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Diving in two Marine Lakes in Croatia

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Abstract

We describe the diving methods used for *in-situ* observations of the scyphozoan medusa, *Aurelia* sp., in two marine lakes on the island of Mljet, Croatia. Both lakes have a strong pycnocline at approximately 15 m. During this study (May, 2004) surface temperature was about 20^o C; bottom temperature about 10^o C. Visibility was 15 m to 30 m. Tide and currents were negligible. A dense resident population of *Aurelia* sp. and a predictable environment made this an ideal study site. *Aurelia* was most abundant in mid-water around the pycnocline. There were several dive objectives: specimen collection for laboratory analysis, population census, discrete plankton tows and direct observation of flow around swimming medusae. We used several methods for maintaining our orientation underwater including working from an anchor line, towing a tethered buoy, and use of a blue water rig. Because the environment was relatively benign we allowed the rig to drift free while the boat was standing by at a short distance. Often a tether was not required. This plan allowed the most freedom and provided an excellent reference throughout the dive.

Introduction

Croatia is located on the eastern shore of the Adriatic Sea across from Italy. This study took place in the region known as the Dalmatian coast which is characterized by hundreds of islands and rugged terrain. The bedrock of the region is limestone and the resulting weathered karsted topography has produced a complex and intricate shoreline with numerous bays, shoals, rocky headlands, and coves with crescent beaches.

In May 2004, an international group of about 14 scientists and students, hosted by the Croatian Institute of Fisheries and Oceanography, gathered on the island of Mljet to study the biology of the scyphozoan jellyfish *Aurelia* sp. This workshop was coordinated by Dr. Jack Costello, Providence College, and was funded by the National Science Foundation and the US State Department. The four authors of this article constituted the US dive team. The site selected for study was a system of two marine lakes (called Big Lake and Small Lake) on the northern end of the island Mljet. This site was chosen because *Aurelia* was known to be consistently abundant in the lakes and the lake waters were known to have relatively good visibility (> 15 m) and stable conditions.

Study area

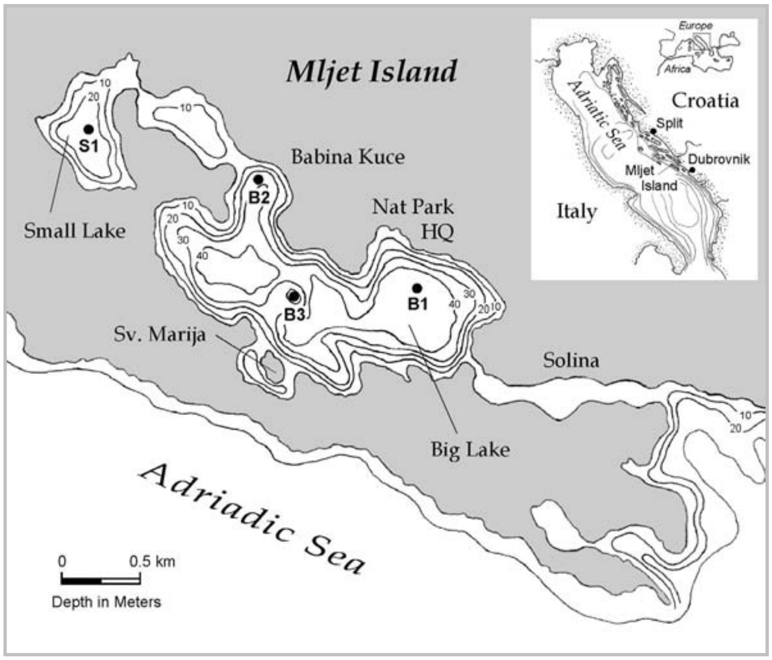

Figure 1. Mljet Lakes Site Map. B1, B2, B3, and S1 indicate the location of the different dive stations. (Adapted from Vanicek, et. al., 2000.)

Mljet is the southernmost major island in the Dalmatian archipelago and is located about 30 km off the coast of Dubrovnik, Croatia. It is oriented NW-SE and is roughly 35 km long by 3 km wide. The northern end of the island has been established as a national park. The main attractions of the park are the two marine lakes known in Croatian as Veliko Jezero and Malo Jezero or Big Lake and Small Lake, respectively in English (Figure 1). Big Lake is about 145 ha and is connected to the adjacent Adriatic Sea through a narrow shallow channel. Small Lake, about 30 ha, is connected to Big Lake through an even narrower channel and has no connection to the Adriatic Sea (Dabelic, 2001). Although there are a few notable shoals and outcrops, both lakes are 25 m to 40 m deep (Figure 2). The lakes are stratified throughout much of the year with a sharp pycnocline at about 15 m from April through October. During this study, which took place in May 2004, water temperature was near 20^{o} C at the surface and 12^{o} C below the pycnocline. Salinity varied from around 34 ppt at the surface to 38 ppt at the bottom. Tidal exchange, while nominal, drove gentile laminar currents at mid-water. Water visibility was good to excellent – 15 m to 30 m – on all dives.

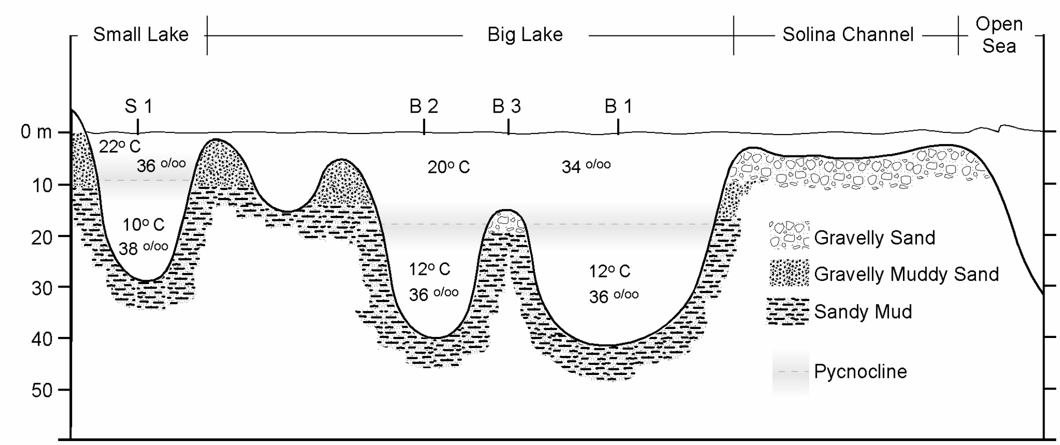

Figure 2. Mljet Lakes schematic profile. (Adapted from Vanicek, et. al., 2000.)

Aurelia sp.
Scyphozoan medusae, including those of the genus *Aurelia*, are one of the first evolved and simplest motile multicellular organisms. *Aurelia*, like many scyphozoans, is a voracious predator, feeding on a range of zooplankton species (Matsakis & Conover 1991). In order to better understand how *Aurelia* feeds, there is interest in understanding the relationship between body form, swimming motion, and prey capture (Costello and Colin 1995; Colin and Costello 2002). The bell of *Aurelia* is blunt and oblate shaped and causes considerable drag to act on the medusae as it swims. Consequently, as *Aurelia* swims it pulses vigorously but moves slowly through the water. However, large vortex rings are generated by each pulse which draw water through the tentacles located along the bell margin. This serves as a feeding current and enables *Aurelia* to capture prey organisms entrained in the fluid.

In the lakes on Mljet, *Aurelia* is highly abundant and found primarily below the pycnocline. It is likely that the population of *Aurelia* in the lakes has been isolated from the main body of the Adriatic Sea for tens of thousands of years (Benovic, et. al., 2000). There is compelling evidence that as a consequence of this isolation a new species of *Aurelia* has evolved in the lakes (Dawson and Jacobs, 2001).

Logistics

Our base of operation was located in an eleventh century Benedictine monastery, Sv. Marija, located on an island within Big Lake. Tanks and compressors were made available by our Croatian hosts and were set up in a make-shift dive locker situated in the cavernous chambers of the monastery. Laboratory space was also located in similar chambers. Small boats were provided by the National Park and we used a long wharf on the island as our dock for boats.

In a worst case scenario, emergency plans called for helicopter evacuation to Split, Croatia, 30 km distant, to an available decompression chamber. All contingency arrangements and contacts were confirmed prior to arrival. All divers possessed DAN international membership. It was our good fortune that our work concluded without incident, but it was impressive that plans existed to deal with any contingency, even in such a remote area.

Dive Methods

We used standard recreational gear and techniques. All dives were on air and limited to no-decompression excursions. On all dives each diver wore a dive computer to monitor their dive and safety diver was designated to manage contact and communication. Most dives were mid water, 10 m to 20 m, typically around the pycnocline where the medusan population was most abundant. Expert buoyancy control skills were essential for our planned tasks.

We used several methods for maintaining our orientation underwater and contact with the support boat. Since most of our work was within the water column, we used a blue-water rig for the dives. The blue-water rig was provided by DISL and, when fully rigged, was constructed similar to the designs recommended by Heine (1989). It was used for these dives because the rig provided an excellent frame of reference for mid-water work. These types of dives can be quite disorienting since divers are suspended in the water column with the surface and bottom out of sight. Orientation was facilitated by the large plastic tabs attached to the downline that indicated the depth. There tabs provided a strong vertical cue and produced a sense of perspective that is simply not achievable with a wrist mounted depth gauge.

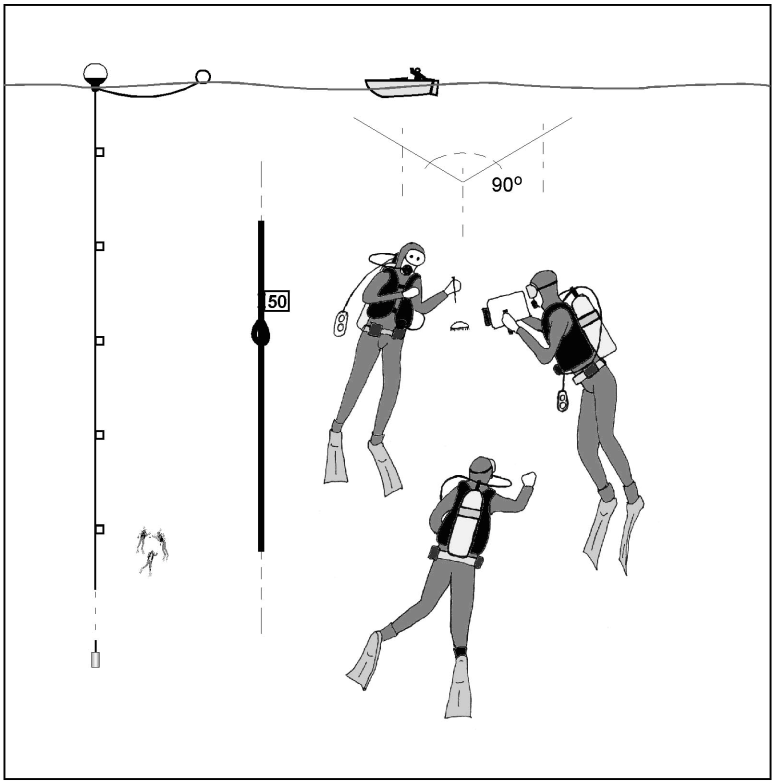

Figure 3. Dive method used for a majority of dives. Divers drifting on gentle tidal current along with blue water rig. The support boat stands off, unattached to the surface buoy, so as not to drag the rig with the wind.

As a result of the benign conditions in the lake we adapted typical blue-water procedures (Figure 3). First, visibility was generally high in the lakes (> 20 m) and currents were slow, therefore, the divers did not tether themselves to the blue-water rig. This enabled the divers to move more than the 10 m tether distance while still using the rig for visual orientation. Second, while conditions were quiescent, we often encountered nominal horizontal advective currents moving in different directions than the winds. Therefore, we did not tether the surface buoy of the blue-water rig to the support boat. Independence from the support boat allowed us to drift gently with these currents rather than being dragged by the boat in the wind. These modifications facilitated working with the drifting medusae by permitting more freedom for movement and enabling the divers to drift with the medusae (Figure 3). These are critical factors when attempting to get long-term and highly focused video sequences of individual jellyfish. Divers were instructed to keep the downline of the blue-water rig in their sight as one would keep an eye on their buddy. Further, depending on visibility, currents and decompression limits the divers agreed upon a maximum depth and a maximum allowable distance to drift from the downline. These limits were further maintained by the safety diver.

Underwater Research Methods

The primary goals of the project were to gather direct *in-situ* observations of the kinematics and flow of swimming medusae and to collect samples for determining prey diversity and abundance. Divers performed a number of sampling and data collecting tasks. Some of the sampling was as straightforward as recording observations onto underwater slates. Individual jellyfish were routinely collected into plastic bags for further examination in the laboratory. Plankton samples were collected at discreet depths using a diver-controlled plankton net. In that case, the diver was tethered to the blue-water rig and would swim out horizontally to the length of the tether, turn 180^{o}, swim to the limit of the tether in the opposite direction and return. The safety diver would tug the tether as the end of the line was approached. At the end of each run the nets were closed by hand and the cod end jar removed and capped.

A novel approach to obtaining a dynamic view of swimming was employed by using dye to visualize the flow around swimming medusae. Specifically, a small amount of fluorescent dye was released either just outside or inside the bell of a swimming medusa (Figure 4). The vortices generated by the swimming medusa – now clearly defined by the swirling dye – were video recorded. Two divers were involved in these sequences – one to release the dye, one to video the medusa. The divers would orient themselves in the water column at 90^{o} to a medusae and gradually move close to a single selected individual. A Sony digital video in an Amphibico housing was used to record the event. All dye studies were done with natural lighting so as not to affect the behavior of the jellyfish.

Figure 4. Dye release around swimming *Aurelia*. Divers are positioned at a 90^{o} orientation to each other. Fluorescent dye was released close to a swimming medusa with great care so as not to disturb the fluid surrounding the medusa.

Conclusion

The marine lakes of Mljet are fascinating ecosystems ideally suited to the study of *Aurelia*. A predictable population of the species in consistently calm environmental conditions allowed us to collect significant amounts of data under replicable circumstances in a relatively short period of time; a condition sometimes difficult to realize when working in the field. The facilities made available to us were equally ideal. Proximity to the dive sites and available space for lab, dive locker and meals was unparalleled. Incorporating this area into a National park will – one hopes preserve this natural wonder for generations.

Literature Cited

Benovic A., A. Lucic, V. Onofri, M. Peharda, M. Caric, N. Jasprica, and S. Bobabovic-Colic. 2000. Ecological characteristics of the Mljet Island seawater lakes (South Adriatic Sea) with special reference to their resident populations of medusae. Sci Mar, 64 (Supl 1): 197 – 206.

Colin S. P., and J. H. Costello, 2002. Morphology, swimming performance and propulsive mode of six co-existing hydromedusae. Jour. Exp. Biol. 205: 427 – 437.

Costello J. H., and S. P. Colin, 1995. Flow and feeding by swimming scyphomedusae. *Mar. Biol*. 124: 399-406.

Dabelic I., Mljet, The Green Island, Turisticka naklada. Zagreb. 2001.

Dawson M., and D. Jacobs, 2001. Molecular evidence for cryptic species of *Aurelia aurita* (Cnidaria, Scyphozoa). Biol. Bull. 200: 92 – 96.

Heine J (ed), 1986. *Blue Water Diving Guidelines.* California Sea Grant. No T-CSGCP-014. 46pp.

Matsakis, S., R.J. Conove,. 1991. Abundance and feeding of medusae and their potential impact as predators on other zooplankton in Bedford Basin (Nova Scotia, Canada) during spring. Can. J. Fish. Aquat. Sci. 48: 1419-1430.

Vanicek V, M. Juracic, Z. Bajraktarevic, and V. Cosovic, 2000. Benthic foraminiferal assembliages in a restricted environment – an example from the Mljet Lakes (Adriatic Sea, Croatia). Geol Croat. 53/2: 269 – 279.