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Settlement of the Acorn Barnacle *Balanus* From Mobile Bay and Weeks Bay, Alabama

STEPHEN C. LANDERS AND SCOTT W. PHIPPS

Barnacle cyprids and metamorphosed settlers were collected using glass slides as artificial substrates at six sites in the Mobile Bay area. Three sites were located in Weeks Bay, Alabama, where the highest settlement concentration occurred near the entrance to Mobile Bay. Two sites in the north end of Weeks Bay near the Fish River had very reduced settlement. The remaining three locations were on the north shore of Dauphin Island, Alabama. Settlement at Dauphin Island was most abundant at the deeper of two sites at the Dauphin Island Sea Lab boat dock, possibly because the substrates were exposed to less wave action. The other two sites at Dauphin Island were shallow and relatively unsettled when compared with the deep site. Adult barnacles recovered from the Weeks Bay and Dauphin Island locations include *Balanus eburneus*, *B. venustus*, *B. improvisus*, and *B. subalbidus*. Our data indicate two primary settlement periods for these species, late winter to spring and late summer to fall, with the highest settlement occurring in Feb. and March.

Settlement and anatomical studies of acorn barnacles have indicated various reproductive periods for these crustaceans. A study of *Semibalanus balanoides* in Rhode Island reported peak settlement during Feb. to April, with settlement patterns varying depending on tidal height of the substrate (Bertness et al., 1992). Numerous breeding and settling periods have been reported; for example, *Balanus glandula* produces several broods from Dec. to March in southern California (Hines, 1978) but in Puget Sound produces several broods from Feb. to Dec. (Branscomb and Vedder, 1982). In addition, *B. cariosus* releases only one brood in early spring in Puget Sound (Branscomb and Vedder, 1982), *Chthamalus fissus* broods during a long summer season from March to Oct., and *Tetraclita squamosa* broods from June to Sep. in southern California (Hines, 1978). These and many other studies indicate that barnacle reproductive seasons vary from species to species as well as between locations (see Barnes, 1992, for a review). Many factors influence barnacle brooding and settlement, including temperature, photoperiod, food availability, salinity, substrate availability, and settlement factors released from adults (Hines, 1978; Barnes, 1992; Dineen and Hines, 1994; Pineda, 1994). This study was undertaken to report the monthly settlement frequency of balanoid barnacles from six different locations in the Mobile Bay area and to determine if larval settlement correlates to selected environmental factors.

MATERIALS AND METHODS

Data for this report were collected during two earlier studies of protozoan colonization, where the field methods are also described (Beech and Landers, 2002; Landers and Phipps, 2003). Glass slides were used as substrates for cyprid larval attachment. The slides were cleaned with isopropanol to remove residual oil and dirt and loaded into plastic slide boxes that had large holes cut into the sides for water flow. The boxes were either suspended by wire from boat docks or tied to dock pilings or cement cinder blocks for 1 wk during each month of the study. Two separate studies were performed. At Dauphin Island, duplicate boxes were submerged at each site, with each box containing eight slides in case any were broken. Three slides were randomly chosen for study each month from each site. At Weeks Bay, one box was submerged at each site (the need for duplicate boxes was unnecessary) with five to eight slides per box. Each month, three slides were randomly chosen from each site for data analysis. After 1 wk, the slides were recovered and stained with hematoxylin and fast green for permanent preparations (Galigher and Kozloff, 1971). All settled barnacles, attached cyprids, and barnacle scars (from barnacles that had settled but were dislodged) that were located under the coverslip of each processed slide were counted; the data were converted to barnacles per centimeter². Adult barnacles were recovered for species identification from nearby substrates at each collection site and immersed in a bleach

solution to clean and separate the terga and scuta. Identifications were done based on Gittings et al. (1986) and were checked by S. Gittings (see Acknowledgments).

Water temperature, salinity, and dissolved oxygen were measured using LaMotte® test kits, a refractometer, and a salinity–oxygen probe (Dauphin Island) or with Yellow Springs Instruments Datasonde® dataloggers (Weeks Bay). Readings at Dauphin Island were taken at the beginning or end (or both) of the 7-d collection period each month. If two readings (start and finish) were available for a collection week, the data were averaged. At Weeks Bay, data were collected every 30 min during the collection week. Data from these readings were averaged to obtain the value used as representative of the sample period. Statistical correlations used the Spearman correlation on SPSS® 10.1.

SITE DESCRIPTIONS (Fig. 1)

Dauphin Island, Alabama. June 1999 to Oct. 2000.—1) Airport/salt marsh (SM)—Shallow,

sandy bottom, near *Spartina* marsh. Mostly soft substrate in the vicinity. The slides were anchored to submerged cinder blocks ~0.2 m below the water surface at mean low tide, ~3 m from shore. 30°15'25"N 88°07'22"W.

2) Verrill dock shallow (VDS) site at the Dauphin Island Sea Lab—Rocks and hard substrata nearby. The slides were anchored to a dock piling ~0.2 m below the water surface at mean low tide, ~3 m from shore. 30°15'07"N 88°04'52"W.

3) Verrill dock deep (VDD) site at the Dauphin Island Sea Lab—Rocks and hard substrata nearby. The slides were suspended by wire ~0.6 m below the water surface at mean low tide, ~23 m from shore. 30°15'07"N 88°04'52"W.

Weeks Bay, Alabama. Jan. 2001 to Dec. 2001.—1)

South dock (SD)—Shallow, sandy bottom, near southern end of the bay. The slides were suspended by wire ~0.5 m below the water surface at mean low tide, ~30 m from shore. 30°21'46"N 87°49'56"W.

2) North dock shallow (NDS) site—Sandy bottom, near northern end of the bay near Fish River. The slides were suspended by wire ~0.5 m below the water surface at mean low tide, ~5 m from shore. 30°24'53"N 87°49'32"W.

3) North dock deep (NDD) site—Sandy bottom, near northern end of the bay near Fish River. The slides were suspended by wire ~1.0 m below the water surface at mean low tide, ~20 m from shore. 30°24'53"N 87°49'32"W.

RESULTS

At Dauphin Island, the VDD site was preferentially settled by barnacle larvae over the other two sites (Fig. 2). Barnacle settlement indicates two reproductive periods: Feb. to March and Aug. to Sep. Barnacle density reached a peak of 38 barnacles/cm² in March 2000 at the deep site. Reproduction was not successful in the fall of 2000 as it had been the previous year. The settlement patterns did not reveal a significant correlation to water temperature, salinity, or dissolved oxygen at any site (Table 1). Settled barnacles had an average size of 1.05 × 0.85 mm (mean value, n = 10) and were too small to identify to species. However, adult barnacles recovered directly from pilings on the Verrill dock were identified as *B. eburneus*, *B. improvisus*, and possibly *B. venustus*. Adults recovered from an old submerged cinder block at the SM site were *B. eburneus* and *B. improvisus*. These adults were collected and identified after the slide collections of 1999–2000, during the preparation of the manuscript.

At Weeks Bay, the SD site was preferentially settled over the two north dock sites (Fig. 3). As with the Dauphin Island data, two reproductive periods were evident, although the appearance and decline of settlers was more prolonged at Weeks Bay. Barnacle density exceeded the values reached at Dauphin Island, with a high value of 49 barnacles/cm² in Feb. 2001 at the SD. Settlement did not correlate to water temperature, salinity, or dissolved oxygen at any site (Table 1). Barnacles collected from the glass slides were not identifiable because of their small size (mean value, 0.98 × 0.79 mm; n = 10), although adults recovered from the highest settlement area (SD) were identified as *B. eburneus* and *B. venustus*. Adults recovered from the north dock site were identified as *B. venustus* and *B. subalbidus*. These adults were collected and identified after the slide collections of 2001, during the preparation of the manuscript.

DISCUSSION

This study has revealed information about the settlement periods of *Balanus* spp. in the Mobile Bay region. Reproductive periods of balanoid barnacles are known to vary from region to region even for the same species (Barnes, 1992). Settlement was highest at the south end of Weeks Bay, near the entrance to Mobile Bay, and also at the Verrill dock at the Dauphin Island Sea Lab, at the entrance of

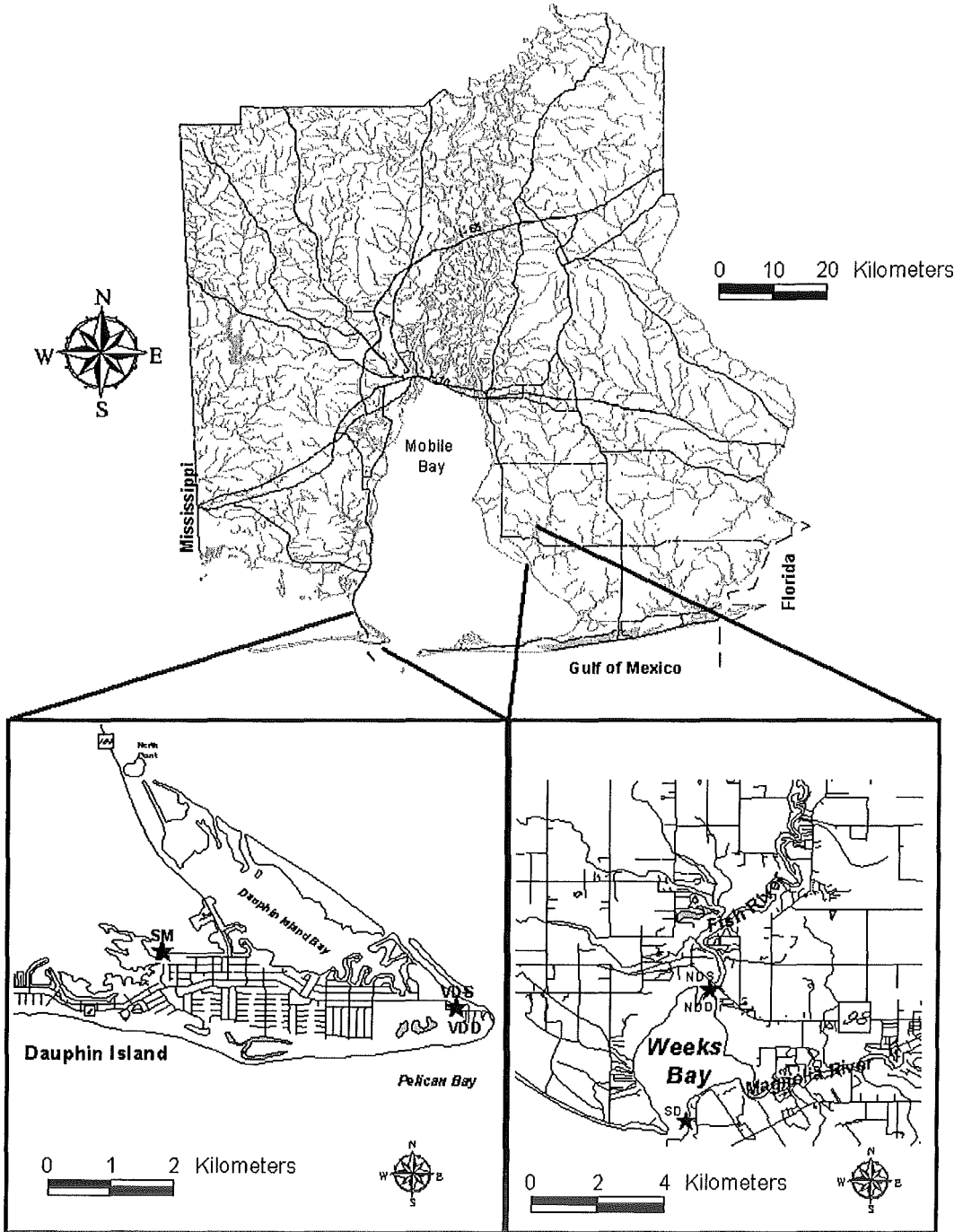


Fig. 1. Mobile Bay, Alabama. The study sites at Weeks Bay and Dauphin Island. (Map courtesy of Sarah E. Johnston, Weeks Bay National Estuarine Research Reserve).

Mobile Bay into the Gulf of Mexico. These two sites are approximately 30 km apart and experience different salinity fluctuations and water currents. Although we recovered four species of *Balanus* from Weeks Bay and Dauphin

Island, we cannot report which species were dominant or rare without more extensive collections and identifications. It is probable that a combination of species accounts for our settling data. Three of the four species of barna-

Barnacles at Dauphin Island

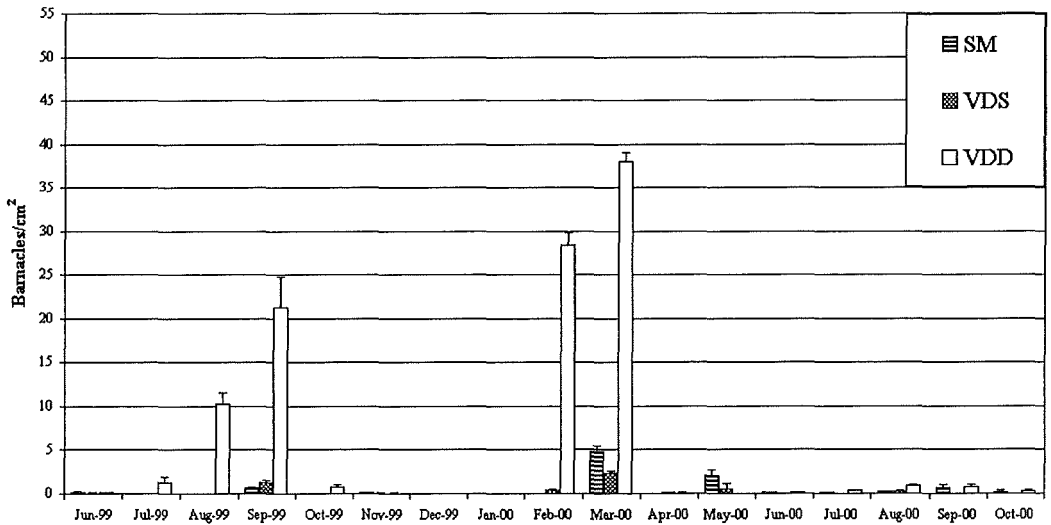


Fig. 2. Barnacles at Dauphin Island (1999–2000). VDD, Verrill dock deep; VDS, Verrill dock shallow; SM, salt marsh. Each column represents the average of three colonized slides and has the standard error indicated.

cles we collected (*B. eburneus*, *B. improvisus*, and *B. venustus*) are among those found often in estuaries and nearshore areas of brackish waters in the Gulf (Wells, 1966; Gittings et al., 1986). The fourth species, *B. subalbidus*, is found in low-salinity waters, including up rivers throughout the Gulf (Gittings et al., 1986), which agrees with our findings of this species near the Fish River.

At Dauphin Island, all three sites were exposed to similar water temperature and salinity, although the deeper site at the Verrill dock was more heavily colonized. The effect of water flow and depth may be a factor accounting for differences at these three sites. At the Verrill dock, the deep site (~23 m from shore) was more heavily settled than the shallow site (~3 m from shore), likely because there was less wave action and physical stress on the sub-

strates at the deeper location, allowing more efficient attachment of the cyprids. The highest value recorded for the VDD site was 38 barnacles/cm² in March 2000. Protozoans collected with the barnacles at these locations revealed a similar pattern, with the glass slides at the deeper site more heavily colonized by protozoans than slides at the shallow site (Beech and Landers, 2002). Similar to the VDS site, the slides at the SM were not colonized heavily during the 1-wk exposures. The slide boxes at this site were anchored inside submerged cinder blocks in shallow water, where they were exposed to rapid water flow during tidal changes. Barnacles are able to colonize substrates at this site, however, because a cinder block “lost” during the project and recovered from this site years later was completely covered with adult barnacles and oysters.

TABLE 1. Statistical correlations between barnacle population and environmental factors (Spearman). No significant correlations were obtained at the $P = 0.05$ level.

| Site | Temperature | Salinity | Dissolved oxygen |
|------|------------------------|-------------------------|-------------------------|
| VDD | $r = 0.382, P = 0.130$ | $r = -0.282, P = 0.273$ | $r = 0.007, P = 0.982$ |
| VDS | $r = 0.017, P = 0.949$ | $r = -0.335, P = 0.188$ | $r = 0.233, P = 0.424$ |
| SM | $r = 0.253, P = 0.327$ | $r = -0.117, P = 0.655$ | $r = 0.437, P = 0.104$ |
| NDD | $r = 0.178, P = 0.579$ | $r = 0.399, P = 0.281$ | $r = 0.100, P = 0.758$ |
| NDS | $r = 0.142, P = 0.661$ | $r = 0.385, P = 0.216$ | $r = -0.171, P = 0.596$ |
| SD | $r = 0.014, P = 0.966$ | $r = 0.007, P = 0.983$ | $r = -0.189, P = 0.557$ |

Barnacles at Weeks Bay

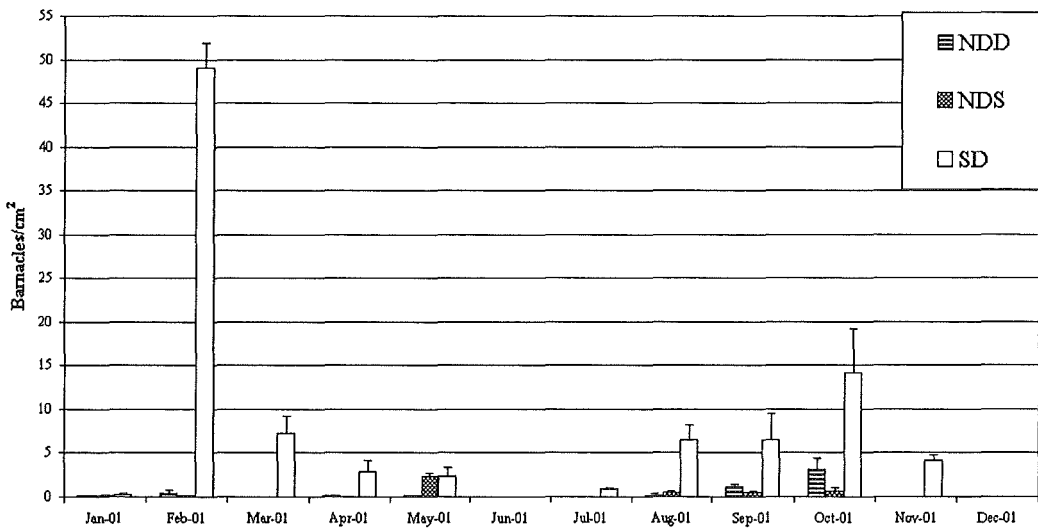


Fig. 3. Barnacles at Weeks Bay (2001). NDD, north dock deep; NDS, north dock shallow; SD, South dock. Each column represents the average of three colonized slides and has the standard error indicated.

At Weeks Bay, species differences among the settlers and proximity to Mobile Bay may be factors influencing settlement differences between the study sites and should be examined in future studies. Colonization was high at the SD site, reaching 49 barnacles/cm² after only 1 wk of substrate exposure to the water. At the SD site there is moderate water flow from incoming tides from Mobile Bay and, conversely, fresh water from the Fish and Magnolia rivers flowing with the outgoing tides. At north dock the salinity is lower than that at SD (average salinity at north dock = 8.6 ppt, average salinity at SD = 11.8 ppt), and there is less input of water from Mobile Bay, attenuating the number of larvae coming from distant locations. Resident adult barnacles were numerous at the north dock and SD sites, though larval settlement was much lower at the north dock than at the SD during the year of our study.

The presence of resident barnacles may influence colonization but was apparently not the most important factor in our study. Resident barnacles can greatly influence settlement because of the factors they release, which contribute to their gregariousness. In a study of *B. eburneus* cyprid larval settlement (Dineen and Hines, 1994), few larvae settled in the absence of adult extract. Barnacles were present at most of our sites: at Weeks Bay, they were present on both docks, and at Dauphin Island, they were present at the Verrill dock. At the SM site, there were none in the immediate vi-

cinity, although a nearby seawall at the airport was covered with barnacles. If the presence of adults in the immediate vicinity was the most important factor, we would have expected a similar settlement at all dock sites.

In summary, we report two primary seasons for acorn barnacle settlement in the Mobile Bay area, late winter to spring and late summer to fall, and we also report the following species of barnacles from the Mobile Bay area: *B. eburneus*, *B. venustus*, *B. improvisus*, and *B. subalbidus*.

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