Can we identify the geographic source of individuals to marine populations? A test of the approach using kelp rockfish, *Sebastes atrovirens,* larval otolith microchemistry to assign juveniles to plausible origin.

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Introduction:

The level of larval retention and larval connectivity among marine populations has far-reaching consequences for understanding population dynamics and the structure of marine communities (Caley et al. 1996, Warner and Cowen 2002) as well as the development of effective management strategies for exploited marine populations (Carr and Reed 1993, Warner et al. 2000). Along the coast of California, most of the productive areas are heavily exploited and many fisheries (including species of rockfish, genus *Sebastes*) are showing clear signs of overutilization (Reilly et al. 1993, Ralston 1998). The use of marine reserves as a management strategy to achieve sustainability in overexploited populations is receiving serious attention (Allison et al. 1998, Yoklavich 1998, Carr and Reed 1993, Hastings and Botsford 1999). Understanding the extent to which young produced from adults within a marine reserve ultimately recruit to unprotected areas outside the reserve for harvest and the exchange of individuals among marine reserves is critical for the effectiveness of current reserves and developing the optimal design of additional marine reserves (Carr and Reed 1993, Carr and Raimondi 1998, Botsford et al. 2001, Botsford et al. 2003, Gaines et al. 2003, Shanks et al. 2003). Given the small size of fish and invertebrate larvae and their potential for long distance dispersal, determining the dispersal pathways larvae travel has been a very challenging task. Elemental signatures within the hard parts of fish have shown immense promise as a method of reconstructing the past histories of individuals. Otoliths (balance organs of fish) incorporate environmental information into the carbonate structure matrix as the fish grows (Kalish 1989, Bath et al. 2000, Elsdon and Gillanders 2003) and are metabolically inert ensuring that the deposition of elements remains unaltered (Campana and Neilson 1985, Campana and Thorrold 2001). Thus, otoliths may provide a site-specific marker that can be used to define specific origin-destination links.

Several studies have successfully used the elemental composition in juvenile otoliths to assign adults to natal estuary to determine rates of natal homing (Thorrold et al. 2001, Patterson et al. 2004) and nursery habitat use (Forrester and Swearer 2002, Gillanders 2002). Estuarine-dependent species have primarily been used to test this approach because juveniles spend several months to a year in their natal estuary or nursery habitat and therefore the portion of the otolith representing the natal or juvenile nursery region is quite large and apparent. Moreover, there are dramatic gradients in environmental features among the habitats that result in large differences in the otolith elemental composition among individuals from different locations (Gillanders and Kingsford 1996, Gillanders and Kingsford 2000, Thorrold et al. 2001). However, for most coastal species who spend their entire lives in the marine environment the challenge is whether gradients in environmental conditions are large enough to create detectable differences in site- or population– specific otolith elemental markers. Recently, Warner et al. (in review) sampled pre-release larval otoliths of the kelp rockfish (*Sebastes atrovirens*) and found geographic structure in elemental signatures among three regions in southern California. These findings suggest that it may be possible to use elemental concentrations at the natal portion of the otolith to track dispersal of individuals from source to settlement in adult populations along the open coast.

For this study, I used the larval elemental signature data for *Sebastes atrovirens* (Warner et al. in review) to ask: Can chemical fingerprints from the natal portion of juvenile otoliths be used to evaluate the plausible origin of juveniles that have settled to nearshore populations?

Species Characteristics and Methods

The kelp rockfish, *Sebastes arovirens,* is very abundant within the subtidal kelp community along the central and southern Californian coast and is the target of an important recreational and nearshore live-fish fishery (Love et al. 1992,Ventresca et al. 1995). The range of *S. atrovirens* extends from central Baja California to Albion in Northern California. Adults are relatively sedentary (Love et al. 2002). Females are primitively viviparous (Wourms 1991), producing larvae that are subsequently pelagic.

Larval development occurs within the female for a substantial period of time allowing for the formation of larval otoliths at the site of origin before parturition. Once released, larvae remain in the plankton for approximately one to two months (Moser 1996), before settling to nearshore communities.

The portion of the otolith representing the natal origin encompasses a relatively small region of the otolith (~ 30 um) that forms the core in the center of the otolith as the fish grows. Forty-two recruits collected by UCSB PISCO from Santa Cruz Island throughout the recruitment season in 2002 were used to evaluate the elemental concentrations at recruit natal cores and were compared to the larval natal signatures (Warner et al., in review). No recruitment of kelp rockfish occurred on the mainland in 2002 to include in the analysis. Michael Sheehy extracted sagittae and analyzed individual otolith cores from the recruit samples for trace metal concentrations using a laser and mass spectrometry techniques.

To test the approach of using larval chemical fingerprints to evaluate the origin of recruits, I used the larval data from Warner et al. (in review) as discriminant criteria to generate ordination scores for the 42 *S. atrovirens* recruits from Santa Cruz Island. The larval otoliths were taken from 14 near-term females that were sampled from Santa Cruz Island and Ellwood (Warner et al., in review). The number of broods collected varied per location (southern Santa Cruz Island - 6 broods, northern Santa Cruz Island – 2 broods, Ellwood – 6 broods). The analysis was limited because larvae were collected from only three potential source populations in southern California. The purpose here was not to obtain unequivocal assignment of the recruits but rather to test the approach by determining if the larvae and recruits lay in generally the same ordination space.

Preliminary Results

I used Barium (Ba) and Strontium (Sr) for the comparison of the core region of recruit otoliths and larval otoliths. Both elements were in comparable concentrations in both larval and recruit otolith cores, the method used to acquire the elements was similar for larval and recruit natal signatures, and the southern California regions significantly differed in the mean concentrations of both elements in the larval samples.

Using Ba and Sr, I re-examined the geographic structure of *S. atrovirens* larval signatures from Warner et al. (in review) using canonical discriminant analysis. The analysis showed significant discrimination among regions in southern California (MANOVA: $F = 15.762$, $p < 0.0001$) and the discriminant ability of the model was 61% (Figure 2). Hence, the distinct elemental fingerprints among regions indicated that I could test the approach of evaluating recruits to origin by using the elemental concentrations at the core of the otoliths. I used the 2002 *S. atrovirens* pre-release larval elemental fingerprints to generate discriminant criteria to assign ordination scores to juveniles collected from Santa Cruz Island in 2002 (Figure 3). Most of the recruits from Santa Cruz Island generally fell into a similar space and were associated with the southern island natal signatures (Figure 3). It is impossible to infer the origin of these recruits since not all possible source populations were sampled. However, larval areas not associated with recruit ordination space may provide insight about exchange among regions. For instance, although the majority of the recruits generally overlay the same ordination space as the larvae, there were clearly some areas that were not contributors to the Santa Cruz Island recruits. Interestingly, less than 2% of all island recruits were classified as having originated from the portion of the mainland sampled (Ellwood).

These results illustrate that this type of approach has the potential to provide information on the sources of dispersive larvae. By analyzing elemental fingerprints from a large, representative collection of natal sites it may thus be possible to determine the patterns of exchange of individuals among marine populations along the coast. While the larval discriminant model used here has its limitations, this is the first attempt to apply this approach to a fully marine species.

Proposed Analysis

I plan to broaden the *S. atrovirens* larval discriminant model to include larval chemical signatures collected from Monterey, California. Central California waters are very different from southern California (e.g. different concentrations of trace elements, lower temperature and salinity) and these properties may be reflected in the elemental fingerprints of larval otoliths. In December 2004, I will analyze larval otoliths from one kelp rockfish collected in May 2002 from Lover's Cove and incorporate them into the model. Moreover, recruit natal signatures collected from several central California locations in 2002 (see Section 2) will be included with the southern California recruit samples in the DFA classification. As above, this analysis will not be used to assign explicit source to recruits but rather to examine the ordination space occupied by the larvae and recruits from different regions. The ordination space of the recruits may point to similarities or differences in the core chemical composition of samples taken from very different regions along the coast. More importantly, the use of this approach to examine sources *not* contributing to recruits offers insight about the exchange (or, more importantly, a lack of exchange) of individuals among locations that may generate valuable information for fisheries management and conservation.