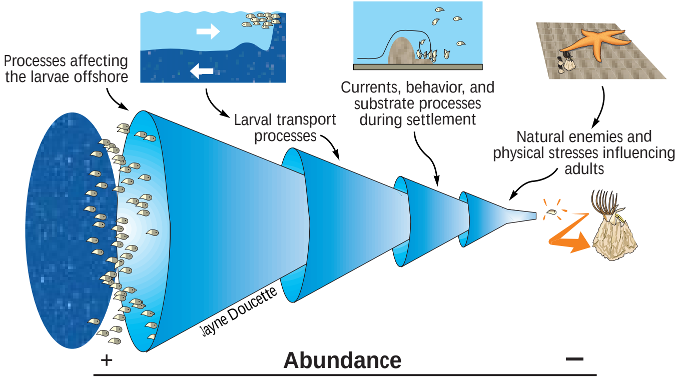
Larval Transport By Internal Tidal Bores

Jesús Pineda, Associate Scientist

New generations of bottom-dwelling coastal marine animals face a complication on their way to establishing new colonies. The early life stages of such organisms as clams, mussels, shrimp, and barnacles live suspended in the water, drifting at the mercy of ocean currents in a "larval phase" that generally lasts a few weeks. At the end of it, the larvae must find a suitable habitat where they can grow into adults and complete their life cycles.

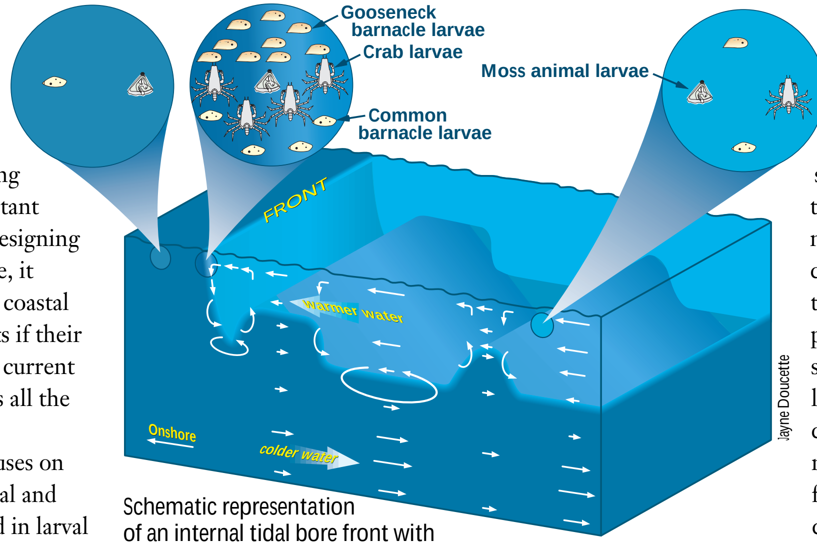
Because ocean currents disperse the larvae far from their birthplaces, they may find themselves several miles offshore in deep water just when they are ready to settle in the shallow coastal water—a waste of larvae because they will not survive in this situation.

After several weeks suspended in the ocean, the probability of a larva returning to its birthplace must be minimal, and the abundance of the colonizers at a given site is uncoupled from the living conditions of the adults. A site with no natural enemies and rich in food may be vacant because currents do not bring larvae, or, on the other hand, a sub-optimal habitat with scarce food may contain a large number of organisms if currents bring many larvae. Knowledge of



Processes that influence the population abundance of coastal bottom-dwelling organisms, with a barnacle as example. The number of larvae is larger than the number of adults, as each adult produces a myriad of larvae. Larvae are often found offshore, and before they can settle successfully at the coast, several conditions must be fulfilled. In each case, the proportion of larvae moving to the next set of processes is smaller. Small changes in the proportion of larvae that pass from one step to the next can produce large population changes.

ocean currents that return the larvae to coastal habitats is therefore key to understanding the maintenance and dynamics of coastal species. Understanding larval transport is also important for managing fisheries and designing marine reserves. For example, it would be futile to preserve a coastal site that contains many adults if their larvae are all wasted because current circulation at that site carries all the larvae offshore.



Schematic representation of an internal tidal bore front with observed circulation. Larvae of two species of barnacle and crabs accumulate at the front, but larvae of a moss animal (bryozoan) do not. All larvae occur offshore of the front, while most larvae found shoreward of the front belong to the bryozoan and one species of barnacle.

Much of my research focuses on studying the various biological and physical phenomena involved in larval transport by internal tidal bores. When waves traveling at the surface of the ocean approach the beach, they "feel the bottom," break, and produce a surge of surf running upslope. Internal (subsurface) waves, which are also ubiquitous, but slower and much larger than surface waves, also break when they shoal, producing internal surf. Rather than propagating along the air-sea interface, internal waves propagate along the interfaces of layers of water of different temperature and salinity that are found in most oceans. These internal tidal bores or breaking internal waves often occur about every 12.4 or 24 hours.

Recent observations in California show that when internal tidal bores occur, parcels of water that may be several miles long and extend from the beach to about 2 miles offshore are fully replaced by offshore waters once or twice a day. This dramatic exchange of water brings larvae of coastal species shoreward and occurs in two phases. First, the large internal tidal bore transports vast masses of colder water found at depth towards the shore, displacing the nearshore warmer water offshore. A few hours later, in the second phase, the heavier cold water recedes offshore, and is replaced by warmer offshore surface water. A front or line in the sea parallel to the shoreline marks the boundary between cold and warm water and leads the surface water in the second phase, with several other lines or slicks following shortly. The lines are created by currents that concentrate surface buoyant material, and, in the case of a front, the line contains a large concentration of floating debris, surf grass, and several species of larvae. Observations of these fronts revealed both striking patterns of circulation, capable of concentrating buoyant material, and frontal accumulation of some species of larvae but not of others.

With funding from the National Science Foundation and WHOI's Rinehart Coastal Research Center, we are pursuing many questions related to internal tidal bores. They range from the effects of El Niño on this mechanism to its variability along the shore in sites separated by several tens of miles to the fine mechanics of the process of frontal accumulation (the latter in collaboration with Karl Helfrich of the Physical Oceanography Department) and the reasons why only some types of larvae accumulate in the fronts while others do not. Further study should also elucidate the physical effects and ecological consequences of internal tidal bores, a process with profound yet largely unexplored implications for coastal communities.

For more information, visit http://mathecol.whoi.edu/~pineda/