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Vertical distribution of *Aurelia labiata* (Scyphozoa) jellyfish in Roscoe Bay is similar during flood and ebb tides

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ABSTRACT

The vertical distribution of the jellyfish, *Aurelia labiata*, was assessed during flood and ebb tides in April, May, June, and August 2009 in Roscoe Bay (British Columbia, Canada). Assessments were made at locations along the entire length of the bay. The average tide change was 3.7 m. The vertical position of medusae (in 2 m intervals) did not differ significantly during ebb ($N = 17$) and flood tides ($N = 18$) in 6 and 8 m water columns. These results indicate that *A. labiata* do not use tidally synchronized vertical migration to maintain their location or presence in Roscoe Bay.

1. Introduction

Behaviour as well as tidal currents influence the horizontal distribution of *Aurelia* sp jellyfish (Hamner, et al., 1994; Toyokawa et al., 1997; Purcell, et al., 2000; Rakow and Graham, 2006; Magome et al., 2007; Lo and Chen, 2008; Albert, 2007, 2009). *Aurelia* sp also space themselves vertically (Papathanassiou et al., 1987; Rakow and Graham, 2006; Malej, et al., 2007; Han and Uye, 2009; Albert, 2009). Shanks and Graham (1987), Zavodnik (1987), Malej (1989), and Dawson and Hamner (2003) have provided similar evidence for the scyphozoans *Stomopolus meleagris* L. agassiz, *Pelagia noctiluca*, and *Mastigias*, respectively.

In the Wadden Sea, the hydrozoans *Rathkea octopunctata*, *Sarsia tubulosa*, *Bougainvillia ramosa*, and *Eucheilota maculata*, and the ctenophore *Pleurobrachia pileus* remained in the inner part of an estuary by migrating to the moving surface water during flood tides and to the still water near the bottom during ebb tides (van der Veer and Sadée, 1984; Kopacz, 1994). Some copepods and mysids behave in a similar way (Trinast, 1975; Wooldridge and Erasmus, 1980; for reviews see Creutzberg, 1975; Naylor, 2006). Vertical migrations enable these species to drift to the inner part of the estuary on flood tides and to avoid drifting out of the estuary on ebb tides.

Aurelia labiata are a resident population in Roscoe Bay. When the population is small, medusae usually accumulate at the end of the bay farthest from the bay's entrance (Albert, 2009). Further, *A. labiata* swim down when they are swept over a gravel bar and out of the bay on ebb tides and swim up when the tide turns to flood (Albert, 2007). These observations raise the possibility that *A. labiata* are using vertically synchronized tidal migration to stay in Roscoe Bay just as some hydrozoans use it to stay in the Wadden Sea (van der Veer and Sadée, 1984; Kopacz, 1994). The validity of this line of reasoning is suspect since *A. labiata* spread across the entire length of Roscoe Bay when the population is large (Albert, 2007, 2009). Further, preliminary observations by Verwey (1966) on *Chrysaora hysoscella* and *Rhizostoma pulmo* suggest that these scyphozoans do not display tidally synchronized vertical migration in the Wadden Sea.

The present observations examined the possibility that *A. labiata* are using tidally synchronized vertical migration to assist them in remaining in Roscoe Bay. Assessments of the vertical location of medusae were made along the entire length of the bay during the time of year when large tide changes would make the use of vertical migration most advantageous.

2. Method

2.1. Vertical distribution of medusae

Lift nets were used to assess the position of medusae in the water column. The lift nets were in the shape of an open cone (0.70 m diameter at the large end; 0.75 m deep, 0.30 m dia. at the small end, 3 mm mesh). The mesh was attached to a ring of 1.6 cm dia. plastic pipe at the top and a ring of 1 cm dia. polyethylene tubing at the bottom. Both rings were filled with sand. Each net was weighted at the bottom with a 19 cm length of 1.5 cm dia. copper pipe. Nets were released into the water with the plastic rings in a vertical orientation. The open cone shape allowed medusae to be easily spilled from the net and the large mesh facilitated water flow.

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Observations were made from a 7.1 m polyethylene rowboat (Sportyak) anchored with a large scope to allow it to swing with breezes and water currents so that the lift nets were not repeatedly raised through the same water column. When this movement was not sufficient (as judged by the position of the rowboat relative to landmarks on the shore), the anchor rope was shortened or lengthened 2 m every second lift. One net was used at each end of the boat. The two nets were lowered to the same depth and raised alternately, so that one net was always static in the water. Keeping one net still in the water ensured that there was always an interval of a few minutes between lifts for each net.

The first two lifts were always made from the bottom. If these lifts did not produce 8 to 10 medusae in each net, the process was moved to another location. The use of assessment sites with a minimum number of medusae in the water column ensured that the presence of a few more or less medusae would not create large distortions when the observed numbers of medusae at various depths were converted to percentages of the total number of medusae in the water column. For example, if there was only one medusa in the water column, whichever zone it was in would have 100% of the medusae at that assessment location.

Once a location had been found with sufficient medusae, ten lifts were made at successive 2 m levels, beginning at 2 m and continuing to the even numbered m level closest to the bottom. In order to minimize the influence of the lift net procedure on the entire water column, lifts always began 2 m from the surface. Medusae were counted as they were gently spilled from the net. Since the assessments were made while the tide was ebbing or flooding, medusae spilled from the net were carried away from the observation area by tidal currents.

The assessments coincided with the large tides of April, May, June, and August 2009. During these months, the largest tides always occurred during the day. Assessments began about 1 h after the tide change and ended about 1 h before the next tide change. Both ebb and flood tides were assessed on each day. Tidal data were from the Canadian Hydrographic Services Tide Tables (2009).

2.2. Temperature and salinity

Temperature and salinity measurements were made at least once during each monthly assessment period (see Albert, 2007, for procedural details). The measurements were made on the centreline of the bay, midway between the west end and the gravel bar. Measurements were made at about 0800 h.

2.3. Size of medusae

Medusae were measured on April 4 and 5 and May 20, 21, and 22, 2009 (see Albert, 2005, for procedural details).

2.4. Statistical analysis

For each individual assessment, the average number of medusae in each 2 m zone (with the exception of the upper-most zone) was calculated by subtracting from the average medusae count for that zone, the average number of medusae obtained from lifts 2 m above. The average number of medusae in each 2 m zone was then converted to a percentage of the average number found with lifts through the entire water column (i.e., the deepest depth assessed). The percentage values for 6 m and 8 m water columns were each subjected to two-way analysis of variance followed by paired comparisons using a Newman–Keuls test (StatView Software).

3. Results

3.1. Vertical distribution of medusae during high and low tides

The vertical distribution of medusae was not significantly different during flood and ebb tides in 6 m water columns (Fig. 1; Tide Effect: $F(1/60) = 0.12$, $p > 0.70$). There were fewer medusae in the top 2 m than at any other depth (Depth Effect: $F(2/60) = 25.7$, $p < 0.001$; Neuman–Keuls paired comparisons: 2 m vs 4 m or 6 m, both p's < 0.05; 4 m vs 6 m, $p > 0.05$; Tide × Depth Interaction: $F(2/60) = 0.75$, $p > 0.50$). A similar pattern of results was obtained in 8 m water columns (Tide Effect: $F(1/44) = 0.001$, $p > 0.95$; Depth Effect: $F(3/44) = 4.78$, $p < 0.006$; Neuman–Keuls paired comparisons: 2 m vs 4 m, 6 m, or 8 m, all p's < 0.05; all other depth comparisons p's > 0.05; Tide × Depth Interaction: $F(3/44) = 0.21$, $p > 0.85$). The mean number of medusae (±Standard Error of the Mean) in the 6 m water columns was 10.9 (±0.4) and 15.4 (±0.8) during ebb and flood tides, respectively, and 11.4 (±1.2) and 11.6 (±0.7) in the 8 m water columns during ebb and flood tides, respectively.

These observations were made on April 6, 24, 25, and 27, May 20, 21, and 23, June 23, and 24, and August 5, 6, and 7, 2009. The assessments of the vertical location of medusae were made along the length of the bay (Fig. 2).

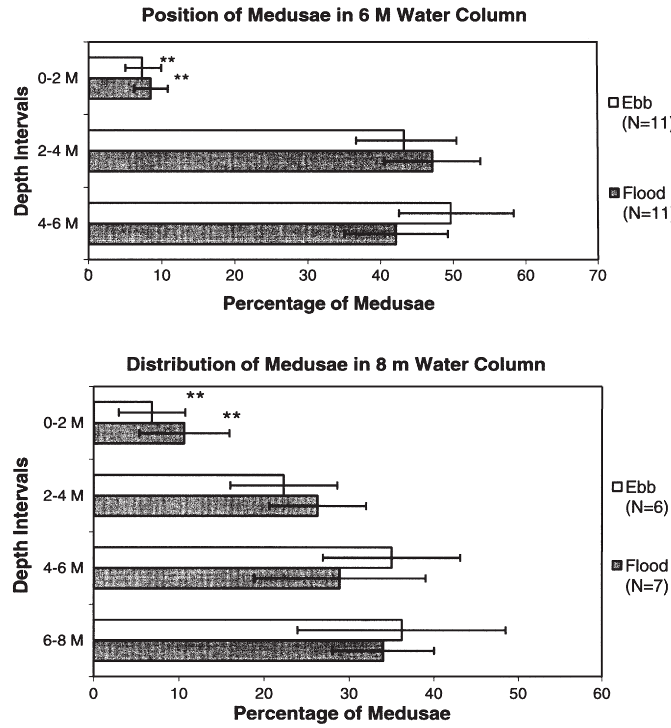

Fig. 1. The vertical distribution of medusae during flood and ebb tides in 6 m and 8 m water columns. *N* is the number of tides observed. Error bars are Standard Error of the Mean. There were no significant differences in the vertical distribution of medusae during flood and ebb tides. **Significantly different from the number of medusae at other depths during this tide.

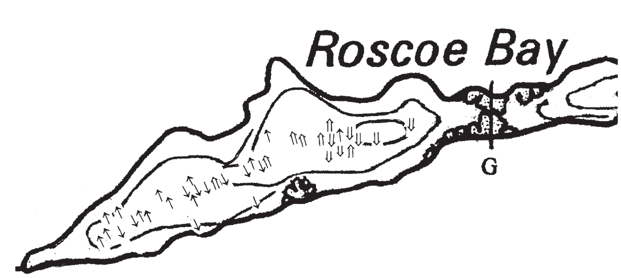

Fig. 2. The single arrows show the location of assessments of 6 m water columns and the double arrows of 8 m water columns. Arrows pointing up are flood tides; arrows pointing down are ebb tides. The chart is modified from one by Canadian Hydrographic Services (Chart 3538; 1996). "G" is the gravel bar at the east end of the bay. Roscoe Bay is at 124° 46′W, 50° 09′36″ N. North is at the top. Contours are at 5 m intervals. The bay is approximately 1 km long.