Kerguelen Islands (Ross and Newman, 1969; Brueggeman and Wu, 2010.). The purpose of the present study was to determine the periodicity of reproduction of *Bathylasma corolliforme*.

This article is dedicated to Dr. Margaret Barnes, who through her editorial skill made important contributions to the study of marine sciences.

2. Materials and methods

2.1 Sample collection

Plankton samples were collected with a conical three-quarter-meter net with a mesh size of 240 μm. Two hundred meters of wire was paid-out at about 10 m^{-min} to an estimated depth of 150 meters. All samples were examined at a magnification of 6X or 12X, and all nauplius barnacle larvae were removed and preserved in 80 percent formaldehyde or 70 percent alcohol.

2.2 Locations and dates of sampling

A total of 154 plankton samples were taken between the southern front of the Antarctic Circumpolar Current at ~61°S and the Antarctic Circle at 67°S (Fig. 1A). Three voyages were made during austral spring, from October 19–November 10, 1994, December 5–24, 2001, and December 1–18, 2004. During the austral autumn two expeditions were made, from May 19–June 10, 2000 and May 2–June 10, 2006.

2.3 Identification of the nauplius larvae

The first report of a distinctly balanomorph barnacle nauplius from Antarctic waters was that of Foster (1989), who concluded that "because *Bathylasma corolliforme* is the only balanomorph [species] known in the Antarctic ocean…tentative identification of larvae is possible...but the absolute confirmation will require rearing larvae from embyos of known parentage." Perhaps the positive identification of larvae will become possible by DNA barcoding for both the adults and larvae (Webb et al., 2006).

The barnacle nauplius larvae encountered in Bransfield Strait and throughout the region of the Antarctic Peninsula are readily characterized as balanomorph barnacle larvae (Fig. 2A, B). They appear to be identical to those taken from McMurdo Bay by Foster (1989, p.176), and it is concluded that the species from plankton samples taken in Bransfield Strait and along the west coast of the Antarctic Peninsula all belong to *B. corolliforme*. Advanced stages of *B. corolliforme* nauplii cannot be distinguished from each other because they have not yet been described from laboratory culture.

Although several species of lepadomorph ("stalked" or "goose") barnacles occur in Antarctic waters (Ross and Newman, 1969), their nauplius larvae with a long posterior spine of the carapace are readily distinguished from those of balanomorph larvae.

3. Results

The precise data, including date, location (latitude and longitude), and seawater surface temperatures where nauplius larvae were encountered, are tabulated in Tables 1, 2 and 3; these data are summarized in Table 4 and illustrated in Figure 1B. Table 4 shows that 59 of the total 87 spring samples (1994, 2001, and 2004), or approximately two-thirds (68%), included balanomorph barnacle nauplii. The number of locations with nauplius larvae seemed to decline from mid-October to the third week of December.

No cyprid stage larvae were included at any of the sampling localities, probably because sampling nets did not exceed a maximum depth of 150 m. Tapia et al. (2010) found from vertical samples taken off southern California that "cyprids remain within mid-depth and bottom." Our net therefore may not have reached the depth where cyprids occurred. Alternatively, it may have been too early for larvae in the spring samples to have reached the cyprid stage.

Table 4 shows that nauplius larvae of barnacles were completely absent in the autumn between May 2 and June 10. The data summarized strongly suggest that reproduction of *B. corolliforme* is periodic and occurs in spring months.

4. Discussion

Periodicity and seasonal reproduction varies greatly among Antarctic benthic invertebrate species. Planktonic larvae are encountered every month during all seasons of the year (Shreeve and Peck, 1995; Freire et al., 2006; Bowden et al., 2009). Some species reproduce continuously, whereas others are restricted to specific times of the year. The question arises, What are the cues that initiate periodic reproduction among seasonally reproducing species?

Two conspicuous periodic seasonal changes are (1) seawater surface temperature and (2) phytoplankton productivity, related to day length. Laboratory experiments and field observations of temperate species show that growth and survival of balanomorph barnacle nauplii are determined by temperature and the species and quantity of phytoplankton (Barnes and Barnes, 1958; Crisp, 1959; Scheltema and Williams, 1982). The spring and summer increase in shallow seawater temperatures (10–20 m) in the region of the Antarctic Peninsula is variable in summer but quite constant in winter; the increase in spring temperatures during November and December at Anvers Island was from –1.5° to +1.25°C (an average of seven years' data) (Barnes, D.K.A. et al., 2006). The recorded temperatures taken along transects of spring cruises reported here are close to these values: 1994, -1.5° to -0.5°C; 2001, -0.8° to +0.2°C; and 2004, -1.5° to -0.3°C (Tables 1–3). These surface temperatures do not necessarily reflect changes in temperature on the bottom, however, where the first nauplier stage is retained by the adults before release of larvae (Foster, 1989).

The biomass of phytoplankton starts to increase in mid-November (Burkholder and Sieburth, 1961; Smith et al., 1998). This increase in phytoplankton biomass and temperature closely parallel the occurrence of *B. corolliforme* nauplius larvae, but the larvae of nonseasonal species do not respond to episodic occurrence of increased biomass (Mincks and Smith, 2007).

The geographic distribution of adult *B. corolliforme* must be related to widespread dispersal of its nauplius larvae. Its known distribution around the periphery of the Antarctic continent which includes the Ross Sea, Bransfield Strait, and Weddell Sea may be attributed to the passive dispersal of its nauplii by the Antarctic Coastal Current (East Wind Drift), which flows westward along the Antarctic coastline. The adults of *B. corolliforme*, however, are also known to occur in subpolar regions. Widespread dispersal and its relationship to the geographic distribution of benthic invertebrates has been demonstrated among tropical species between the Caribbean and west Africa (Scheltema, 1968), but the plankton data on Antarctic balanomorph nauplii are presently insufficient to relate their larval dispersal with certainty to the geographic distribution of *B. corolliforme*.

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Figure captions

Fig. 1. (A) The locations of 154 plankton collections made during austral spring 1994, 2001, and 2004; and autumn 2000 and 2006. (B) Locations where balanomorph barnacle nauplii occurred during spring 1994 (circles) and 2001 and 2004 (squares).

Fig. 2. (A, B) Balanomorph nauplii larvae from 62°00'S, 56°01'W inferred to be those of *Bathylasma corolliforme* (Hoek). Length approximately 7 mm. (C) *Bathylasma corolliforme*, a widely distributed benthic species in Antarctic and Subantarctic waters (copyright Rob Robbins).

Table 1
Locations south of 61° S, Oct 21 – Nov. 10, 1994, where barnacle larvae were encountered.

Date	Latitude S		Longitude W		Deg C
1994	Deg	Min	Deg	Min	
21.10	64	043	63	195	-1.0
22.10	62	391	62	458	-1.5
24.10	61	370	58	230	-1.0
24.10	61	259	58	079	-1.0
25.10	61	425	57	292	-1.0
26.10	61	393	58	002	-1.1
26.10	61	060	55	577	-1.0
27.10	61	101	56	101	-0.9
27.10	61	095	56	111	-1.2
28.10	61	184	56	041	-1.0
28.10	61	074	56	093	-1.0
29.10	61	549	56	562	-1.0
29.10	61	102	58	095	-1.0
30.10	61	477	59	212	-0.9
30.10	61	341	58	413	-1.0
31.10	62	111	58	229	-0.6
01.11	62	161	58	251	-1.0
02.11	62	107	59	253	-0.5
03.11	61	399	57	293	-0.8
03.11	61	364	56	473	-0.8
04.11	61	206	56	478	-1.0
04.11	61	197	56	147	-1.0
05.11	61	231	56	259	-0.8
06.11	61	046	56	047	-1.0
06.11	61	216	56	087	-0.8
07.11	61	271	56	455	-0.8
08.11	62	088	57	292	-
09.11	62	536	59	506	-
10.11	64	310	62	301	-

Table 2
Locations south of 61° S, Dec. 8–22, 2001, where barnacle nauplii were encountered.

Date	Latitude S		Longitude W		Deg C
2001	Deg	Min	Deg	Min	
08.12	64	45.005	62	45.636	0.0
09.12	64	11.150	61	50.900	0.0
09.12	63	35.112	61	05.497	0.9
09.12	63	07.465	58	30.035	0.2
09.12	62	52.593	58	30.517	0.5
09.12	62	52.370	57	46.641	-0.1
09.12	62	45.009	57	01.462	0.0
10.12	62	29.770	56	29.383	-0.8
10.12	62	15.115	56	15.105	0.0
10.12	62	00.205	56	01.325	0.1
10.12	61	19.883	55	20.170	0.8
20.12	60	54.514	55	34.857	1.2
22.12	63	47.240	61	25.168	1.1
22.12	64	24.118	62	00.170	0.3

Table 3
Locations south of 61° S, Dec. 1–18, 2004, where barnacle nauplii were encountered.

Date	Latitude S		Longitude W		Deg C
2004	Deg	Min	Deg	Min	
01.12	61	32.909	55	28.672	-0.3
02.12	61	59.349	67	10.630	-0.5
02.12	63	18.370	56	48.988	-1.5
05.12	63	40.295	56	44.934	-1.0
05.12	62	51.015	59	27.249	-0.5
05.12	63	19.342	59	05.790	-0.5
09.12	63	07.581	61	28.900	-0.5
09.12	63	28.024	62	22.969	-0.5
09.12	63	21.074	61	28.397	-1.0
10.12	63	26.821	61	49.660	-0.5
10.12	64	05.678	63	35.297	-1.0
11.12	64	20.363	64	47.818	-1.0
13.12	66	31.355	70	00.310	-0.5
13.12	65	15.5	67	04.4	-1.5
14.12	65	06.161	66	45.221	-0.25
15.12	64	47.078	63	04.116	-0.5

Table 4
Number of locations where balanomorph barnacle nauplii were encountered (see Fig. 1).

Date	No. samples	Samples with nauplii
	Spring	
Oct 19–Nov 10, 1994	35	29
Dec 5–24, 2001	19	14
Dec 1–18, 2004	33	16
Total	87	59[a]
	Autumn	
May 19–June 10, 2000	33	0
May 2–June 10, 2006	34	0
Total	67	0
Total samples collected		154

[a] Two-thirds (68%) of the spring samples included larvae

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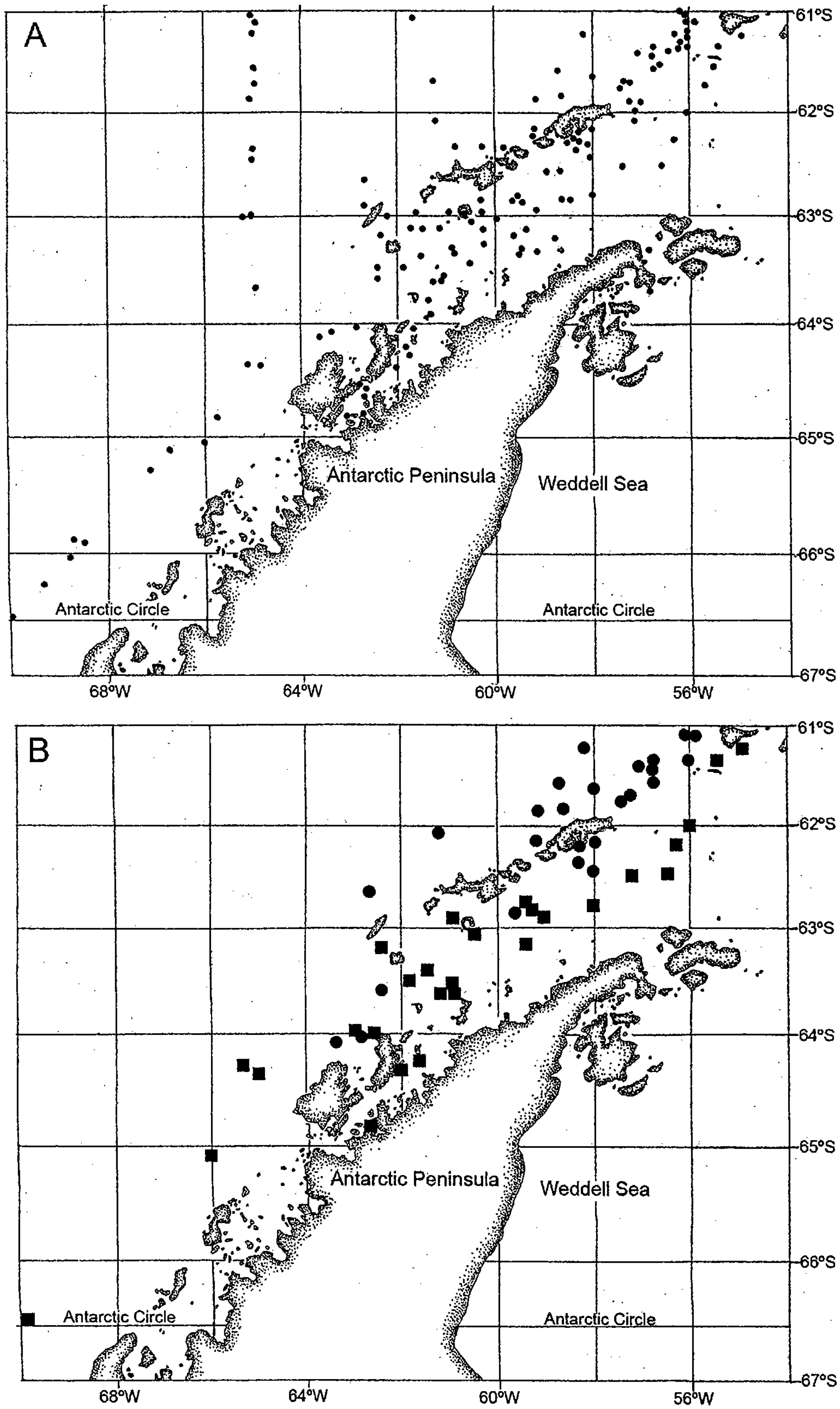
fig 1


A
-61°S
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Antarctic Peninsula
Weddell Sea
Antarctic Circle
Antarctic Circle
68°W
64°W
60°W
56°W
B
-61°S
-62°S
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-64°S
-65°S
-66°S
-67°S
Antarctic Peninsula
Weddell Sea
Antarctic Circle
Antarctic Circle
68°W
64°W
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fig 2