Bay-Ocean Exchange Processes: Development and Application of A Meroplankton Tracer Technique

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LONG-TERM GOALS

The overall objectives of this research are to evaluate the distribution and influence of trace element contaminants in bay and coastal decapod larvae and to utilize elemental tags to determine larval origins and fluxes in San Diego Bay (SDB). Our research has focused on the uptake and retention of bay contaminants by larvae as well as the effect of contaminants on larval survival, rates of larval development, dispersal and recruitment. Long term goals of this research are to: (1) develop the use of elemental fingerprinting of individual larvae to evaluate sites of origin, (2) use this approach to assess the extent of larval exchange between bay and coastal populations, and (3) evaluate consequences of larval transport for population dynamics.

OBJECTIVES

Our objectives over the past year were to: (1) Examine concentrations of multiple trace elements in marine invertebrate larvae sampled from SDB, neighboring embayments and the nearshore coastal zone of southern California and to evaluate ability to discriminate site of origin based on elemental fingerprints. (2) Quantify the exchange of planktonic larvae sampled *in situ* during phases of tidally driven exchange between San Diego Bay and the nearshore coastal environment. (3) Examine the interaction of physical processes and larval behavior in determining the short-term dispersal, export and retention of newly hatched crab larvae (*Pachygrapsus crassipes*) and other decapod species.

APPROACH

Characterization of trace element composition in individual *P. crassipes* larvae is being carried out using an Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). Multiple elements (Cu, Al, Zn, Sr, Mn, Mg) are used in conjunction with discriminant function analysis to distinguish larvae from coastal populations, inner and outer San Diego Bay, and neighboring embayments. Field studies combining larval temporal and spatial distributions, hydrographic data (ADCP, CTD) and ICP-OES-based elemental analysis of larval origins allow first order estimates of larval crab flux between inner and outer San Diego Bay and between San Diego Bay and the nearshore coastal habitat. Additional estimates of larval dispersal are being made with drifters released and tracked (Global Positioning System) in San Diego Bay and with simulations by TRIM, a 2-dimensional hydrographic model.

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WORK COMPLETED

(1) Characterization of trace element concentrations in stage I *Pachygrapsus crassipes* larvae collected from 7 locations along an axial transect of SDB, 4 neighboring embayments, and 3 San Diego coastal sites. Cu, Al, Zn, Sr, Mn, and Mg serve as tags to distinguish larvae originating in Bay vs. coastal habitats, and in inner and outer SDB. (2) Determination of horizontal and vertical distributions of *P. crassipes*, xanthid (*Lophopanopeus* sp.) and pinnotherid larvae relative to tidal and diel cycles and assessment of consequences for bay-ocean exchange. (3) Integration of CTD, ADCP, and larval distribution data to estimate *P. crassipes* fluxes between (i) the inner and outer regions of San Diego Bay and (ii) the outer bay and coastal zone. (4) Additional deployments of GPS drifters in inner San Diego Bay to stimulate larval crab dispersal for comparison to field estimates and TRIM (hydrographic model) simulations.

RESULTS

Multi-element analyses conducted with the ICP-OES indicate five elements (i.e., Cu, Al, Zn, Sr, Mn) detectable for individual zoea which exhibited statistically different concentrations among larvae originating from SDB, neighboring embayments and exposed coastal habitats. A linear discriminant function analysis (DFA) performed on a preliminary MODEL data set demonstrates that larvae originating from San Diego Bay were discriminated from larvae which originated from coastal or neighboring embayments (Figure 1). Additional elements (Ag, Pb, Cd,, Cr, Hg, Sn) were examined but either were not detectable in individual larvae or revealed no predictable gradient in concentration. Sampling over vertical, horizontal and temporal gradients revealed that *P. crassipes* were concentrated in the eastern region of the SDB channel, near adult habitats. Horizontal distribution patterns of larvae agreed with hydrographic patterns and distributions predicted with TRIM, implying that San Diego Bay tides and currents influence the distribution of *P. crassipes* pelagic larvae. Peak concentrations of *P. crassipes* larvae in surface layers during the ebbing tidal phase and at the bottom during flooding tides indicate behavioral facilitation of export out of San Diego Bay by newly spawned larvae. Larvae of other crab taxa (Pinnotheridae) were more abundant in the surface layer during flooding tides, suggesting enhanced retention within the Bay. *Pachygrapsus crassipes* larvae experienced a net flux out of San Diego Bay.

IMPACT

This research has documented varying *in situ* concentrations of anthropogenically enriched contaminants, such as copper, aluminum and zinc, in crab larvae from San Diego Bay, neighboring embayments and exposed coastal habitats. There is considerable potential to employ trace element concentrations in larvae as indicators of larval origin and of contamination level. Trace element measurements in individual larvae allow this stage of development to be implemented in biomonitoring studies. Simultaneously collected physical (CTD, ADCP) and biological (distribution, behavior, and origin of larvae) measurements represent a novel approach to estimating larval fluxes and may provide more accurate information for population-dynamic models. The ability to determine larval origin using elemental tags will help assess larval transport and bay-ocean exchange, and thus the interdependence of bay and coastal habitats. This has important implications for future management of navy bays and coastal habitats. TRIM has been applied to simulate and predict the fate of chronic and acute sources of pollution in SDB by modeling their transport and residence time within the bay. Our efforts represent the first validation of TRIM with biological data and will aid future use of TRIM to determine trajectories of biological organisms within SDB.

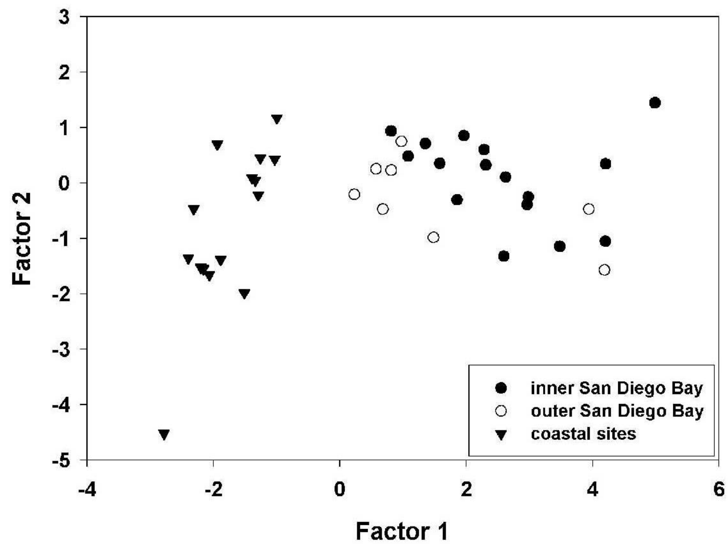

Figure 1. First and second canonical discriminant function scores plotted for individual crab zoea. San Diego Bay zoea cluster together while larvae sampled from coastal sites also cluster.

TRANSITIONS

Trace element concentration gradients documented for newly hatched *P. crassipes* larvae are being employed to (1) track dispersal of newly released larvae, and (2) quantify the exchange of larvae between regions of SDB and between SDB and open coastal sites. This technique should be applicable in systems other than SDB where elemental concentrations distinguish larvae originating from different regions. Future goals include application of elemental fingerprinting techniques to barnacle and bivalve larvae and new recruits to assess origins and dispersal trajectories

RELATED PROJECTS

Our studies of larval transport are directly linked to San Diego Bay circulation studies (John Largier, Scripps and University of Cape Town, S. Africa) and computer models which simulate the dispersal of pollutant-laden larvae (Don Sutton, San Diego Supercomputer Center). Larval transport hypotheses are being investigated in conjunction with Bart Chadwick (SPAWAR, NCCOSC RDT&E Division) whose work characterizes spatial and temporal variations in tidal flow and residence time for various regions within San Diego Bay.