**Introduction**

Management of the world’s living resources is becoming an increasingly important challenge as human population size and disturbances increase, and demand for these resources continue to grow. The persistence of natural populations depends not only on the reproductive success of individuals but can also be impacted by population size and environmental variation. Management plans vary widely among species due in part to the range of variation in life histories among organisms. For example, protection of reproductive females of a specific size or age class is one management practice that is widely used for a variety of taxa including terrestrial species, such as the capybara *Hydrochaeris hydrochaeris,* and aquatic species such as the oyster *Striostrea margaritacea* (Frederico & Canziani 2005, Bruyn et al. 2009). Similarly, in many states American ginseng *Panax quinquefolius* L. may only be collected if it is at least five years old (Case et al., 2007). Other methods include seasonal restrictions and gear limitations, as is the case for salmonid management (Solomon et al. 2003). The need for successful management plans for marine organisms is widely acknowledged and studies on the impact of exploitation and disturbance are vital to the success of management plans. Evidence of the impact of human disturbance and exploitation of the species abundance and diversity in the world’s oceans can be seen in data from various disciplines (Jackson et al. 2001).

Marine fisheries are most often managed by assessing the relationship between stock and recruitment, and then determining the maximum sustainable yield. Accurate assessment of population size is vital to the success of a management plan. Estimating the population size of aquatic organisms is especially challenging and is further complicated when only fishery-dependent data are available (Cadrin & Pastoors, 2008). Benthic fisheries are increasingly being managed through spatial management (references), or sometimes based on density thresholds (abalone), but this is less common.

The effects of human exploitation and disturbance on marine fish & invertebrates is well documented, but little is known about the impacts of human exploitation on populations of seaweed. Seaweeds have been used by humans for centuries and are becoming increasingly popular in the western United States. We rely on seaweed for food, fertilizer, extraction of alginates, in pharmaceuticals, and in water purification systems. Many seaweeds that were once abundant on the coasts of Asian countries are now scarce in nature (McHugh, 2003) and aquaculture is increasing in some parts of the world (FAO, 2004). There is a growing market in the United States for edible seaweeds and they can be found in restaurants, health food stores, farmer’s markets, and online (Thompsen et al., 2010). Furthermore, recent interest in kelps as a feedstock for biofuels and for abalone aquaculture is increasing the potential demand for seaweeds. Althoughthis resource is not yet threatended with overexploitation in the western United States, the growth in popularity of local seaweed leads to concern over the adequacy of current management and regulations to protect this resource from market pressures.

*Postelsia* *palmaeformis* (hereafter *Postelsia*) is one of the most popular and commercially important seaweed species being gathered in the western United States. *Postelsia* is also one of the more vulnerable species of seaweed to overexploitation in part due to its limited dispersal capabilities, patchy distribution, and annual life history. The spores do not disperse further than ~4 m from the macroscopic sporophyte creating the potential for spore limitation especially in small, patchy populations (Paine, 1979). Studies done in Washington have shown that populations smaller than 25 individuals have a high probability of going extinct between one year and the next(Paine, 1988). Many of the ‘patches’ are reproductively isolated populations that are unlikely to receive spores from an outside source. Due to *Postelsia’s* limited spore dispersal, patchy distribution, range of population sizes (isolated patches) and sessile,benthic lifestyleit has the potential to be an excellent model benthic organism for studying the relationships among population size, intensity of exploitation and recruitment. However, its cryptic gametophyte stage, characteristic of all kelps (order Laminariales), adds a layer of complexity that is challenging to study in the field. There has been limited research into how kelp gametophytes are impacted by environmental variables. To develop a successful management plan for *Postelsia*, it will be necessary to learn more about how both of its life history phases are impacted by environmental variation as well as by human exploitation. To explore the role of spore limitation on recruitment when populations suffer biomass losses and how environmental conditions might impact germination success of haploid spores, I used field and laboratory experiments to answer the following questions:

1. Does reduction in spore production caused by biomass loss result in spore-limited recruitment??
2. How does biomass loss affect the rate of spore release, germination success and reproductive effort over the reproductive period?
3. What are the effects of variation in environmental conditions (e.g., light, temperature, and nutrient levels)experienced by spores upon settlement on germination success?

# Methods

## Study Organism

*Postelsia* is a brown kelp of the Order Laminariales that is endemic to the west coast of North America. It is an annual seaweed with a heteromorphic life history (similar to ferns) alternating between a microscopic, filamentous gametophyte and a large sporophyte. *Postelsia* fronds form a shelter providing canopy for other intertidal organisms and play an important role in the intertidal zone as a major primary producer (Leigh et al. 1986). *Postelsia’s* annual life history begins with the germination of haploid spores that grow into dioecious haploid gametophytes. Sporophytes typically become apparent on the shore between February and March, and begin to produce reproductive sori around June, but these times vary with latitude (Nielsen, unpublished data) and among years. Spores are released during low tide from the grooved fronds. Sporophytes begin senescing in late fall and are torn off the rocks by winter storms (references Paine, Dayton, Blanchette).

## Study Design

## Field experiment: effects of biomass loss on population size, survivorship, recruitment, growth and reproductive status

To test the hypothesis that biomass loss to populations would result in spore-limited recruitment the following year, I experimentally manipulated the frequency of biomass loss to 32 isolated (and presumably closed) populations of *Postelsia.* The populations were isolated by a minimum of 5 m from any adjacent population (average 7.4 m + 3.3 SD) based on prior work on maximum dispersal distances (Paine, 1979).  I established three treatments levels: control, trim once (in June), and trim twice (in June and again in August) that were haphazardly assigned to populations within a site. I measured recruitment of juvenile *Postelsia* sporophytes to the same location (found using GPS coordinates) in June of the following year. I repeated the experimental treatment for two years (2007 & 2008).  In the second year, I haphazardly chose four populations from the trim twice populations to be trimmed a third time (adding a July trimming to the ones in June and August).  All populations were monitored in June and August of 2007, 2008 & 2009).  The experiment was set up at four different sites along the northern California coast, Bodega Marine Lab (38° 18.97’ N 123° 4.33’ W; n=6), Sea Ranch (38° 43.80’ N, 123° 29.32’ W; n=3), MacKerricker State Park (39° 28.54’ N, 123° 48.31’ W; n=17), and Kibesillah Hill (39° 36.00’ N, 123° 47.36’ W; n=6).  The populations I used were distributed unequally among these sites because they were chosen based on population size and isolation from adjacent populations.  Each year I maintained the minimum isolation by distance of 5 m by removing any individuals encroaching on my subject populations well before the reproductive period. The initial population sizes ranged from 33 to 2729 individuals.  Each site had at least one population assigned to each of the treatment levels. In each of these populations I also assessed growth and reproductive status to understand how variation in environmental conditions and the effects of trimming might impact growth and phenology.

*Field experiment: effects of biomass loss on individual spore production, germination success and reproductive effort*

To test the hypothesis that loss of biomass reduces or delays *Postelsia* spore release, germination success and overall reproductive effort (the product of spore production and germination success), I monitored these response variables from individuals within a single population in each treatment level of my field experiment at one site (MacKerricker State Park) every two weeks. Haphazardly selected individuals from the same populations were sampled over time thus the same set of individuals was unlikely to have been sampled more than once.  To make sampling possible at this frequency throughout the reproductive period (late summer through fall) I chose the 3 populations to sample from based on reliability of safe access at this time of year. Because the tides are not very low between late August and October my choices were restricted and favored populations at higher tidal elevations on the shore. I determined spore release rates and germination success using standard methods described in detail in Thompson et al. (2010).  To measure spore production I cut sorus tissue into 1 cm2 pieces and placed them in 1-dram vials with 0.95 mL filtered seawater. After 24 hours, I removed the sorus tissue from the vial and discarded it.  To preserve the samples I added 0.05 mL formalin.  To determine germination success I placed a 2-4 cm piece of sorus tissue into seawater on a slide in a petri dish. These were then incubated at 7.5 C for 48 hours. I varied day length within the incubators to match natural day length at the time of each experimental run.  I collected 30 samples (each from a different individual and 10 from each treatment level) every low tide series (or approximately every other week) between late July and mid-November in 2008.

*Laboratory experiment: effects of light, temerpature and nutrients on germination success*

To assess the effect of environmental variation on germination success of *Postelsia*, I performed a fully crossed experiment in environmental chambers with 2 levels of light, nutrients and temperature. For this experiment I used samples from the same control field populations being samples above. I assigned two treatment levels for each environmental variable: high and low nutrients (nitrates specifically), high and low temperature, and high and low light with 5 replicates per treatment level.  Experiments were repeated monthly throughout the season while sorus tissue was present and plants had not yet been ripped off the rocks by winter waves and storms. Nutrients were added directly to culture medium in Petri dishes, temperature and day length were set for each incubator and light levels were adjusted within each incubator using shade cloth. Nutrient and temperature levels were adjusted to represent the extremes in the range of environmental variation observed from field records in prior years (0 & 30 micromolar nitrate; 7.5 and 15.5 degrees C).  The light levels were by necessity substantially less than full sun, but similar to the habitats spores tend to inhabit (underneath the mussel bed, among algal holdfasts, etc.).  When running the loss of biomass experiment (described above) simultaneously, I shared control samples (no nutrients added, no light reduction, 7.5 degrees C) for efficiency. Conditions for germination success of field experiment population samples corresponded to these conditions.

## Response Variables

At the beginning of the recruitment study I recorded how far each population was from the nearest adjacent population by measuring the shortest distance between two individuals from each population and the tidal height of each population as covariates.  Every June and August from 2006 through 2008 I recorded the size of each population. June is when population sizes are at their annual maximum, but the vast majority of individuals are reproductively immature and by August sporophytes are becoming visibly mature and starting to release spores. From the population size data I derived 4 response variables: 1) the change in population sizes of juveniles (counted each June) and 2) adults (counted each August) between years, 3) survivorship over the growth season (change in population size from June to August within each year), and 4) change in population size due to recruitment (in June) from reproductive adults (in the preceding August). The latter response in combination with survivorship allows for interpretation of the potentially separate effects of the treatments on survivorship of adults over the growth season and their subsequent reproductive success. This is important as *Postelsia* survivorship typically declines sharply over the course of the summer under natural conditions (references: Blanchette , Nielsen, etc.).

To understand how variation in environmental conditions from year to year as well as the effects of trimming might impact growth and phenology of these populations I also measured stipe diameter and height as well as reproductive status of a subsample of 10 haphazardly chosen individuals from each population on each census date. Stipe heights and diameters are metrics of annual growth and biomass production by individuals (Citations).  I examined the fronds of each of these individuals for the presence of darkened tissue indicating the reproductive sori had started to develop; if a single sorus was present the individual was scored as reproductive. Sori can be seen clearly on *Postelsia* fronds when held up to the sky as a darkened patch or stripe along the center of frond.  All metrics were averaged up to the level of the population for analysis.

To measure spore production I took two 10 L samples from each vial of preserved spores and placed them on a hemacytometer slide under 40x magnification on a compound microscope.  I randomly chose three squares within the hemacytometer grid and counted all spores within those squares. To measure germination success I calculated the percent of spores germinating in each sample after 48 hours. I counted the number of spores germinated and un-germinated in three fields of view on a compound microscope under 40x magnification. Subsamples were averaged up to the level of the individual plant for both these metrics.

## Data Analysis

To analyze the effect of trimming on recruitment, survivorship and change in population sizes I used mixed linear models. Trimming treatment was modeled as a fixed factor, site was modeled as a random factor and initial population size was used as a covariate because extinction risk increases with decreasing population size (Paine 1988). The interaction between initial population size and treatment was included to assess model fit, but the term was dropped from the model if the p-value was < 0.10. For changes in juvenile and adult population sizes the initial population size used as a covariate was the size of the juvenile or adult population, respectively, in 2007 (the first year of the field experiment). For changes in survivorship from June to August of each year and changes due to recruitment from August to the subsequent June, the initial population size in June of each year was used. I included tidal height and distance from the closest adjacent population as covariates in early models to assess if variation in these factors might influence the responses. These two factors were important to examine because prior work has shown strong variation in growth and other individual metrics of ecological performance along tidal height and wave exposure gradients and to test the assumption that the dynamics of our populations were independent of other nearby populations due to the distance separating them (as assumed). Neither of these covariates were statistically significant, and thus they were not included in final models.

I analyzed the effect of treatment and year on stipe height and diameter as well as reproductive status on data collected in August after all trimming treatments had been applied for at least one month. I analyzed just the effect of year on data collected in June (before treatments were applied) as an indication of how environmental conditions affected recruitment and juvenile growth. As a test of the assumption that there were no effects of treatment before they were applied I included treatment in the June models, but (as expected) this factor was not statistically significant. I did however include and retain tidal height as a covariate in the analyses as it had a strong influence on these responses variables. I used mixed linear model in all cases with year and treatment as fixed effects and site as a random effect. As above, interaction terms were used to assess the fit of the main effects model and dropped from the model if the p-value was < 0.10.

Spore production, germination success and reproductive effort of individuals from the 3 field populations subjected to different trimming treatments as well as the laboratory germination success experiment were analyzed using either a general or mixed linear model, as appropriate. The data collected from the 3 field populations (and not subjected to laboratory manipulations) were analyzed using a general linear model with treatment and date as fixed factors. The sporophytes in the control population used for the laboratory germination success experiments did not begin to release spores until October, so I was only able to run two trials (one in October and another in November 2008) and these were treated as random factors while nutrient, light, and temperature levels were treated as fixed factors.

For all statistical models above, residual plots were examined visually to determine if transformation of the response variables was required to meet model assumptions. Transformations were done when necessary and are indicated in the resulting statistical tables.

**Results**

Field experiment: effects of biomass loss on population size, survivorship, recruitment, growth and reproductive status

The change in population size of reproductively mature adults from 2007 to 2008 was strongly affected by initial population size (F1, 21= 25.42, p< 0.0001), but was not significantly affected by the trimming treatment (F2, 21= 2.52, p = 0.1042) (Table A1). All three treatment levels declined in abundance, with larger populations experiencing greater declines than smaller ones. There was weak evidence suggesting that control and twice trimmed populations declined slightly more than populations only trimmed once (F2, 21= 3.35, p = 0.0545; Fig. 1, Table A1). The change in population size of adults across the second year of the experiment (2008 to 2009) was not affected by either treatment (F2,25= 1.39, p = 0.2684) or initial population size (F1,25= 1.74, p = 0.1992) (Fig. 1, Table A1). The effect of two years of trimming on adult population sizes depended on initial population size (F2,21= 9.18, p = 0.0014; Fig. 1, Table A1). Populations less than ~200 individuals did not change in size regardless of treatment, while those greater than ~ 400 individuals all declined in size but those trimmed only once declined less than control populations and those trimmed twice.

The change in population size of juveniles between year one and year two (2007-2008) was negatively affected by both treatment (F2,21= 11.85, p = 0.0004) and initial population size F1,21= 182.21, p < 0.0001) (Fig. 2, Table A2). Juveniles in control populations with an initial population size of less than ~400 individuals actually increased in size while those in trimmed populations either did not change or declined (Fig. 2a). At population sizes greater than ~400 individuals all populations declined in abundance, but the declines were greater in those populations that were trimmed. There was no difference between juvenile abundances in those populations trimmed once and those trimmed twice the prior year (Tukey-Kramer post-hoc comparison, t= -0.95, df=21, p=0.6130), but control populations were larger on average than trimmed populations by 215 to 268 individuals (Tukey-Kramer post-hoc comparisons, p<0.0048). The change in population size of juveniles between year two and year three (2008-2009) was affected by treatment (F2,21= 5.07, p = 0.016) but not initial population size (F1,21= 0.23, p = 0.6344) (Table A2). Populations of juveniles not trimmed in the prior year declined in size more than populations that had been trimmed (Fig. 2). The change in the size of the juvenile population as a function of initial population size across both years varied depending on the trimming treatment (F2,21= 5.75, p = 0.0102; Table A2). Overall, the three treatment levels suffered a decrease in population size (F1,21= 81.58, p < 0.0001; Table A2), but populations trimmed only once declined slightly less primarily due to the leverage of a single population (Fig. 2).

The number of recruits in June produced by the reproductively mature but trimmed populations from the prior year, was reduced relative to control populations t (F2,21= 8.7, p = 0.0018; Fig. 3, Table A3). Furthermore, there was no effect of initial population size (F1,21= 0.09, p = 0.7725; Table A3). Control populations increased in size but the populations that were trimmed did not (Fig. 3). The number of recruits in June 2009, the second year of the experiment, was a function of initial population size only (F1, 19 = 5.68, p = 0.0278; Fig. 3, Table A3).

Survivorship from recruit to reproductive adult in year one was affected by initial population size (F1,25= 231.88, p < 0.0001), but not by treatment (F2, 25= 0.48, p = 0.6243) (Fig. 4, Table A4). As initial population size increased, survivorship decreased (Fig. 4). In the second year of the experiment, survivorship in larger populations was lower than in smaller ones as in 2007, but the effect varied somewhat with treatment (F2, 19= 4.02, p = 0.035, Table A4). In general, large populations trimmed only once fared better than those trimmed twice or not at all (Fig. 4). The identical pattern emerged in the third year (2009): survivorship depended upon both treatment and initial population size (F2, 23 = 4.09, p = 0.0303; Table A4), with large populations only trimmed once having the highest survivorship (Fig. 4).

We assessed the effect of inter-annual variation in ocean conditions by comparing stipe heights and diameters of field populations in early June before treatments were applied each year. Stipe diameter and stipe height differed among years (diameter: F2,73= 7.02, p= 0.0016; height: F2, 73 =13.29, p< 0.0001) after correcting for anticipated variation in growth with tidal height (diameter: F1,73=13.29, p= 0.0005; height: F1,73 = 4.61, p= 0.0352) (Fig. 5, Table A5). Stipe growth in both these dimensions was lowest in 2009 (Fig. 5a). Treatment effects on these growth metrics were assessed in August of each year after treatments had been applied. Both stipe height and diameter were negatively affected by the trimming (diameter: F2,76 =4.59, p= 0.0131); height: (F2,76= 8.59, p= 0.0004), after correcting for variation in tidal height (diameter: F1, 76= 25.79, p< 0.0001; height: F1,76 = 22.70, p < 0.0001) (Fig. 5, Table A5). The additive effects of year-to-year variation were also still evident (diameter: F2,76 = 4.65, p = 0.0124; height: F2,76 = 8.18, p= 0.0006; Fig. 5, Table A5). The proportion of visibly reproductive individuals was also assessed each August and while there was a suggestion of year-to-year variation (F2,75= 6.10, p= 0.0901) , trimming clearly had a negative effect overall (F2,75= 4.35, p= 0.0141), after accounting for variation with tidal height (Fig. 5, Table A5).

Field experiment: effects of biomass loss on individual spore production, germination success and reproductive effort

Spore production, germination success and reproductive effort varied as a multiplicative function of both date and treatment (spore production: F12, 187= 6.67, p < 0.0001; germination success: F12, 107= 1.91, p < 0.0412; reproductive effort: F12, 188= 5.87, p < 0.0001) (Fig. 6, Table A6). Reproductive effort was largely a reflection of spore production as germination success varied more over time than it did among treatments (Fig. 6). Populations trimmed once had the greatest spore production and reproductive effort, with the peaks for both occurring in September (Fig. 6). Surprisingly, populations trimmed twice had the same very low level of reproductive effort and spore production as the controls (Fig. 6).

Laboratory experiment: effects of light, temperature and nutrients on germination success

Germination success varied as a complex interaction of light, temperature, and nutrients (F1, 60 = 5.00, p = 0.0291; Fig. 7, Table A7). Spores under higher light levels had greater germination success overall (Fig. 7, Table A7), but there were no consistent patterns with respect to nutrients or temperature. Under low light, the greatest germination success was observed under the low temperature and high nitrate treatment, while the under high light it was greatest under low temperature when no additional nitrates were added (Fig. 7). This latter treatment combination (high light, low temperature and no added nitrates) had the highest germination success overall (Fig. 7).

**Discussion**

## Recruitment

Treatment had an effect on change in juvenile population size from year 1 to year 2 and year 2 to year 3 (fig. 2). In year 1 to year 2 the Trim 1 and Trim 2 populations decreased at increasing initial population sizes. In year 2 to year 3 the Control populations decreased while Trim1 and Trim 2 populations stayed the same. The change seen from year 1 to year 3 was affected by initial population size, and there was an interaction between treatment and initial population size. At increasing population sizes, the Trim 1 populations decreased the least followed by Control populations then Trim 2. The patterns seen in the change in juvenile population size from year 2 to 3 and year 1 to year 3 are consistent with anecdotal evidence from seaweed harvesters who have found that thinning *Postelsia* populations can encourage growth in the individuals of the under story. This pattern has been shown in terrestrial plants (**paper citation**) and deserves further investigation. Density was not a variable measured in this study but our personal observation is that the larger populations we measured were more dense than the smaller populations. Changing environmental conditions may have caused the difference in results between the years. In 2007 (the end of an El Nino cycle) upwelling was weaker than in 2008 (fig). It is possible that within a year where populations are experiencing environmental stress, the added impact of trimming has a stronger effect than in years when ocean conditions are less stressful. The results were not the same when looking at the change in population size of reproductive adults in the same years (fig. 1). There was no effect of treatment seen in year 1 to year 2 or year 2 to year 3. As seen in the juvenile population, there is an effect of initial population size seen from year 1 to year 2. At larger initial population sizes, there was a decrease in population size from year 1 to 2. This is consistent with the patterns seen in juveniles in the same years. There was an effect of initial population size and the interaction between treatment and initial population size. Control and Trim 2 populations experienced a greater decrease in population size than Trim 1 populations. This is consistent with the patterns seen in juvenile populations. The results from this study showed that the effects of trimming and initial population size can change greatly between years. It was necessary therefore to look at variations in environmental conditions between years to give an indication to the cause of these results.

From 2007-2008 we see that control populations have an increase of population size of recruits. Trim 1 and Trim 2 decrease in recruit population size (fig. 3). From 2008-2009 we see that there is no effect of treatment, but there is an effect from initial population size. At greater initial population size, there were a greater number of recruits. It may be that during a time of strong upwelling, when the water is nutrient rich as seen in the summer of 2008, trimming does not impact population size. In a time period when upwelling is weak, as seen in the summer of 2007, the effects of trimming are experienced.

In 2007 we see that trimming did not have an effect on the survivorship of individuals, and that survivorship decreased with increasing initial population size (fig. 4). In 2008 there was an effect from initial population size and the interaction between treatment and initial population size. This pattern is also seen in 2009. In both 2008 and 2009 we see that at higher initial population sizes, Control populations and Trim 2 populations had a greater decrease in survivorship than Trim 1 populations. Consistently through all three years we see that there is an effect of initial population size on survivorship. This strengthens the impression that in the larger more dense populations, competition for resources causes a greater die-off within the year, and that some “thinning” of the populations may actually be beneficial.

Diameter & Height: Treatment had a significant effect on stipe diameter & stipe height. We see in fig. 5 that the Control populations had significantly higher diameter and height than Trim 1 and Trim 2 populations. This may be caused by the redirection of energy towards re-growth of fronds from the growth in stipe height and diameter seen in Control populations. Year also had a significant effect on stipe diameter and stipe height (fig. 5). Stipe height and diameter were significantly lower in 2009 than in the previous years. This may be due to the delayed onset of upwelling experienced in 2009 (fig. 5).

# *Biomass Loss*

For this experiment three populations were chosen based on their similar tidal heights and their accessibility for frequent sampling. The control and trim 2 populations were in a similar location approximately 5 m away from each other. The trim 1 population was much farther away, and as the season advanced it became obvious that this population experienced a much different microclimate than the other two populations. For this reason I do not have confidence that this part of the experiment can provide a very clear comparison between the three treatment levels. The trim 1 population had a much higher sporulation success overall, and a different pattern of spore release. This population is in an area that is much more wave exposed. Research by Nielsen et al (2006) shows that *Postelsia* individuals at higher tidal heights grow more slowly, have a lower total biomass, and a delayed reproductive output due to desiccation stress and light saturation. Although all three populations were at similar tidal height, the Trim 1 population was in a location where it did not suffer the same desiccation stress as the Control and Trim 2 populations. It is clear that the benefit from being in a more wave exposed area outweighed the effects of treatment. There is a comparison that can be made between the two extreme treatment levels, control and trim 2. Control and trim 2 have similar patterns of sporulation for most of the season, until November when the Control populations have a slightly higher sporulation success (fig. 6). When looking at the germination success it is clear that the trim 2 populations are greatly delayed compared to the control populations (fig. 7). Control populations peak in August while Trim 2 populations peak in November.

## Environmental Variation

The significant interactions we found when analyzing the effect of environmental variation on *Postelsia* sporulation show the need for a more in depth study on this topic. The experiment we performed does not give enough information to explain the results with confidence.

The high nutrient treatment had higher germination success than the low nutrient treatment. The greatest germination success was seen at low light and low temperature levels. This is consistent with research by Nielsen et al (2006) that shows that individuals at higher tidal height, where desiccation and light saturation are highest, have lower reproductive success and lower photosynthetic efficiency.

#### Conclusion

The results of these experiments have shown that the effects of trimming on *Postelsia* populations are highly dependant on environmental variation and initial population size. The negative effects of trimming can be absent in a year with a strong pattern of upwelling whereas a year where upwelling is delayed can strengthen the negative effects of trimming…