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Growth and Distribution of the Invasive Bryozoan *Watersipora* in Monterey Harbor, California

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Abstract

Invasive species are common inhabitants of harbors along the coast of California. Tunicates, sponges, and bryozoans are among the more common invertebrates found in fouling communities on floating docks and pilings. An invasive bryozoan, tentatively identified as *Watersipora subtorquata*, has been in Monterey Harbor since the early 1990s, but only recently has it been detected outside of the harbor. Since relatively little is known about *Watersipora* and its interactions with other sessile species in California, sanctuary staff studied the growth and distribution of *Watersipora* in Monterey Harbor beginning in 2010. Sanctuary science divers used monthly fixed photo quadrats to collect percent cover data from cement pier piling surfaces in four orientations and at two depths. Colony growth of the invasive bryozoan was rapid (up to 0.33 mm/d) and exhibited differences by piling, orientation, and depth. Percent cover of several native invertebrate species was correlated with the presence/absence of *Watersipora*, and the invader has the potential to form monocultures, smothering all other species. Sanctuary staff will continue to characterize the spread of this invader within the harbor and collaborate with academic researchers to determine its ecological impact in nearby kelp forests.

Keywords: bryozoa, invasive species, photo quadrats, *Watersipora*

Introduction

Global homogenization has increased at an alarming rate over the last 20 years (Cohen and Carlton, 1998). San Francisco Bay, which is home to a thriving shipping industry and thousands of recreational sailing vessels, is often characterized as the most invaded bay in the world (Cohen and Carlton, 1998). In general, the bays and estuaries of California have undergone dramatic change in the latter half of the 20th century, in part due to extreme habitat loss and modification, but also because of an increasing number of invasive species that have established and spread from one embayment to the next, usually via ballast water exchange and hull fouling. Although invasive species are widely recognized as key contributors to significant changes in native community structure and function (reviewed in Grosholz and Ruiz, 2009), examples of successful eradications or management efforts to minimize their impacts and rate of spread are few (but see Miller et al., 2004; Anderson, 2005).

Recent research has focused on the impacts of invasive species on native communities, and in particular species interactions. In some cases, invaders contributed to the decline of endangered species (Gurevitch and Padilla, 2004) or modified community structure, thereby facilitating the establishment of other invasive species (Simberloff and Von Holle, 1999). In contrast to studies focused on the negative impacts of invasive species, some studies suggest positive impacts on the native community by providing a new resource, such as food or shelter. For example, Hooton (2012) found that native fishes preferentially utilized habitat provided by the invasive Asian kelp *Undaria* *pinnatifida*, and that densities were higher in the presence of the invader as compared to the native habitat.

Monterey Harbor in central California has several invasive species. Presumably, the majority of these were introduced via hull fouling since container vessels containing ballast water are too large to port there. The floating docks and pier pilings in the harbor are covered with native and invasive invertebrates and algae. A deep red bryozoan, tentatively *Watersipora subtorquata* (d'Orbigny, 1852), has been in the harbor since at least the early 1990s. In the last 10 years, sanctuary divers noted increasingly dense patches of the invasive bryozoan in certain sections of the marina and an apparent expansion into sections lacking *Watersipora*.

Relatively little is known about *Watersipora* interactions with fouling communities native to Monterey Harbor. Building upon an undergraduate study (Traiger, 2010) focused on *Watersipora*, sanctuary staff continued to monitor its expansion and used fixed photo quadrats on cement pier pilings to determine if *Watersipora* distribuiton varied by piling location, depth or orientation, and to calculate *in situ* growth rates of undisturbed colonies. Here we present preliminary findings from this ongoing study.

Methods

Study site

Located in central California, Monterey Harbor is one of four municipal marinas between San Francisco Bay and Morro Bay. With just over 400 berths, Monterey Harbor is a small port of call with less than a dozen commercial fishing vessels (<20 m long) and no access for large (>25 m) ships. Most of the vessels are private sailboats (<15 m long) and used infrequently. The marina has nine floating docks, tiers A through I, which are enclosed and protected on two sides by cement sea walls. The tiers are anchored in place by cement pier pilings at 5-m intervals, which have four sides (60 cm wide), generally facing the cardinal directions (N, S, W, E), and extend vertically 3 to 5 m below the surface. Subtidally, the pilings are densely covered throughout the year with fouling invertebrates (e.g., tunicates, anemones, bryozoans, bivalves, barnacles) and seasonal algal cover.

Tier A (36.604178 N, -121.891821° W) is 40 m from the main entrance to the marina and receives the brunt of incoming tidal flow (Figure 1). The adjacent commercial wharf, which is supported by wooden pilings, is the putative source of *Watersipora* larvae and lies upstream of the marina entrance. Substantial colonies of *Watersipora* persist year-round on the wooden pilings of the wharf, and in some areas completely cover pilings. We monitor six pilings along a linear spatial gradient, but for this paper focused on the two pilings on tier A closest to the marina entrance since they were covered with relatively high densities of *Watersipora* and likely represented a focal area for subsequent spread.

Figure 1. Satellite image of Monterey Harbor, Monterey, CA. ‘A’ indicates the western end of tier A and the white arrow denotes the marina entrance. Inset shows the location of Monterey Bay. Satellite image by Google.

Fixed photo quadrats

Each piling was wrapped with clothesline at two heights above the bottom (2 and 3.5 m), both of which were well below the lowest intertidal section of the piling (5 m). The clothesline was quickly overgrown and remained fixed in place but was still visible to divers. During each dive, digital photographs were taken of the same area at 16 locations on each piling.

A PVC quadrat frame was attached to an underwater camera housing (Subal 300D) with a fixed distance of 0.5 m, lens to subject (Figure 2). Using a 50 mm macro lens, the image captured 0.025 m^2 of the piling. The photo quadrat framer was placed in the same orientation prior to each photo: the left frame upright was aligned with the left edge of a piling face at a vertical height both above and then below the fixed clothesline. Images above and below the line were taken on each of the four faces, starting with the north face, and then east, south and west faces, for a total of 8 images. This was repeated at the second vertical height, totaling 16 images per piling.

Figure 2. Diver taking digital image of a fixed photo quadrat on a cement piling in Monterey Harbor. Image courtesy of Chad King, NOAA MBNMS.

Prior to photographing a quadrat, large mobile invertebrates were removed (e.g., *Pisaster*, *Pugettia*) and broad algal blades (e.g., *Dictyoneurum*) draped over the area were moved aside. Images were taken at two-week intervals from 22 February 2010 to 18 March 2010, and at monthly intervals thereafter.

Estimating percent cover

To estimate percent cover of the piling community we used a point sampling technique and overlaid a grid with 49 uniformly distributed points stretched over the entire image (Figure 3). Any point where the picture was out of focus, shadowy, or could not be identified was recorded as "unknown." We included only the top layer of sessile organisms in the percent cover estimate, so each photo quadrat had a maximum value of 100% cover. Points intersecting small mobile invertebrates (e.g., shrimp, hermit crabs) were recorded as "unknown."

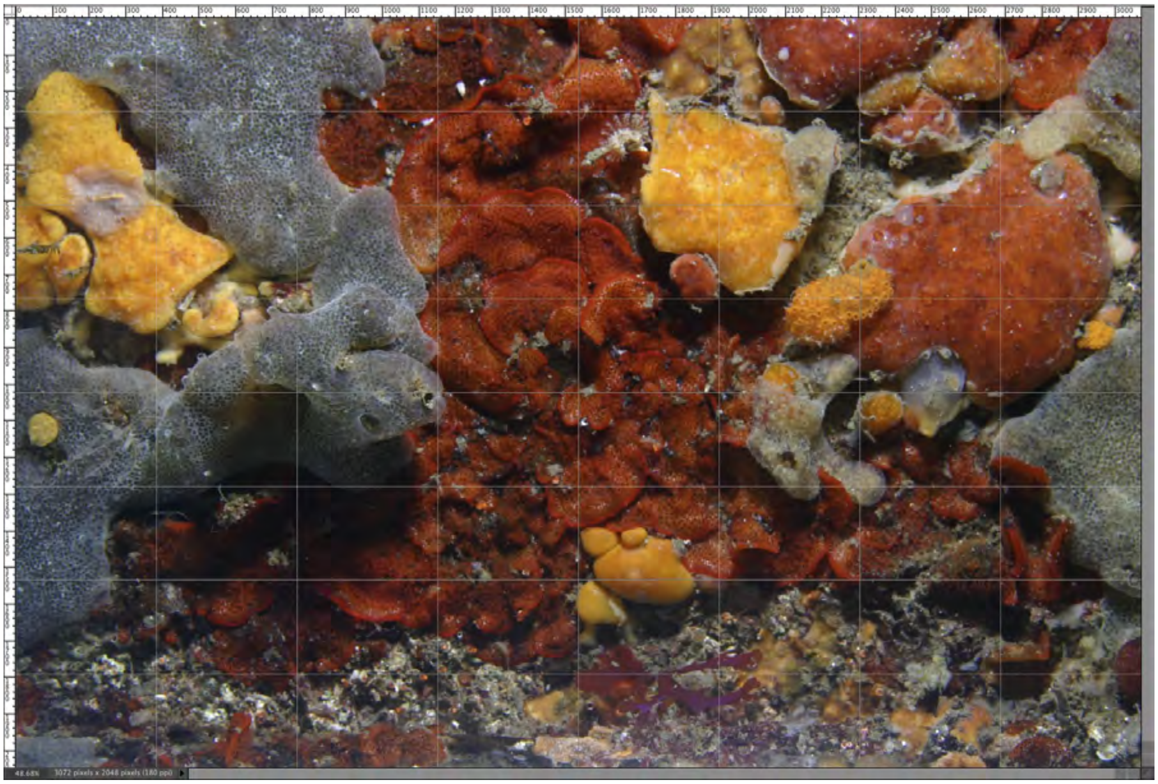

Figure 3. Digital image of a photo quadrat (0.025 m^2) with grid lines overlaid. Percent cover was estimated by identifying organisms under the 49 intersections. *Watersipora* is the bright red, foliose organism in the center. Photo by Steve Lonhart.

Growth estimates

Collecting images of a fixed location over time provided an opportunity to measure growth rate of an unmanipulated colony of *Watersipora in situ*. Using a fixed reference point within the photo quadrat and measuring software (PixelStick by Plum Amazing), the distance a *Watersipora* colony increased was measured over four sampling periods spanning 39 d. Since *Watersipora* colony growth is asymmetric, the same angle was used each time to connect the fixed point and the leading edge of the colony.

Analyses

Percent cover data (square-root transformed) were analyzed using PRIMER-E version 6. Initially a permutational multivariate analysis of variance (PERMANOVA) was used to determine if there were patterns of dissimilarity associated with piling, depth, or direction. This was followed by similarity percentage (SIMPER) analysis to compare dissimilarity among pairs of depth and piling for all types of cover. In particular, comparisons were made within pilings (deep vs. shallow) and between pilings (deep vs. deep).

Results

Percent cover patterns

Images were collected on four sampling dates (22 February, 05 March, 18 March, and 02 April) in 2010, with an average of 13 d between sampling dates. During each sampling date, all 16 fixed quadrats were photographed on each piling. For this preliminary analysis, a total of 64 images for each piling was analyzed by displaying the image in Adobe Photoshop Elements at 100% magnification. The 49 uniformly distributed points were draped over each image and assigned to one of the following 39 categories:

- 9 ascidians (*Diplosoma listerianum*, *Ascidia ceratodes*, *Distaplia occidentalis*, *Botryllus schlosseri*, *Botrylloides* sp., and 4 unidentified species)
- 7 bryozoans (*Watersipora* dead and alive, *Rhynchozoon rostratum*, *Bugula neretina*, and 3 unidentified species)
- 4 mollusks (*Hermissenda* egg cases, *Mopalia* sp., *Lottia* sp., and *Pododesmus cepio*),
- 4 annelids (*Serpula columbiana*, *Salmacina tribranchiata*, an unidentified serpulid and an unidentified chaetopterid)
- 4 cnidarians (*Ectopleura* sp., unknown hydroid, unknown anemone, and *Corynactis californica*)
- 4 algae (juvenile laminariales, *Botryocladia pseudodichotoma*, unknown calcareous crust and an unknown red)
- 1 phoronid (*Phoronis* sp.)
- 1 echinoderm (*Strongylocentrotus purpuratus*)
- 5 miscellaneous ($CaCO_3$, detritus, unknown, filamentous diatom, and PVC)

The distribution of *Watersipora* differed significantly by piling, depth and orientation (side). The piling effect was particularly striking (Figure 4), with distinct differences between the two pilings, which were separated by only 5 m.

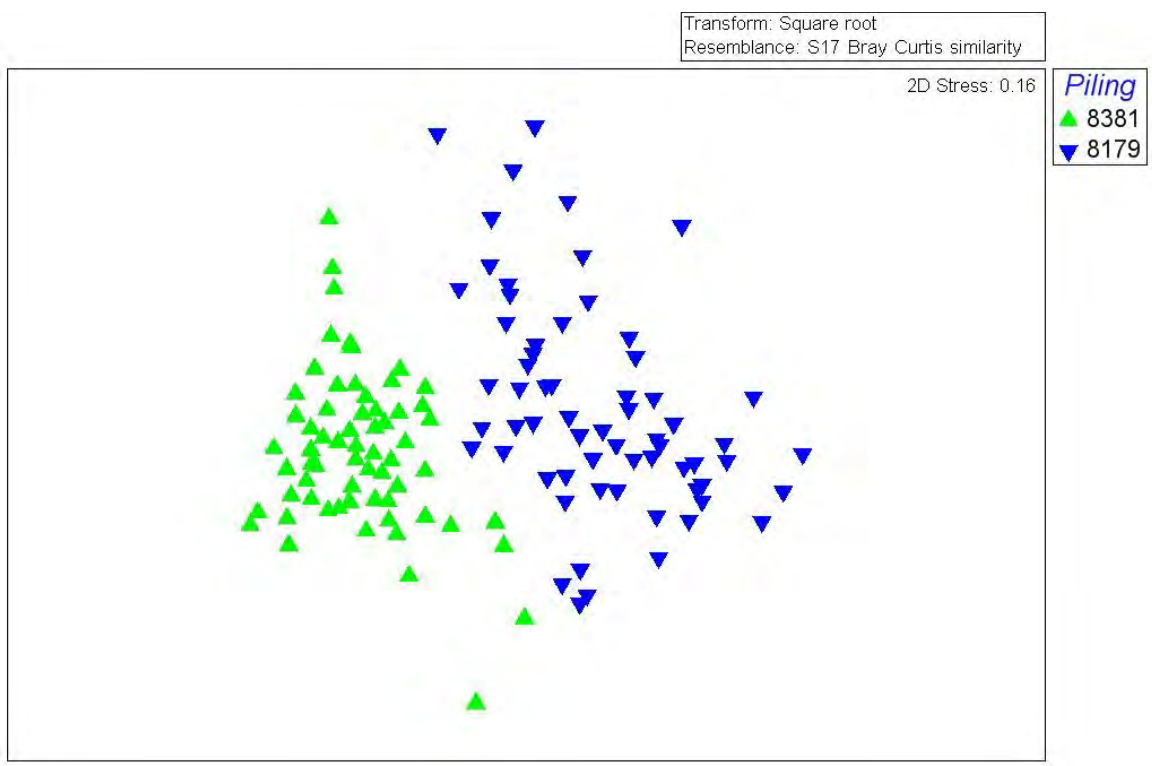

Figure 4. MDS plot showing differences in communities of sessile organisms on two pilings (8381 closest to the marina entrance, and 8179 slightly farther away). Data were square-root transformed to reduce the effect of an abundant species.

The community of sessile organisms inhabiting the pilings, the piling by depth effect was different between the two pilings, with the piling closest to the marina entrance showing more overlap by depth, whereas the more distant piling showed relatively little overlap (Figure 5). For piling 8381, which was the western-most piling and closest to the marina entrance, live *Watersipora* and $CaCO_3$ (dead but unidentifiable calcareous species) drove the dissimilarities by depth. For piling 8179, the differences were driven by the invasive tunicate *Diplosoma listerianum* (shallow depth), detritus and the strawberry anemone *Corynactis californica* (deep).

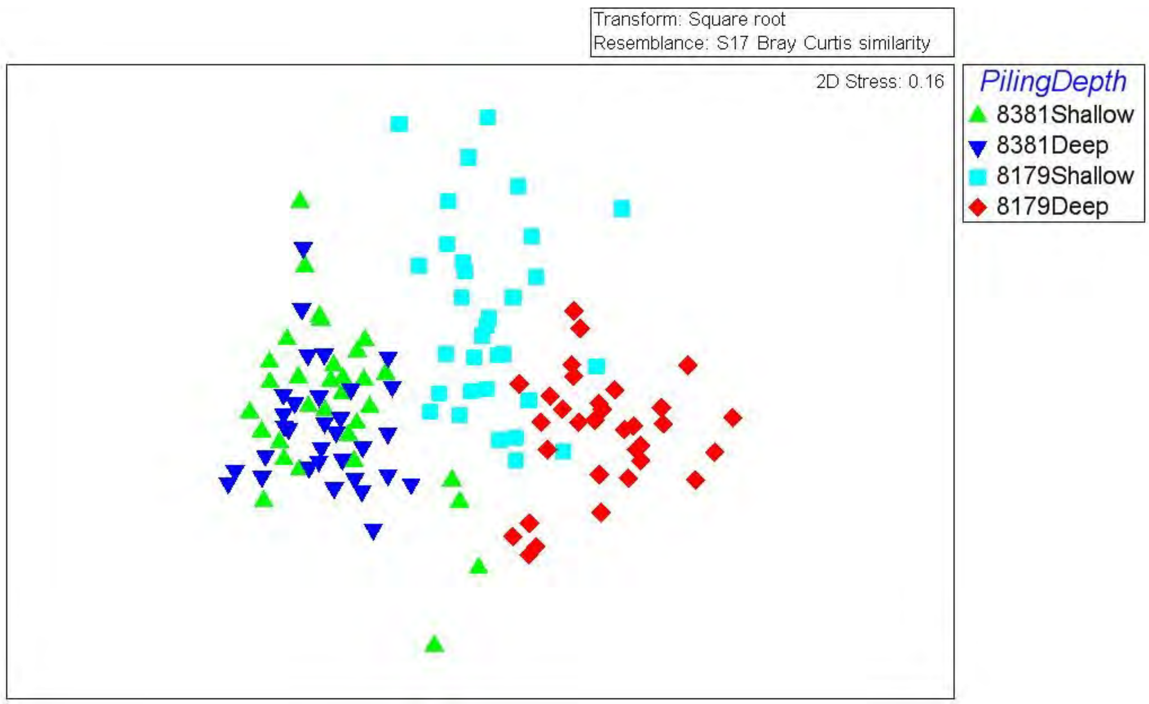

Figure 5. MDS plot showing differences in communities of sessile organisms on two pilings (8381 closest to the marina entrance, and 8179 slightly farther away) by depth (shallow vs. deep). Data were square-root transformed to reduce the effect of an abundant species. 8381 had fewer differences by depth, whereas 8179 showed little overlap.

Colony growth rate

Watersipora, like all bryozoans, grows the colony through the addition of separate zooids (asexual reproduction) rather than by enlarging an individual. These zooids are individual units (~350 µm long, 125 µm wide) that filter feed with an eversible lophophore but remain connected to adjacent individuals within the colony. Once the ancestrula (i.e. parental larva) has settled, it reproduces asexually by budding off new zooids and the margin of the colony expands outward by adding hundreds to thousands of zooids. Growth is irregular and can remain crustose or can develop into foliose 'heads' that superficially resemble a coral.

For one particular colony, there was a single, natural, fixed feature in the photo quadrat that served as a reference point. Between the first and second sampling intervals (11 d), the colony expanded 1.9 mm (Figure 6). Measuring with the same fixed point and angle, the colony extended an additional 4.7 mm during the subsequent 13-d interval. Over the last sampling interval (15 d), the colony expanded an additional 6.1 mm. In a total of 39 d the colony advanced, in one direction, 12.7 mm, which averages to 0.33 mm per day of colony growth.

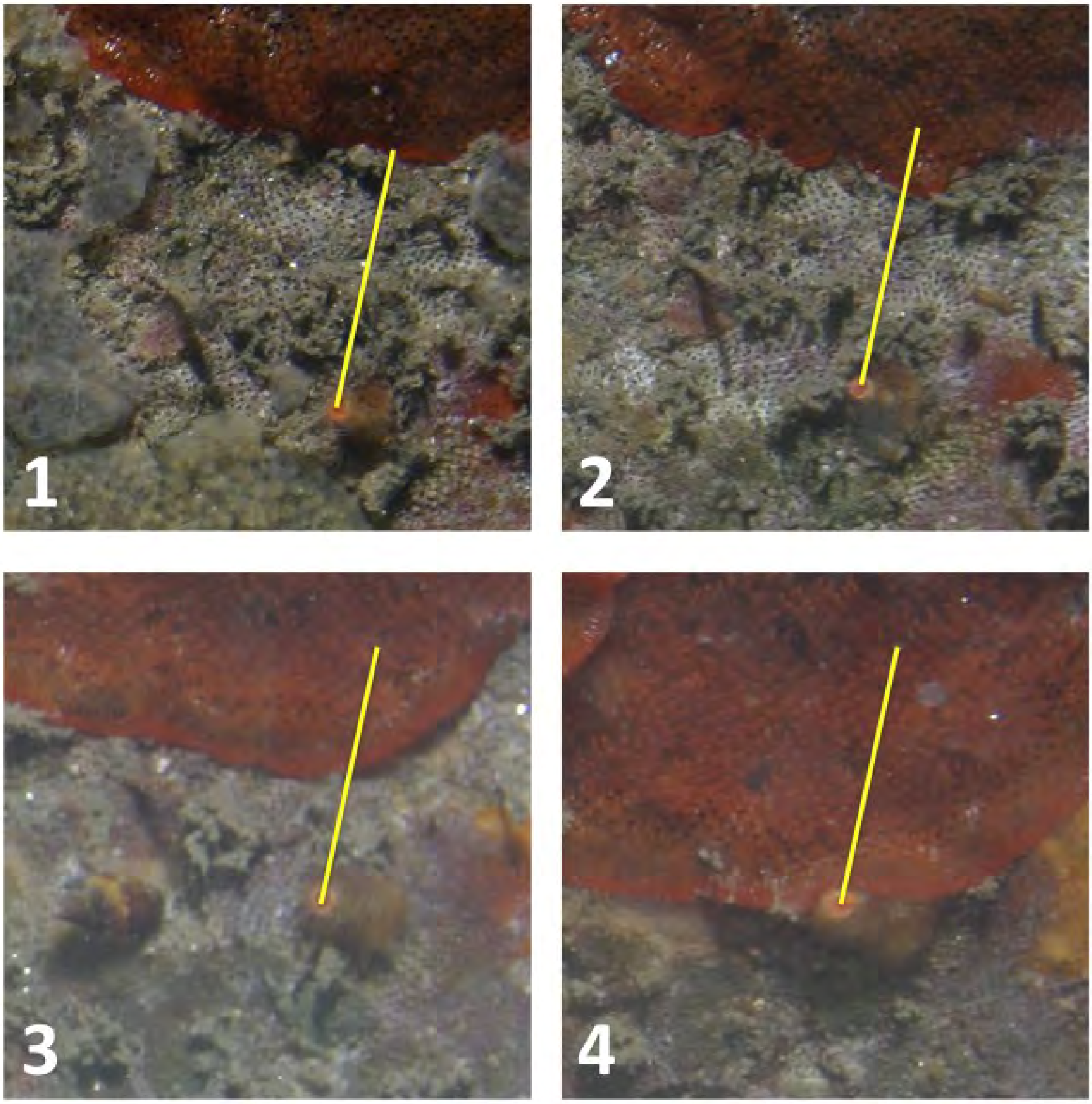

Figure 6. Series of images capturing the growth of a *Watersipora* colony *in situ*. In all panels, the yellow line is at the same angle and distance, and is fixed in place. Panel 1: this is an enlargement of an image taken at the start of the photo quadrat series. Panel 2: after 11 d the colony expanded 1.9 mm along the axis of the yellow line. Panel 3: after 13 d the colony added 4.7 mm. Panel 4: during the last interval (15 d) the colony added 6.1 mm. Overall the expansion rate of the colony was 0.33 mm per day along this axis. Photos by Steve Lonhart.

Discussion

Watersipora subtorquata is an invasive bryozoan, that until very recently has been confined to harbors, bays and estuaries. As part of an ongoing study that includes other pilings, the goal is to determine if the invasion and spread of *Watersipora* on pilings in the Monterey Harbor varies as a function of the three variables: piling location, depth, and orientation (side). Even though the cement pilings are virtual replicates of one another, their relative location and intrinsic history of colonization by fouling invertebrates and algae is idiosyncratic. Differences in *Watersipora* (and overall community structure) by depth may be a function of algal cover, which generally declined with depth (personal observation). Even the differences due to the sides of the four-sided pilings (not presented here) were not surprising given recent work in Australian harbors by Glasby and Connell (2001), who showed that the orientation and position of substrate strongly impacts the epibiotic assemblages that colonize them.

Ongoing field studies along the open coast in kelp forests, where *Watersipora subtorquata* has recently been reported (Watanabe, pers. comm.), may broaden our understanding of how it interacts with native species. Although almost all of the species found on pier pilings also occur in kelp forests, their relative densities are extremely different, perhaps with the exception of *Corynactis californica* (personal observation). With collaborators from the Smithsonian Environmental Research Center, we are examining species and habitat associations in the open coast. In the future we plan to compare and contrast these open coast interactions with those found within the harbor.

We did not initially intend to measure the growth rate of *Watersipora*, but the data collected in fixed photo quadrats afforded a unique opportunity to track colony expansion in an unmanipulated colony *in situ*. Measurements did not necessarily target the edge displaying greatest colony growth. Therefore, colony expansion rates are likely conservative. This is, to our knowledge, the first estimate of growth for *Watersipora subtorquata* in the field. With a conservative expansion rate of 0.33 mm per day, this approximates the addition of another zooid daily. It is not known if this estimate varies seasonally and ongoing studies are addressing this potential source of variation.

Acknowledgments

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References

Anderson LWJ. California's reaction to *Caulerpa taxifolia*: a model for invasive species rapid response. Biol Invasions. 2005; 7:1003-16.

Carlton JT, Geller JB, Reaka-Kudla ML, Norse EA. Historical extinctions in the sea. Ann Rev Ecol Syst. 1999; 30: 515-38.

Cohen AN, Carlton JT. Accelerating invasion rate in a highly invaded estuary. Science. 1998; 279: 555-8.

Glasby TM, Connell SD. Orientation and position of substrata have large effects on epibiotic assemblages. Mar Ecol Prog Ser. 2001; 214: 127-35.

Grosholz ED, Ruiz GM. Multitrophic effects of invasions in marine and estuarine systems. In: G. Rilov G, Crooks JA, eds. Biological Invasions of Marine Ecosystems: Patterns, Effects, and Management. Ecological Studies 204. Berlin: Springer-Verlag; 2009, 305-24.

Gurevitch J, Padilla DK. Are invasive species a major cause of extinctions? Trends Ecol Evol. 2004; 19(9): 470-4.

Hooton B. Associations between fishes and the invasive kelp *Undaria pinnatifida* in Monterey Harbor, Monterey, CA. MS thesis, Moss Landing Marine Lab; 2012, 77 pages.

Miller AW, Chang AL, Cosentino-Manning N, Ruiz GM. A new record and eradication of the northern Atlantic alga *Ascophyllum nodosum* (Phaeophyceae) from San Francisco Bay, California, USA. J Phycol. 2004; 40: 1028-31.

Simberloff D, Von Holle B. Positive interactions of nonindigenous species: invasional meltdown? Biol Invasions. 1999; 1: 21–32.

Traiger S. Community effects of an invasive bryozoan, *Watersipora subtorquata*, in the Monterey harbor. Senior thesis, UC Santa Cruz; 2010, 17 pages.