BAY-OCEAN EXCHANGE PROCESSES: DEVELOPMENT AND APPLICATION OF A MEROPLANKTON TRACER TECHNIQUE

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LONG TERM GOALS

The overall objective of this research is to determine the influence of San Diego Bay (SDB) contaminants on dynamics of decapod and other invertebrate crab larvae which naturally inhabit both embayments and more pristine coastal habitats. 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 **(1)** to develop the use of elemental fingerprinting to evaluate sites of larval origin and **(2)** to use this approach to assess the relative significance of self-seeding (larval recruitment to parental populations) and larval exchange between bay and coastal populations as alternate recruitment mechanisms.

OBJECTIVES

This year's objectives were to examine **(1)** trace element concentrations (copper, zinc) in marine invertebrate larvae sampled from SDB, neighboring embayments and the nearshore coastal zone of southern California. **(2)** the feasibility of utilizing these elements as larval tags. **(3)** the effects of SDB water and pollutants on larval survivorship, development rates and metamorphosis relative to open coastal waters and neighboring embayments. **(4)**the uptake rate and retention of copper, a recognized pollutant in SDB, by larvae through their planktonic period. **(5)** the interaction of physical processes and larval behavior in determining the short-term dispersal, export and retention, of newly hatched (stage I) crab, *P. crassipes*, larvae and other decapod species. This project is supported by the Harbor Processes Research Program.

APPROACH

Laboratory culturing experiments evaluated the effects of brood site and culture water on the survivorship and rate of development of *P. crassipes* larvae originating from and/or reared in water collected from SDB, Mission Bay and an open coastal sites. Parallel culturing experiments were conducted to monitor the uptake and retention of copper by newly hatched larvae. Initial elemental analyses focused on copper and the first larval stage of development due to time restrictions associated with the ability to measure only one element at a time (i.e., Atomic Absorption Spectrometry, AAS). Since this time, a multi-element analyzer (Inductively Coupled Plasma-Atomic Emission Spectrometer; ICP-AES) has been purchased with DURIP funding. The ICP-AES will aid identification of additional elements that distinguish crab larvae from 7 stations along an axial gradient in SDB as well as from several neighboring embayments and exposed coastal sites. Field

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sampling was conducted to examine the vertical distribution (i.e., behavior) of first stage crab larvae with respect to tidal, lunar and diel cycles as well as depth and tidal phase. Continuous 16-20 hour collections were made to determine if specific or stages of development aggregate at preferential depths within the water column in order to maximize their export from or retention within SDB. Hydrographic data (CTD, ADCP) were collected during these field efforts to make first order larval flux estimates in two regions of the Bay (at the entrance and half way in) where elemental analysis has been successful in distinguishing larval origin. Preliminary GPS drifter studies were carried out to emulate larval dispersal and results are being compared to simulations of dispersal trajectories run on TRIM, a 2-dimensional hydrographic model of SDB.

WORK COMPLETED

(1) Laboratory culturing experiments examining crab larval survivorship, development rates, and uptake and retention of copper in SDB, Mission Bay, and nearshore coastal water. The data have been analyzed and are being prepared for publication. **(2)** Characterization of copper concentrations in newly hatched crab, *P. crassipes*, larvae collected along an axial transect of SDB (7 stations), 4 neighboring embayments, and 3 coastal sites. **(3)** Identification of additional elements (calcium, magnesium, strontium) to serve as larval tags in distinguishing larvae originating from bay *vs* coastal populations and/or distinguishing between regions of SDB. **(4)** Field efforts consisted of 3 programs, including; (i) sampling crab larvae from SDB, neighboring embayments and open coastal sites to characterize trace element concentrations, (ii) examining the vertical and horizontal distribution of taxa specific crab larvae relative to tidal and diel light cycles and the implications identified patterns have on larval dispersal, (iii) tracking GPS drifter to emulate the dispersal of newly released crab larvae. **(5)** Collection of CTD (temperature, salinity, depth) and ADCP (vertical and horizontal shear/velocity) data simultaneous with plankton samples to estimate larval fluxes between (i) the inner and outer regions of SDB and (ii) the outer Bay and coastal zone. **(6)** Sorting and preservation of larvae of *P.* crassipes and *H. oregonensis* collected in (4) above for elemental analysis to evaluate origin. **(7)** Preliminary GPS drifter studies (12 hr) simulating larval dispersal of newly hatched crab larvae in the inner region of SDB. **(8)** Larval dispersal simulations with TRIM, a 2-dimensional hydrographic model of SDB.

RESULTS

(1) *P. crassipes* larvae reared in coastal waters experienced lower mortality and more rapid development than those reared in SDB or Mission Bay waters. These findings suggest an additional sub-lethal measure to asses the potential effects of contaminants. Laboratory culture experiments revealed that newly-hatched, copper-laden (e.g., 40-50ppb Cu) zoea originating from SDB had the ability to reduce their body burden of copper by approximately 95% to 97.5% two days after hatching. **(2)** Measurement of copper concentration in individual, stage-I *P. crassipes* zoea to distinguish larvae originating from distinct regions of the Bay as well as from coastal habitats and neighboring embayments and allow estimates of net flux of larvae between these areas. **(3)** Multi-element analyses conducted with the ICP-AES indicate additional elements (i.e., Ca, Mg, Sr), detectable for individual zoea and megalopae, exhibit statistically different concentrations between larvae originating from embayments versus exposed coastal habitats. **(4)** Sampling over vertical, horizontal and temporal gradients revealed that *P. crassipes* were concentrated in the eastern region of the channel, near adult habitat. Results agreed with hydrographic patterns and distributions predicted with TRIM. Concentration of *P. crassipes* larvae in surface layers during the ebbing tidal phase suggests a behavior that facilitates the export of newly spawned larvae out of SDB. Conversely, the majority of other sorted crab taxa were considerably more abundant in the surface layer during flooding tides, suggesting enhanced retention within the Bay. **(5)** GPS drifter tracks simulating the movement of newly released crab larvae residing in the upper meter of the water column also suggested a net movement out of SDB by newly hatched *P. crassipes* larvae. **(6)** TRIM simulations (run for 84 h) which did not incorporate any larval behavior suggested that larvae released in the back of SDB would be retained there while simulations incorporating vertical migratory behavior as observed in (4) above, predicted a net transport out of SDB.

IMPACT

This research has improved our understanding of the effects of *in situ* concentrations of SDB contaminants on the survivorship and development of early life-history stages of marine organisms. Increased mortality and reduced rates of development due to SDB toxicants have important life-history implications for *P. crassipes*, but also for species who spend their entire life-cycle within select embayments. The vast majority of biomonitoring studies have implemented condition indices based on adult organisms (i.e., mussel watch program). Because early stages of development tend to be more susceptible to pollutants, there is considerable potential to employ trace element concentrations in larvae as contaminant indicators. This year's field sampling effort represents the most extensive set of simultaneously collected physical (CTD, ADCP) and biological (distribution and origin of larvae) measurements designed to make integrated first order larval flux approximations. To my knowledge, this will be the first time flux estimates have been tied to the origin of sampled larvae. TRIM has been applied to simulate and predict the fate of chronic and acute sources of pollution in SDB. Our efforts represent the first validation of TRIM with biological data and will provide insight into future applications of TRIM in determining the fate of biological organisms with SDB.

TRANSITIONS

A decreasing copper concentration gradient has been documented for *P. crassipes* larvae sampled along an axial transect running from the back of SDB to the mouth and from neighboring embayments and exposed coastal habitats. The ability to distinguish and determine site specific larval origins using elemental tracers are being employed to **(1)** track dispersal of newly released larvae, **(2)** quantify the exchange of larvae between regions of SDB and between SDB and open coastal sites, and **(3)** to determine the origin of newly settled crab recruits. This technique will be applicable in systems other than SDB where elemental concentrations are detectable and distinguishable in larvae originating from different regions.

RELATED PROJECTS

A. Zirino (NraD, NCCOSC RDT&E Division) helped with electrochemical techniques used to quantify the concentration of select trace elements (copper, zinc, lead) in seawater sampled from our 3 study sites. Collaborations with Ken Richter (NRaD, NCCOSC RDT&E Division) and Don Sutton (now at San Diego Supercomputer Center) utilized TRIM to simulate the transport and dispersal of pollutant laden larvae. Larval transport hypothesis, developed in conjunction with Bart Chadwick (NRaD, NCCOSC RDT&E Division) have been addressed with field work targeting the spatial (vertical, horizontal) and temporal distribution of newly released crab larvae.