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Final Report to the Unified Port of San Diego
Environmental Projects Benefiting San Diego Bay

"Maintaining healthy eelgrass beds: fishes, trophic diversity and ecosystem function"

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Introduction

As the human population continues to expand, we have witnessed rapid changes in the environment due to anthropogenic impacts. One of these marked effects has been the global degradation and loss of seagrass habitats (Short and Wyllie-Echeverria 1996, Waycott et al. 2009). Seagrasses are a group of marine angiosperms common to shallow oceans and bays throughout the globe. These foundation species (sensu Dayton 1972) form highly productive and complex beds, dramatically increasing the abundance, biomass, and diversity of organisms relative to unvegetated habitats (Mattila et. al 1999, Williams and Heck 2001). In addition, seagrasses stabilize sediments, filter nutrients, and serve as important nursery grounds for many species of fishes and invertebrates, many of which are economically important (Beck et al. 2001, Larkum et al. 2006). Rampant degradation and loss of seagrass habitats, therefore, is of great and global concern (Orth et al. 2006, Waycott et al. 2009) with losses being attributed to a number of factors, including overfishing. For example, widespread overexploitation of top predators could indirectly contribute to seagrass losses through cascading trophic effects (Williams and Heck 2001)(Fig. 1).

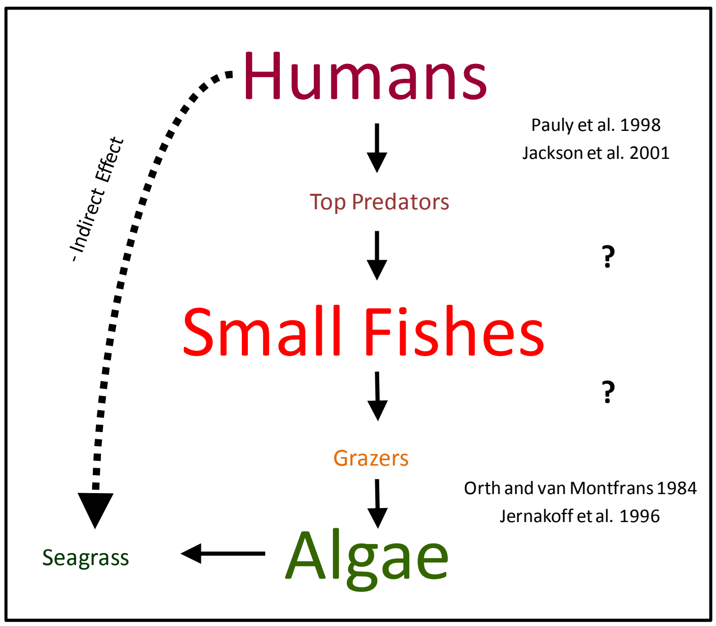

Figure 1. Schematic representation of the "Anthropogenic Food Web Alteration Hypothesis" (modified from Williams and Heck 2001). Note that data gaps exist regarding the role of predators in these systems.

Eelgrass (*Zostera marina*), common to San Diego Bay, has been the most widely studied seagrass species throughout the world; however, relatively few studies have examined how small predators influence the functioning of eelgrass ecosystems. Although eelgrass restoration and conservation are of great interest within San Diego Bay, the long-term success or failure of these efforts may be strongly influenced by trophic interactions such as grazing and predation.

Methods

To explore the trophic dynamics in eelgrass habitats, we executed two field caging experiments consisting of four treatments (Fig. 2A) in Summer 2007 and Spring 2008. In Summer-Fall 2006, all permits were secured (DFG collecting permit, Harbor Police Dive Permit, SDSU Vertebrate Use Permit, etc.) and an experimental design fashioned, consisting of 6 replicates of each of the 4 treatments (24 plots, Fig. 2B). Pilot studies were conducted in Fall 2006 to test various experimental designs. Cages used in experiments were 1 m diameter cylindrical enclosures constructed of a base, rigid internal PVC frame, and a 6 mm clear plastic mesh cover attached to the base by a cinch-strap. Caging experiments employed a randomized block design along Shelter Island in San Diego Bay. The dwarf perch (*Micrometris minimus*) and kelp bass (*Paralabrax clathratus*), two common eelgrass-associated fishes, were used as predators.

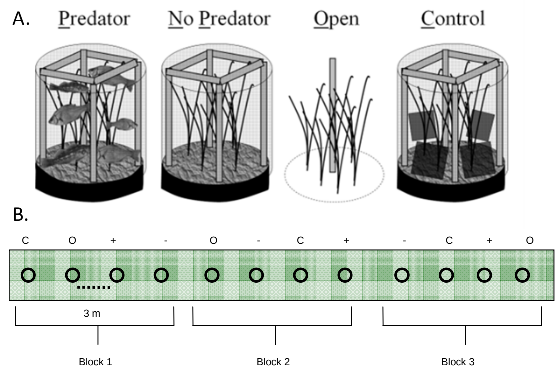

Figure 2. Schematic representation of cages and treatments used to manipulate predator abundances in Exp. 1 (A), and example of half of one array of the randomized blocked experimental design.

To improve the interpretation of our findings from field experiments, we explored the feeding relationships of dominant fish and invertebrate taxa in eelgrass. This work was conducted in collaboration with an undergraduate research assistant, James Farlin, and contributed to the completion of his undergraduate senior thesis. In October to November 2008, we collected, processed, and analyzed stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) (Peterson and Fry 1987), using continuous flow mass spectrometry, for 10 replicate samples of several eelgrass-associated taxa from a wide range of trophic levels (e.g. producers, grazers, predators) and phyla (e.g. arthropods, mollusks, chordates, etc.). Stable isotope analyses were completed in Spring 2009.

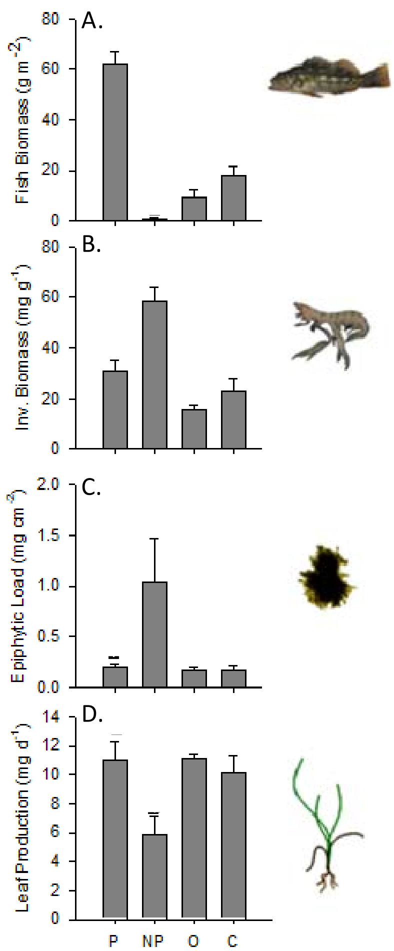

Figure 3. Results from Experiment 1 demonstrating strong cascading effects of predators (A) on epifaunal invertebrates (B), epiphytic loads (C) and eelgrass growth(D).

Results

Field Experiment 1 (June-August 2007)

When fishes were excluded, invertebrate abundance increased by 300-1000%, epiphytic loads increased by

600% and eelgrass production declined by 20-50%. Similarities in community metrics between enclosures, open plots, and control plots indicated that the effects of predators in enclosures were similar to natural levels and that cages exerted little influence on the results. Though fishes appeared to exert a strong influence on invertebrate communities, no response in algal biomass was observed, possibly due to low nutrients characteristic of summer conditions. Contrary to our expectations, however, increased invertebrate biomass observed in predator exclosures also resulted in increased epiphytic loads, likely due to the structures produced by numerous tube-building invertebrate taxa. Furthermore, when predators were excluded, eelgrass growth rates were reduced, likely due to both increased fouling by tube-building taxa and direct damage caused by abundant eelgrass-grazing limpets (Zimmerman 2001) . In contrast to theory that predicts small predators exert negative indirect effects on seagrass production by limiting the abundance of beneficial mesograzers (Williams and Heck 2001), our research demonstrated that, during summer conditions, epifaunal invertebrates can actually reduce seagrass productivity and microcarnivorous fishes may mediate these effects by regulating the abundance and structure of the invertebrate community. These unexpected results highlighted the need for further examination of the role of microcarnivores in structuring seagrass ecosystems.

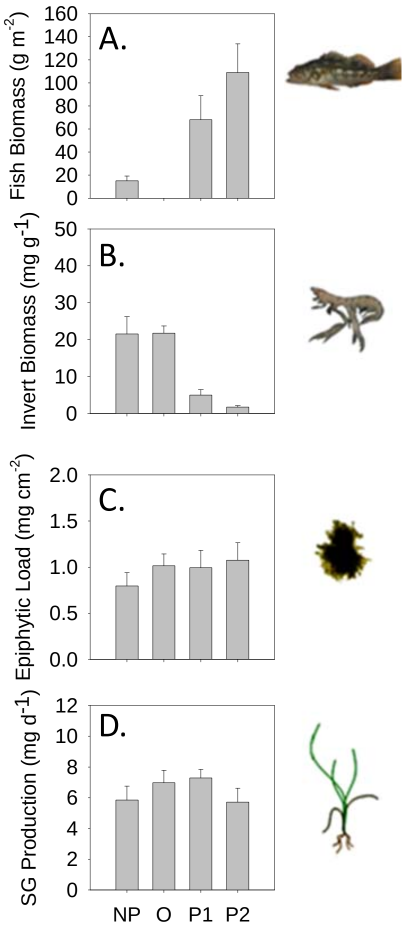

Figure 4. Results from Experiment 2 demonstrating no cascading effects of predators (A) on epifaunal invertebrates (B), epiphytic loads (C) and eelgrass growth (D).

Field Experiment 2 (April-June 2008)

To examine whether these strong effects of predators persisted during cooler spring conditions, we repeated the experiment in spring 2008. Because kelp bass were not available, only dwarf perch were used as predators. Cage controls (C) were not used because cages exerted little effect on seagrass growth in the previous experiment. Instead, we used both low (P1) and high (P2) densities of dwarf perch to examine the influence of different predator densities. Though cages were effective at manipulating predators (Fig. 4A) and predators greatly affected the invertebrate community (Fig. 4B), no effects on epiphytic loads or eelgrass production were observed (Fig. 4C-D). These results indicated that predator and epifauna effects may vary among seasons. For example, ambient predator densities failed to limit invertebrate abundances during summer (Fig. 3B) but not in spring 2008 (Fig. 4B). This was in agreement with the reduced ambient densities of predators during spring months. Furthermore, the reduced abundance of grazers in predator enclosures did not appear to exert influence on epiphytic loads in Spring 2008. This suggests that epiphytic loads likely exerted strong effects on seagrass growth in Summer 2007, though these loads were, in fact, less than those observed in Spring 2008.

Stable Isotope Study of Eelgrass Food Web (October-November 2008)

Amphipods (small peracarid crustaceans) are often dominant components of benthic marine communities and may exhibit taxon-specific differences in feeding behavior (Duffy and Hay 1991). As a result, variation in the composition of amphipod communities is likely an important metric for the interpretation of trophic dynamics in benthic marine ecosystems. We used stable isotope ratios of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) to examine trophic structure among amphipod taxa belonging to five different families (Ischyroceridae, Oedicerotidae, Hyalidae, Ampithoidae and Caprellidae) in an eelgrass (*Zostera marina*) ecosystem in San Diego Bay, California. Isotopic signatures of these groups were determined using continuous-flow mass spectrometry and differences in isotopic signatures were compared by ANOVA. Results were interpreted based on trophic fractionation values from the literature (carbon=0,nitrogen=1.5).

We detected significant differences in both $\delta^{13}C$ and $\delta^{15}N$ signatures among amphipod taxa, indicating taxon-specific differences in feeding habits that support previous work on amphipod diets (Fig. 5). Taxa within the Ischyoceridae and Hyalidae were supported by carbon derived from algae and seagrass, respectively, whereas other taxa exhibited a more heterogeneous diet. The relatively high $\delta^{15}N$ signatures of oedicerotids indicated this group was likely carnivorous. Our findings based on stable isotope ratios demonstrated significant functional diversity among amphipod taxa and demonstrated the utility of stable isotopes for detecting and describing the functional roles of mesograzers in seagrass ecosystems.

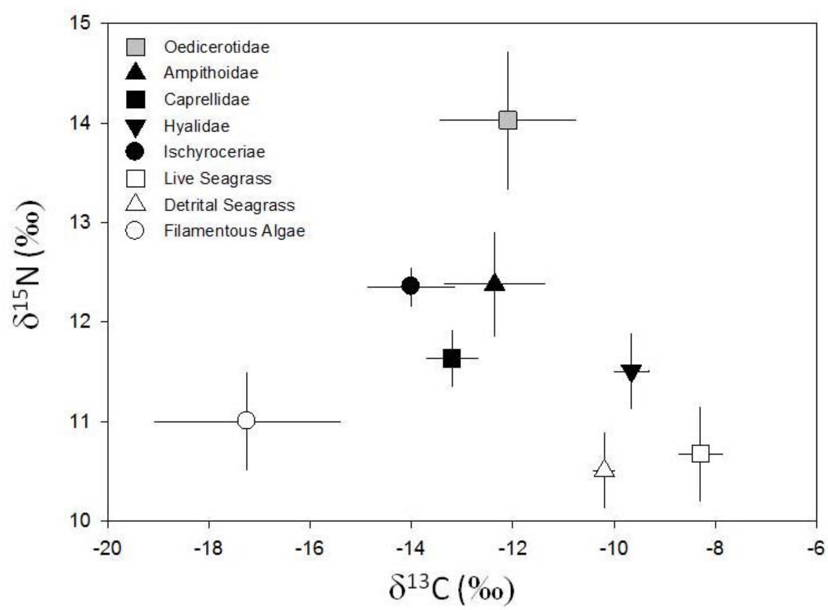

Figure 5. Isotopic signatures of amphipods (filled) and sources of primary production(open). Error bars represent one standard error.

Summary:

Seagrass ecosystems provide a myriad of ecosystem services, and therefore, warrant protection from and mediation for any anthropogenic losses or degradation. The importance of healthy community dynamics (including predators) in facilitating the persistence and function of seagrasses, however, has not been rigorously tested. Here, we examined the importance of small fishes in regulating invertebrate communities and demonstrated a strong positive role these small fishes assume during summer months, but that this role may change seasonally due to changing environmental and biological characteristics of the system. Our work demonstrated trophic interactions in seagrass beds that have not been previously reported. The strong negative effects of epifaunal invertebrates and positive indirect effects of fishes in San Diego's eelgrass beds during summer conditions is an important new finding that highlights the importance of healthy communities to the functioning and persistence of seagrass ecosystems. Our finding of different trophic dynamics in the spring emphasize the need for more experiments exploring how trophic interactions vary in space and time. Furthermore, using stable isotope analyses, we demonstrated that small organisms (e.g., amphipods) that may appear to be functionally redundant in these systems, may in fact exhibit a diversity of feeding behaviors that likely contribute to the structure, function, and stability of seagrass ecosystems. The identification of significant functional diversity among similar invertebrate taxa highlights the cryptic complexity contained within seagrass ecosystems. Successful restoration and conservation of seagrass ecosystems likely requires protection of the organisms that facilitate persistence. Our work suggests that a healthy community of small predators may be a key component in assuring the long-term persistence of seagrass ecosystems and the services they provide.

Presentations and Awards

Levi Lewis presented preliminary results from field experiments in lecture format at the 2007 annual meeting of the Western Society of Naturalists (Monterey, CA) and the 2008 San Diego State Symposium (San Diego, CA) where he received the "Deans Award." Results were also presented in poster format at the 2008 annual meeting of the Southern California Academy of Sciences (Fullerton, CA) and 2008 annual meeting of the Western Society of Naturalists (Vancouver, British Colombia) where he received the award for "Best Poster." During Spring 2009, Levi conducted final statistical analyses from his field caging experiments and analyses were reviewed by his advisor, Dr. Todd Anderson. The final master's thesis of Levi Lewis was completed in Summer 2009, followed by his successful defense and awarding of a M.S. in Biology from San Diego State University. In Fall 2009 through Spring 2010, Levi conducted further analyses of his data and reformatted his thesis for submission to a peer-review journal (Ecology).

James Farlin presented his results at the 2009 San Diego State Research Symposium and the CSU-wide 2009 Symposium receiving a "President's Award" and "First Place Award," respectively. In May 2009, James presented his research at the Southern California Academy of Sciences meeting (Los Angelese, CA) and in November 2009, presented his work at the annual meeting of the Western Society of Naturalists (Monterey, CA). In Dec. 2009, James submitted a written thesis to SDSU and successfully defended his honors research and was awarded a B.S. in Biology from SDSU. In Fall 2009 through Spring 2010, James conducted further analyses of his data and reformatted his thesis for submission to a peer-reviewed science journal (Marine Ecology Progress Series).

Final synthesis of this work was conducted in Spring 2010 and papers were prepared for peer review. Results were presented to the Port of San Diego on February 19, 2010 by Levi Lewis.

Summary of Student Support, Presentations, Awards, and Manuscripts

(A) Student Support

- 1 M.S. Thesis, Levi Lewis (completed summer 2009)
- 1 Undergrad. Honors Thesis, James Farlin (completed fall 2009)
- > 12 undergraduate research assistants and volunteers

(B) Presentations and Awards:

2009. **First Place**. James Farlin. CSU Statewide Research Symposium
2009. **President's Award.** James Farlin. SDSU Research Symposium
2009. James Farlin. Southern California Academy of Sciences
2008. **Best Poster**. Levi Lewis. Western Society of Naturalists
2008. **Deans Award.** Levi Lewis. SDSU Research Symposium
2008. Levi Lewis. Southern California Academy of Sciences
2007. Levi Lewis. Western Society of Naturalists

(C) Manuscripts:

Farlin, JA, Lewis, LS, Anderson, TW, and Lai, C. In review. Functional diversity of amphipods revealed by stable isotopes in a seagrass ecosystem. *Marine Ecology Progress Series.*

Lewis, LS and Anderson, TW. In prep. Microcarnivorous fishes benefit eelgrass (*Zostera marina)* by limiting the abundance of fouling and grazing invertebrates. *Ecolog*y.

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