Black Development Corporation

360 PAPA PLACE, SUITE 101
KAHULUI, HAWAII 96732
TELEPHONE (808) 545-1700, EXT. 40
FAX (808) 871-8773

December 2, 2015

Land Use Commission
PO Box 2359
Honolulu, HI 96804
Fax: 808 587-3827
E-mail: luc@dbedt.hawaii.gov

Re: Testimony IN FAVOR of Final Environmental Impact Statement
Olowalu Town Master Plan (DKT. NO. A10-786)

Dear Land Use Commissioners,

I am writing to provide my support for the approval of the Final Environmental Impact Statement for the Olowalu Town Master Plan; DKT. NO. A10-786. I believe the EIS was performed professionally and support the project for the much needed housing it will create.

The Olowalu Town plan is designed to be a complete community based on a zoning model that is different than the standard zoning code used with most recent developments. This flexible zoning code allows construction of towns similar to Maui's historical towns. This flexibility allows for apartments, multi-family units, live-work units, senior housing, and single family housing to co-exist along the same street. This wide variety of housing types will meet the needs of Maui's families throughout their lives as incomes and family needs change with life.

The majority of the housing units within Olowalu are planned to be apartments, multi-family units, and small single family units. These housing types have a smaller footprint which allows the cost of the infrastructure to be much less than standard single family homes in many of the new subdivisions. The result is lower cost housing options for Maui's families which is sorely needed. Similar to the way most of the multi-family units in Wailuku are affordable to Maui's residents even without government restrictions, most of the housing in Olowalu will be affordable to Maui's residents due to the type of housing to be constructed.

It is my understanding that a Final Environmental Impact Statement is utilized to disclose potential impacts for a proposed development. The Olowalu Town Final EIS utilizes many professionals in their various fields of expertise to provide information about the impacts of the Olowalu Town Master Plan.

It is not surprising that some members of the community do not agree with everything within the document. In fact, it would be impossible to create a document in which someone would not disagree. However, this Final EIS is a complete disclosure document that is well prepared and thorough. If this document is not acceptable, I fear that the system will not allow for worthy projects to progress through the review system which will be detrimental to Hawaii moving forward.

Please approve the Olowalu Town Final Environmental Impact Statement.

Very truly yours,

BLACK DEVELOPMENT CORPORATION

Michael J. Fergus
President

Fwd: 25 reasons why the proposed Olowalu Town is a bad idea
otaheiteshopify
to:
luc
12/03/2015 09:00 PM
Hide Details
From: otaheiteshopify@gmail.com
To: luc@dbedt.hawaii.gov

Aloha LUC commissioners.
I'm forwarding this article to you that states 25 reasons why the LUC should reject the FEIS for the Olowalu Town Development. This article addresses many of the community concerns.

Mahalo
Tiare Lawrence

Save Olowalu! 25 reasons why the proposed Olowalu Town is a bad idea

http://mauitime.com/news/politics/save-olowalu-25-reasons-why-the-proposed-olowalu-town-is-a-bad-idea/

MAUI TIME DECEMBER 2, 2015
BY **ANTHONY PIGNATARO** 21 COMMENTS

A few weeks ago the state Land Use Commission LUC met at the Maui Arts & Cultural Center to discuss the final environmental impact statement (EIS) for **Olowalu Town**, a massive development project pushed by Bill Frampton and Dave Ward. The project is billed as a "complete community"–containing its own housing, public infrastructure, recreation, commercial development and open space. The LUC didn't decide the fate of the EIS (or the project), but will meet again at the MACC on Dec. 7 to take it up again.

Given that the project has been in development for the last decade, there's a considerable cache of documents that outline more than a few concerns. In fact, they catalog a very long list of pretty substantial problems. While the list below is by no means a comprehensive list of everything that's wrong with the proposed Olowalu Town–that would take something approximating a second environmental impact statement–it does include a lot of issues that might doom the plan. For more information, check out **SaveOlowalu.org**.

1. Olowalu Town will include approximately 1,500 homes.

2. That means about 4,000 residents would live there.

3. Olowalu's current population, as of the 2010 census, is 80.

4. The project is so big that it will require the relocation of Honoapiilani Highway as it travels through Olowalu.

5. Though billed as a way to address Maui's housing need, the project will actually build too much housing for West Maui. "The project will exceed the [Planning] Department's estimated housing need and provide a rationale for exceeding the demand," Planning Director Will Spence said in an April 17, 2012 letter to developers Bill Frampton and Heidi Bigelow.

6. Developers bill the project as a "Smart Location" under LEED Neighborhood Development standards. This simply means that it encourages the building of neighborhoods near already existing public transportation. The county's Planning Department took issue with this, in its April 17, 2012 letter to Frampton and Bigelow. "Please justify how this project, located four miles away from the edge of Lahaina, meets 'Smart Location' for LEED Neighborhood Development standards," Spence wrote. In their response written three years later, developers Frampton and Ward denied that this was a problem and insisted that "Olowalu has historically been used for housing."

7. The Draft EIS, issued in 2012, states that "As recently as the 1930's, Olowalu was a thriving plantation town." According to the county Planning Department, this isn't even close to true. "Throughout its history, Olowalu was at most a 'camp' and at most a 'village,'" Spence wrote in his April 17, 2012 letter. "In 1930, census-taker Kenichi Takayama recorded the population of Olowalu as being 447 persons." Spence helpfully offered to Frampton and Bigelow that the county has "extensive information about West Maui's camps, villages, and towns, including Lahaina, Olowalu, Puukolii, and Ukumehame if you would like further clarification."

8. Most of the maps included in the EIS aren't to scale. "[A]almost all maps say "Not To Scale" which makes it difficult to determine distances among and between uses," the State Office of Planning (OP, which advises the LUC) said in a Nov. 17, 2015 letter to the LUC. "The Conceptual Master Plan map in particular, should be to scale."

9. The public has never given a chance to review the developers' complete Traffic Impact Analysis Report, which the state OIP told the developers to prepare back in 2012. "Given the significance of the issue and extensive revisions made following the "Preliminary" TIAR, the public should be given the opportunity to review this final TIAR," the state Office of Planning said in their Nov. 17, 2015 letter.

10. Archaeological studies and surveys "for the entire Olowalu area were not included in the Draft FEIS," stated the OP on Nov. 17, 2015. This is concerning because "new sites and cultural material have been found" in recent surveys and the State Historic Preservation Division (SHPD) "has not reviewed and commented

on the Draft EIS," according to the OP's Nov. 17, 2015 letter.

11. The project will use a lot of water. The EIS approximates the water use at about 750,000 million gallons per day (gpd). But five years ago, the county's Department of Water Supply put the estimate at closer to "between approximately 900,000 and a little more than 2 million gpd, according to system standards," according to an Aug. 5, 2010 letter from then-Water Supply Director Jeffrey Eng to Colleen Suyama, a consultant who was preparing the Olowalu EIS. In that letter, Eng also dryly noted that "as of 2008, the sustainable yield set by the Commission on Water Resource Management for the Olowalu aquifer is 2 million gallons per day."

12. The project will draw water from state lands. "Source of surface water is state lands," states a handwritten note on a Mar. 20, 2012 memo from the state Department of Land and Natural Resources. "Applicants need to work towards getting a water license and license to access state lands." More than three years later, on Oct. 26, 2015, Colleen Suyama replied, stating that "We further acknowledge that the source of surface water is State lands. As required, the applicant will obtain a water license and lease to access State lands."

13. The project will also consume a great deal of agricultural land. And the County of Maui doesn't like that. "[T]he DEIS inadequately justifies the removal of 621 acres of agricultural land, including 121 acres of Prime Agricultural Land," Spence wrote in 2012. "Suggesting that these 621 acres are a small percent of Maui's Agricultural lands neglects the fact that these are prime lands that demand special protection."

14. What's more, the lands the developers have set aside for ag are some of the lowest quality in the area. "[T]he majority–80 percent–of the Master Plan Site Area has 'A' and 'B' classified soils, while about 19 percent of the site is of the lowest, least productive classification 'E,'" Spence noted in his April 17, 2012 letter. "It is noted that this area where the least productive AG soil exists is the area surrounding the Olowalu Stream–the precise area where the Master Plan proposes to retain as AG land within the Olowalu Cultural Reserve." In their response submitted three years later on Oct. 26, 2015, Olowalu Town developers Frampton and Ward argued that "farming is not the sole means of improving or increasing the long-term sustainability of Hawaii's economy" and that "providing homes" could also do wonders. They developers also noted that greenhouses and hydroponic farming are making great strides today.

15. Though they included no detailed protection plan in their EIS, developers insist that "Olowalu Stream will not be altered during implementation of the Master Plan."

16. According to county Planning Director Will Spence (who noted this in his 2012 letter), the project exists in a "known tsunami and flood hazard area." In their 2015 response to Spence, the developers said that their "proposed drainage improvements" would "reduce the potential for flooding."

17. Nene–an endangered species–are found in Olowalu, yet the EIS (as the County of Maui noted in 2012) contains no explanation as to how developers will protect the species. In 2015, the developers responded to the county's concerns by reiterating that their project wouldn't harm the birds.

18. The coral reef off Olowalu is one of the healthiest on Maui–perhaps in the entire state. Biologist Pauline Fiene noted this in her 2012 comments on the EIS. “We don’t get to decide where our special natural places are on Maui,” she wrote. “Nature decides that. All we can decide is where our development is going to be. And if there were a reef on the whole island that cries out for respite and exemption from urban development above it, it would be Olowalu. It has developed over centuries and there is literally nothing to replace it.” For this reason, Fiene noted, she was “baffled” as to why a project on this scale was even being considered for Olowalu.

19. In 2015, the project developers reiterated, despite the concerns of Spence and biologists like Fiene, that Olowalu Town “is not expected to adversely affect the reef environment and nearshore water quality.” Big wave surfer and former Maui County Ocean Safety supervisor Archie Kalepa didn’t buy it. “If they develop Olowalu into a community and a hotel, the effect it will have on that ecosystem–the waterfront and the reefs–will be such a great impact that it will socially ruin that reef,” he said. “When I say ‘socially,’ I’m talking about the fishes, the sharks, all the marine life that exist… Olowalu’s one of the few places we have left. I don’t think that from an environmental standpoint that it’s a good idea for us to develop that area.”

20. Though the EIS notes that Olowalu’s irrigation system is “quite dated, with portions of it built in the late 19th and early 20th centuries,” it neither identifies the system’s location on its maps nor acknowledges that its age may qualify it for listing on the National Register of Historic Places–which Spence said in 2012 may “have an adverse impact on this resource,” as it would require additional protections during the project’s development.

21. The EIS, Spence noted, contains no specific information on how the project will impact police, fire and solid waste services. “It is insufficient to merely state that the hospital or police facilities are located a certain distance from Olowalu, or that a fire station site will be discussed for possible inclusion in the public/quasi-public area,” Spence noted in 2012.

22. Though Olowalu sits astride the only road between Lahaina and Maʻalaea, the county Planning Department noted that the project EIS doesn’t evaluate the project’s traffic impacts (or what might mitigate those impacts) to those two towns.

23. The project also includes 375,000 square feet of commercial development. To put this figure into perspective, the new Target in Kahului covers 140,000 square feet.

24. In 2012, Spence noted that the project EIS “underestimates” costs to county in terms of police, fire, civil defense, housing and human concerns, public works and planning. It also underestimates costs to the state in terms of education, medical, prison and highway services.

25. Based many of these concerns (as well as others), the state Office of Planning concluded in its Nov. 17, 2015 letter that the LUC not approve the Olowalu Town EIS.

Cover design: Darris Hurst
Cover photo: Chris Archer

December 3, 2015

Hawaii Land Use Commission

Subject: Recommending LUC deny Olowalu Town FEIS

Dear Commissioners,

I am a marine biologist with over 20 years of research on Hawaii's marine environment including my doctoral work with the University of Hawaii studying the Olowalu manta ray population. Based on my review of the marine report conducted Marine Research Consultants, Inc., I strongly recommend denying the FEIS. I address the Summary section of the report beginning on page 25 to support my basis for the denial. The numbers below refer to the numbers in the summary (Appendix A).

1. The report states, *"60 water samples that were collected at five ocean sites spaced within the project boundaries*". At each site only a single sample was taken therefore there is no information about sample variance and 60 samples are way to few samples to be characterize the Olowalu Reef area.

2. The report states, "*In all cases, the near shore zone of mixing was restricted to a narrow zone that extended a maximum of only tens of meters from the shoreline. Beyond this distance, water chemistry at all sites was representative of pristine open coastal waters*". Plenty of photos demonstrate that mud water entering the ocean during a heavy rain event can extend several hundreds of meters offshore (Appendix B). The existing sediment stress on the inshore reef at Olowalu extends several hundred meters offshore. The statement is not representative of mixing that can occur during heavy rain events.

5. The report states, "*Ground-truth data and resulting computer generated maps provided estimates of occurrence of living coral cover, as well as cover of algae, sand and mud throughout the various zones of the reef environment."* Less than 1% of the reef was surveyed and carried out in a haphazard way (Appendix C). Much more of the reef needs to be surveyed using a systematic design. The characterization needs to also be three dimensional since a coral 2 meters tall will be characterized in the same manner as a coral that is 2 inches tall when each has very different value and provides very different ecosystem services. This type of characterization cannot be done using general coral cover maps. Since the surveys were carried out in 2010, there has been a significant sediment stress impact to the inner reef from the removal of kiawe trees that destabilized the shoreline and eliminated a fish nursery area, and the construction of three oceanfront homes, two of which cited for BMP violations (Appendix D). All this in addition to the recent mass coral bleaching event over the past few months has significantly altered the reef character since the survey was carried. To obtain a true baseline, a new

survey should be conducted using an appropriate survey design and quantify the recent sediment impacts on the inshore reef in front of the recent oceanfront built homes as a reference and scale that impact to account for 1,500 homes, 800 ohanas, a sewage treatment plant, a shopping mall and 4,000 new residents.

6. The report states, "*Macroalgae accounted for about 8% of bottom cover, 21% of the bottom was covered with sand, and 33% of the bottom consisted of mud and sediment bound in algal turf*". Given the sediment damaged has changed significantly since the survey was conducted, these numbers are not valid.

11. The report states, *"Overall, results of this study indicate that the existing episodic discharge to the ocean of land-derived sediment is the most pervasive stress to the reefs off Olowalu. However, the area extent of such deposition is limited and does not affect all areas of the reef*". Why is there no assessment of how far offshore the sediment stress is impacting to provide some context for the extent of sediment stress?

12. The report states "*Depiction of the existing marine environment indicates that, at present, groundwater is so restricted in distribution that there is essentially no effect on marine community structure."* There are many groundwater seeps as far as 100 yards offshore that aren't being accounted for (personal experience). The sampling design was too small an area, insufficient samples per site to control within sample variability and to temporal sampling to control for across day variability, for example after a rain event or during tree removal and grading to clear a lot for development.

13. The report states *"while the project will increase the area of impervious surfaces, the inclusion of retention basins is predicted to result in no change to discharge of water to the ocean compared to the present scenario. However, with respect to impacts to coral communities, the most important aspect of the retention basins is a potential reduction in discharge of terrigenous sediment".* Theoretically, proper implementation and management of sediment basins should greatly reduce sediment discharge but this is the exception rather than the rule. The Mahana Estates project at Kapalua is a clear example where Marine Research Consultants also claimed that no impact would occur to the marine environment due to the proper use of BMPs. There have been well over 50 mud water events stemming from that construction project over the past 3 years, multiple BMP revisions and a 5-month stop work order. To this day they are still unable to properly control the sediment discharge from their property and into the ocean. Many other similar examples exist throughout Maui where developer with good intentions ultimately destroyed the reef ecosystem offshore from their project. The grading of 432 acres uphill from the reef will surely result in sediment depositing on the reef and therefore should be discussed as a probably impact and present alternatives to minimize and mitigate those impacts.

14. The report states *"as long as best management practices are utilized to avoid any unforeseen impacts during the construction and operational phases of the project, and engineering considerations in the design of the retention basins focus on maximizing sediment trapping, there is no rationale to indicate the potential for negative impacts to the marine environment"*. Any references to coastal development having a positive impact to an adjacent reef are not listed (Appendix E), probably because they don't exist, but plenty of references exist to show the contraire (see Appendix F). The rationale to indicate the likelihood for negative impacts are that every coastal development in Hawaii has had a negative impact on the offshore coral reef and that BMPs have proven to be a dismal failure at preventing sediment discharge from a construction site. Since sediment impacts are very likely going to occur, this EIS needs to describe what will be the impact with respect to the loss of ecosystem services from the coral reef, impacts to fishers, cultural practitioners, recreational users and commercial users. The EIS should state what mitigation measures it will take to replace any loss of coral.

15. The report states, "*The studies conducted for this report, particularly the water quality analyses and coral reef habitat maps, can serve as an initial baseline for any monitoring programs that may be required for the project*". As stated earlier, the recent sediment impacts for the coastal disturbance of vegetation and the mass coral bleaching event warrants a new baseline characterization study. The existing baseline survey can be used to quantify the impacts that have occurred in the past 5 years since the survey was conducted.

Furthermore, in a letter by Dr. Steven Dollar dated September 28, 2015 he states "*my study methodology and outcomes should not be affected by the alternative land use configurations offered by Alternative 1 and Alternative 2"* referring to the alternative to develop on the makai side of the highway. Common sense tells us that the closer a pile of dirt is to the ocean, the more likely wind and water will carry it into the water. The main reason that the GPAC, the Maui Planning Commission, and the Maui County Council decided to remove the makai lands from the Olowalu Town proposal was to provide a buffer area where storm water and sediment could settle out before reaching and impacting the coral reef. For Dr. Dollar to imply that the impacts to the marine environment would be the same (improved reef health) under either scenario is disturbing.

I wish to thank all the Commissioners for your public service and strongly urge you to deny the Olowalu Town FEIS on the grounds of "***failing to fully declare the environmental implications of the proposed action and discussing all relevant and feasible consequences of the action***"*,* a legal requirement for an EIS.

Sincerely,

Mark Deakos, Ph.D.
4993 Lower Honoapiilani Road
Lahaina, Hawaii 96761

Attachments:

- Appendix A
- Appendix B
- Appendix C
- Appendix D
- Appendix E
- Appendix F

or composition of groundwater. As groundwater presently has essentially no effect on existing marine communities, the small changes to groundwater fluxes associated with the project will have no negative impacts to the ocean. Retention basins that will be an integral part of the proposed project should serve to trap terrestrial sediment prior to ocean discharge, which will hopefully mediate some of the stress associated with sediment discharge. A major focus of the Olowalu project will be on the recognition, appreciation and long-term stewardship and preservation of the natural and cultural resources of the land. Thus, all activities associated with the project should concentrate on maintenance of undisturbed areas and improvement of stressed areas. All of these considerations indicate that the proposed Olowalu project will not have any significant negative effects on the coastal ocean offshore of the property.

V. SUMMARY

1. Evaluation of the nearshore marine environment off the Olowalu Master Plan project site in West Maui was carried out in 2010-2011. Assessment of nearshore marine water chemistry was carried out by evaluating data from 60 water samples that were collected at five ocean sites spaced within the project boundaries. Water samples were collected on transects perpendicular to shore, extending from the shoreline to distances of approximately 500-600 m offshore. Analysis of fourteen water chemistry constituents included all specific constituents in DOH water quality standards.

2. Several dissolved nutrients (Si, NO_3^-, PO_4^{3-}, TN and TP) displayed strong horizontal gradients at several ocean transect sites with highest values closest to shore and lowest values at the most seaward sampling locations. Correspondingly, salinity was lowest closest to the shoreline and increased with distance from shore. These gradients were most pronounced at the northern boundary of the project site and weakest at the southern region of the project area southwest of Olowalu Point. These patterns are indicative of groundwater efflux at the shoreline, producing a zone of mixing where nearshore waters are a combination of ocean water and groundwater. In all cases, the nearshore zone of mixing was restricted to a narrow zone that extended a maximum of only tens of meters from the shoreline. Beyond this distance, water chemistry at all sites was representative of pristine open coastal waters.

3. Water chemistry constituents that are not major components of groundwater also displayed distinct gradients with respect to distance from the shoreline. In particular, Chl *a* and turbidity were generally elevated in nearshore samples with decreasing values moving seaward.

4. Application of a hydrographic mixing model to the water chemistry data was used to indicate if increased nutrient concentrations in nearshore waters are the result of mixing of natural groundwater with oceanic water, or are the result of inputs from activities on land. The model indicates that, at the time of sampling, there was a distinct subsidy of nitrate nitrogen (NO_3^-) to the ocean at survey sites located near the northern boundary of the property (Site 1) and off the eastern side of Olowalu Point (Site 4). There was no external supply of nitrate at Site 2, located directly off Olowalu Stream. However, there was a subsidy of phosphate phosphorus (PO_4^{3-}) off Olowalu Stream, which did not occur at any other

location.

5. Evaluating water chemistry from the single sampling in 2010 using DOH specific criteria for Open Coastal Waters indicates that many of the measurements in the nearshore areas (within 10-20 m of the shoreline) exceed standards, particularly for various forms of nitrogen. As these standards do not take into consideration of mixing of high-nutrient, naturally-occurring groundwater with ocean water in the nearshore zone, such exceedances are expected.

6. Characterization of the marine habitat and biotic community structure was carried out using a fully georeferenced WorldView-2 multispectral satellite image of the Olowalu area purchased from the Image Library at DigitalGlobe.com (image data originally acquired on February 10, 2010). Ground-truth data derived from georeferenced digital photographs collected at 200 representative points provided the input to create benthic habitat maps of the Olowalu reefs. Ground-truth data and resulting computer generated maps provided estimates of occurrence of living coral cover, as well as cover of algae, sand and mud throughout the various zones of the reef environment.

7. Analysis of spectral data within the satellite image was classified using georeferenced ground-truth data and covered an area of about 1.8 million square meters, or 454 acres. Overall coral cover in the mapped area was about 37% of bottom cover, while living coral cover within the calibration photo-quadrats equaled about 40% of bottom cover. The difference in cover values using the two estimates is a result of selection of calibration-validation points that are likely biased toward areas of higher coral cover. Macroalgae accounted for about 8% of bottom cover, 21% of the bottom was covered with sand, and 33% of the bottom consisted of mud and sediment bound in algal turf.

8. In most open coastal areas of Hawaii the dominant factor responsible for the physical structure of reefs and species assemblages is stress from wave energy. The reefs at Olowalu are somewhat unique in that sediment deposition (or lack thereof), rather than wave forces, appears to be the major determinant of physical and biotic reef structure. Along the northern side of Olowalu Point, deposition of terrigenous sediment emanating from Olowalu Stream creates a habitat where coral communities are limited to species and growth forms that can withstand the sub-optimal conditions created by sediment deposition. South of Olowalu Point, a shallow, wide, triangular-shaped reef flat, formed from deposition of alluvial material from Olowalu Stream, terminates in a fore-reef composed of actively accreting corals assemblages that show little or no effect of sediment stress. Reefs at that southeastern end of the project site (14-Mile Marker) also showed distinct indications of sediment stress, although no major streams discharge regularly in this area.

9. Motile macro-invertebrates on the reef consist primarily of several species of sea urchins. These species include the bio-eroding burrowing urchins *Echinometra matheai* and *Echinostrephus aciculatus*, and the larger slate pencil urchin (*Heterocentrotus mammilatus*), the collector urchin (*Tripneustes gratilla*) and the long-spined urchin (*Echinothrix diadema*). Urchins were rare in the zones covered by sediment. Other macrobenthos observed consist of sea cucumbers, primarily on the sandy areas of the reef flats, and starfish. The coral-eating crown-of-thorns starfish (*Acanthaster planci*) was not observed in the study area.

10. Populations of reef fish in the area were typical of Hawaii reefs, although numbers of larger fish were low, likely as a result of fishing pressure. The most abundant families consist of wrasses, damselfish and surgeonfish. As is generally the case, density of fish was a function of vertical complexity of the benthic surface, with the highest abundance on the outer fore-reef. Reef fish were rarest in the areas with heaviest deposition of mud. Numerous small sharks were observed on the inner reef flat south of Olowalu Point.

11. Overall, results of this study indicate that the existing episodic discharge to the ocean of land-derived sediment is the most pervasive stress to the reefs off Olowalu. However, the area extent of such deposition is limited and does not affect all areas of the reef. Reef communities on the outer reef flat and fore reef represent essentially pristine ecological settings unaffected by most activities of man (with the exception of fishing).

12. Engineering analysis indicates that, with full build-out of the planned project, there will be changes in groundwater that include a small reduction in flow rate and phosphorus discharge and an increase in nitrogen discharge to the nearshore ocean compared to present conditions. The changes with combined groundwater and surface runoff from episode storm events, is predicted to increase both phosphorus and nitrogen flux to the ocean by small amounts. Depiction of the existing marine environment indicates that, at present, groundwater is so restricted in distribution that there is essentially no effect on marine community structure. Thus, the small changes in groundwater dynamics projected to result from the project do not present a mechanism for future negative effects to offshore marine communities.

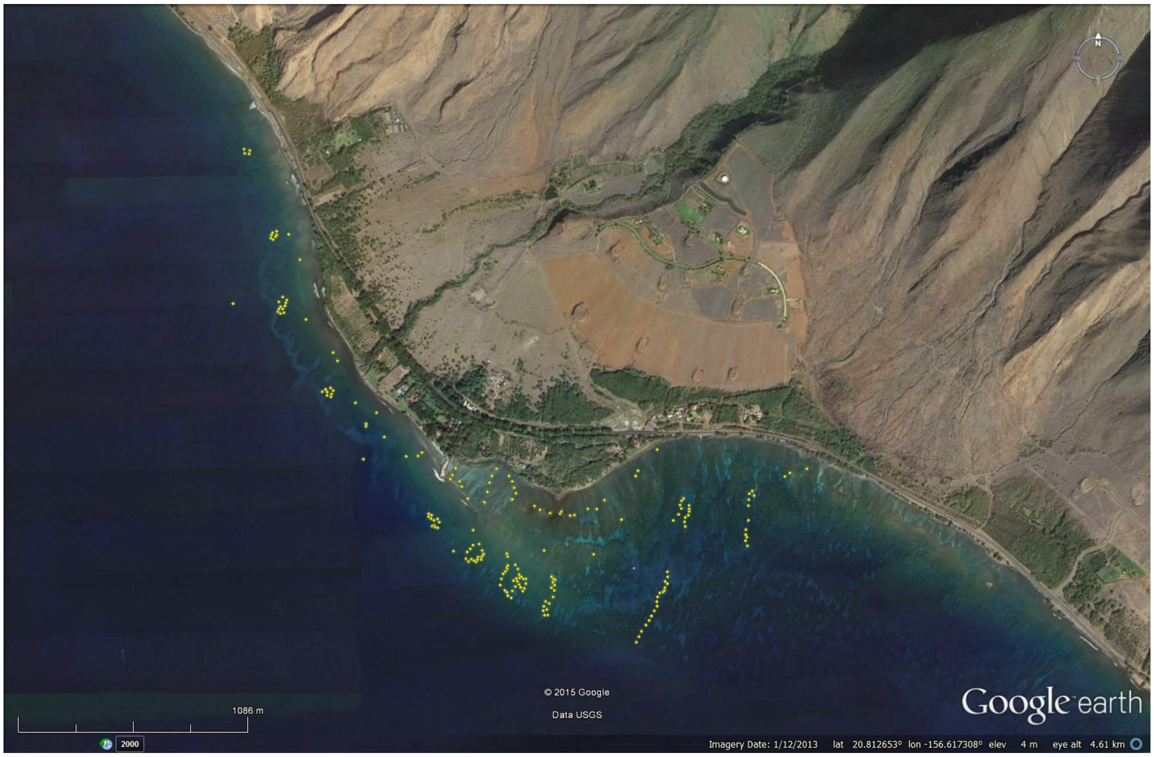
13. A planned component of the Olowalu Town Master Plan is a series of retention basins within the project site for the purpose of retaining storm water runoff prior to discharge to the ocean. While the project will increase the area of impervious surfaces, the inclusion of retention basins is predicted to result in no change to discharge of water to the ocean compared to the present scenario. However, with respect to impacts to coral communities, the most important aspect of the retention basins is a potential reduction in discharge of terrigenous sediment.

14. Planning of the Olowalu Town Master Plan focuses on continued maintenance and stewardship of the unique natural resources of the area. As a result, as long as best management practices are utilized to avoid any unforeseen impacts during the construction and operational phases of the project, and engineering considerations in the design of the retention basins focus on maximizing sediment trapping, there is no rationale to indicate the potential for negative impacts to the marine environment.

15. The studies conducted for this report, particularly the water quality analyses and coral reef habitat maps, can serve as an initial baseline for any monitoring programs that may be required for the project.

Appendix B: Mud Water Photos

Appendix C: MRC Report Survey Areas



Appendix D: Olowalu BMP Violations

County of Maui
Kalana O Maui Building
200 South High Street,
Wailuku, HI 96793-2155

RFS Information for 14-0000860

Call Information

Status	Received Date	Completed Date	Duration (Days)	Entered By	How Taken	Source
DONE	06/29/2014	07/16/2014	17	KIVANET	REMOTE	INTERNET

Requestor Information

Name: TRACY ADAMS
Address:
Company:
(H) Phone: 808-366-8822
(W) Phone:
E-Mail: tracva808@gmail.com

Event Location

Address: 11501 HONOAPIILANI HWY
LAHAINA, HI 96761
Owner(s):
MARTIN,PETER KLINT TRUST
TMK: 2480030460000
Subdivision:
Intersection:
Common Place:
Other Location: HOUSE UNDER CONSTRUCTION, OCEANFRONT, OLOWALU

Memo(s)

House with TMK (2) 4-8-003:046. This house (property line approximately 100 yards front the ocean) is under construction and the BMPs are inadequate (single silt retention fence almost completely collapsed and non-functional) and threaten the offshore reef should a heavy rain event occur. Photos are available of the violation upon request. Please double check the address and TMK to be sure they are valid. Very few houses under construction in this area so the one in violation should be obvious.

Additional Addresses

Address	TMK

Related Permit(s)

Permit	Permit Name	Status

Inspection Information

Problem	Type	Scheduled	Completed	Inspector	Result

RFS#: 14-0000860 TMK#: 2480030460000

County of Maui
Kalana O Maui Building
200 South High Street,
Wailuku, HI 96793-2155

RFS Information for 14-0000860

Call Information

Status	Received Date	Completed Date	Duration (Days)	Entered By	How Taken	Source
DONE	06/29/2014	07/16/2014	17	KIVANET	REMOTE	INTERNET

Requestor Information

Name: TRACY ADAMS
Address:
Company:
(H) Phone: 808-366-8822
(W) Phone:
E-Mail: tracva808@gmail.com

Event Location

Address: 11501 HONOAPIILANI HWY
LAHAINA, HI 96761

Owner(s):
MARTIN,PETER KLINT TRUST

TMK: 2480030460000
Subdivision:
Intersection:
Common Place:
Other Location: HOUSE UNDER CONSTRUCTION, OCEANFRONT, OLOWALU

Memo(s)

House with TMK (2) 4-8-003:046. This house (property line approximately 100 yards front the ocean) is under construction and the BMPs are inadequate (single silt retention fence almost completely collapsed and non-functional) and threaten the offshore reef should a heavy rain event occur. Photos are available of the violation upon request. Please double check the address and TMK to be sure they are valid. Very few houses under construction in this area so the one in violation should be obvious.

Additional Addresses

Address	TMK

Related Permit(s)

Permit	Permit Name	Status

Inspection Information

Problem	Type	Scheduled	Completed	Inspector	Result

RFS#: 14-0000860 TMK#: 2480030460000

Appendix E: MRC Report References

VI. REFERENCES CITED

Dollar, S. J. 1982. *Wave stress and coral community structure in Hawaii*. Coral Reefs 1:71-81.

Dollar, S. J. and M. J. Atkinson. 1992. Effects of nutrient subsidies from groundwater to nearshore marine ecosystems off the Island of Hawaii. Est. Coast. Shelf Sci. 35:409-424.

Dollar, S. J. and G. W. Tribble. 1993. *Recurrent storm disturbance and recovery: a long-term study of coral communities in Hawaii*. Coral Reefs. 12:223-233.

Fletcher, C. H. and 16 others. 2008. Geology of Hawaii Reefs. In: Coral Reefs of the USA. B.M. Riegl and R.E. Dodge (eds.) . Springer Science + Business Media B.V.

Grasshoff, K. 1983. Methods of seawater analysis. Verlag Chemie, Weinheim, 419 pp.

Grigg, R. W. 1998. Holocene coral reef accretion in Hawaii: a function of wave exposure and sea level history. Coral Reefs 17:263-272.

Grigg, R. W. and J.E. Maragos. I974. Recolinization of hermatypic corals on submerged lava flows in Hawaii. Ecology 55: 387-395.

Officer, C. B. 1979. Discussion of the behavior of nonconservative dissolved constituents in estuaries. Est. Coast. Mar. Sci. 9:569-576.

Smith, S. V. and M. J. Atkinson 1993. C:N:P ratios of benthic marine plants. Limnol. Oceanogr. 28:568-574

Smith, S. V. and M. J. Atkinson 1993. Mass balance analysis of C, N, and P fluxes in coastal water bodies, including lagoons. Coastal Lagoon Processes. (ed) B. Kjerfve, Elsevier Oceanography Series, 60. pp. 123-145.

Strickland J. D. H. and T. R. Parsons. 1968. A practical handbook of sea-water analysis. Fisheries Research Bd. of Canada, Bull. 167. 311 p.

Appendix F: Literature on Reef Impacts

<u>POSITIVE</u> Impacts of coastal development on Reefs:

No literature found.

<u>NEGATIVE</u> Impacts of coastal development on Reefs:

From Urbanization

Finkl, C. W., & Charlier, R. H. (2003). Sustainability of subtropical coastal zones in southeastern Florida: challenges for urbanized coastal environments threatened by development, pollution, water supply, and storm hazards. *Journal of Coastal Research*, 934-943.

From Nutrient Loading

Paytan, A., Shellenbarger, G. G., Street, J. H., Gonneea, M. E., Davis, K., Young, M. B., & Moore, W. S. (2006). Submarine groundwater discharge: An important source of new inorganic nitrogen to coral reef ecosystems. *Limnology and Oceanography*, *51*(1), 343-348.

Koop, K., Booth, D., Broadbent, A., Brodie, J., Bucher, D., Capone, D., ... & Yellowlees, D. (2001). ENCORE: the effect of nutrient enrichment on coral reefs. Synthesis of results and conclusions. *Marine pollution bulletin*, *42*(2), 91-120.

Costa, O. S., Nimmo, M., & Attrill, M. J. (2008). Coastal nutrification in Brazil: a review of the role of nutrient excess on coral reef demise. *Journal of South American Earth Sciences*, *25*(2), 257-270.

Gabric, A. J., & Bell, P. R. (1993). Review of the effects of non-point nutrient loading on coastal ecosystems. *Marine and Freshwater Research*, *44*(2), 261-283.

From People

Wong, P. P. (1998). Coastal tourism development in Southeast Asia: relevance and lessons for coastal zone management. *Ocean & Coastal Management*, *38*(2), 89-109.

Richmond, R. H., Rongo, T., Golbuu, Y., Victor, S., Idechong, N., Davis, G., ... & Wolanski, E. (2007). Watersheds and coral reefs: conservation science, policy, and implementation. *BioScience*, *57*(7), 598-607.

Meng, P. J., Lee, H. J., Wang, J. T., Chen, C. C., Lin, H. J., Tew, K. S., & Hsieh, W. J. (2008). A long-term survey on anthropogenic impacts to the water quality of coral reefs, southern Taiwan. *Environmental Pollution*, *156*(1), 67-75.

Moberg, F., & Folke, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological economics*, *29*(2), 215-233.

Davenport, J., & Davenport, J. L. (2006). The impact of tourism and personal leisure transport on coastal environments: a review. *Estuarine, Coastal and Shelf Science*, *67*(1), 280-292.

Creel, L. (2003). *Ripple effects: Population and coastal regions* (pp. 1-7). Washington, DC: Population Reference Bureau.

From Sediment

Syvitski, J. P., Vörösmarty, C. J., Kettner, A. J., & Green, P. (2005). Impact of humans on the flux of terrestrial sediment to the global coastal ocean. *Science*, *308*(5720), 376-380.

Fabricius, K. E. (2005). Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Marine pollution bulletin*, *50*(2), 125-146.

From Urban Development

Wolanski, E., Martinez, J. A., & Richmond, R. H. (2009). Quantifying the impact of watershed urbanization on a coral reef: Maunalua Bay, Hawaii. *Estuarine, Coastal and Shelf Science*, *84*(2), 259-268.

Wilkinson, C. R., & Buddemeier, R. W. (1994). *Global Climate Change and Coral Reefs: Implications for People and Reefs: Report of the UNEP-IOC-ASPEI-IUCN Global Task Team on the Implications of Climate Change on Coral Reefs*. IUCN.

Turner, R. K., Subak, S., & Adger, W. N. (1996). Pressures, trends, and impacts in coastal zones: interactions between socioeconomic and natural systems. *Environmental management*, *20*(2), 159-173.

Hunter, C. L., & Evans, C. W. (1995). Coral reefs in Kaneohe Bay, Hawaii: two centuries of western influence and two decades of data. *Bulletin of Marine Science*, *57*(2), 501-515.

Doney, S. C. (2010). The growing human footprint on coastal and open-ocean biogeochemistry. *science*, *328*(5985), 1512-1516.

To: luc@dbedt.hawaii.gov

Subject: A10-786 Olowalu Town - Testimony on the Final EIS

November 16, 2015

Dear LUC Commissioners,

In reviewing the materials associated with the Final Environmental Impact Statement (FEIS) for the proposed Olowalu Town development, it appears that many of the comments and concerns submitted in 2012 by my colleagues in the science and conservation community were dismissed outright through the responses provided by the developers and contractors. In some cases, the responses are erroneous and could be considered irresponsible from a scientific standpoint. In other cases, descriptions of proposed mitigation measures, such as the implementation of Low Impact Development (LID) strategies to reduce runoff and sedimentation are certainly admirable, though vague in nature and lacking any meaningful metrics for evaluation. It is my opinion that the apparent lack of rigor in the assessment of the marine environment, coupled with the lack of detail pertaining to the proposed LID measures and other Best Management Practices (BMPs), provide sufficient justification for you to reject the Final EIS for the proposed development.

Hawaii Administrative Rules (HAR 11-200) state that an Environmental Impact Statement “shall fully declare the environmental implications of the proposed action and shall discuss all relevant and feasible consequences of the action.” The FEIS does not sufficiently meet these criteria for either of the two aforementioned issues my testimony focuses upon.

Regarding the assessment of the marine environment, I urge you to seriously consider the testimony submitted by seven highly credentialed marine biologists from the Scripps Institution of Oceanography (testifying as individuals), who have collectively spent thousands of hours conducting research at Olowalu, one of their field sites. They found that the FEIS contains flawed methodology, sampling errors, and inaccurate conclusions, and therefore cannot sufficiently address the environmental implications or consequences of the proposed development.

In reviewing Appendix C-2 (Stormwater Quality Enhancements), and other sections of the EIS that reference mitigating the impact of runoff through BMPs and LID, I was unable to find key details about the proposed measures, specifically their respective contributions to pollutant load reduction during both the construction and post-construction phases of the development. The FEIS names the types of LID and BMP measures being considered, describes their function and benefits, and notes the broader categories of the areas within the development where each could be implemented (ie. “Single-Family Residential” or “Commercial”), but this information alone does not sufficiently address the environmental impact of these measures. This lack of detail is concerning, as there is no attempt to provide location siting of specific LID measures within the development, or quantify the amount of nutrients (mg/L of nitrogen and phosphorous) or sediments (mg/cm2/day) that these measures will reduce.

The FEIS also indicates that “Olowalu Town will develop stormwater BMP guidance documents for use by the designers of residential, commercial, public, and green space/recreational facilities within the community.” It is unclear whether developing and providing these documents would be considered “recommendations” or “requirements” for the implementation of specific stormwater control measures, and there is also no indication of oversight and accountability mechanisms to ensure these measures are appropriate, adequate, and implemented properly.

Many of the proposed stormwater management strategies and examples of BMPs represent innovative technologies that have been in use elsewhere for a long time, and have been advocated for use in Hawaiʻi for many years by numerous individuals, agencies, and organizations. Only relatively recently have development projects in Hawaiʻi begun to implement these measures, and some have yet to be tried on Maui at all, much less at the scale proposed. The FEIS references the West Maui Ridge to Reef Initiative’s advocacy for LID measures, but it should be noted that those underway are still considered to be pilot or demonstration projects, such as rain gardens and curb inlet baskets. Maui-specific challenges and barriers to the effective implementation of these and other strategies are only now emerging, and their effectiveness has not been sufficiently measured, demonstrated, and evaluated at this stage.

Given these realities, along with the obvious history of stormwater runoff impacts to Maui’s reefs due to coastal development, I feel that the flaws and lack of detail in the FEIS present a clear case that Olowalu should not be used as a test ground for these technologies, especially when considering the uniqueness and vulnerability of the coral reef ecosystem, its ecological, economic, and cultural importance, and its sensitivity in the face of global climate change on top of the local stressors it already endures. Please reject the Final EIS for the Olowalu Town development.

Thank you for your consideration.

Sincerely,
Liz Foote

Wailuku, Maui
(808) 669-9062
Lfoote@hawaii.rr.com

B.S., Ecology, Behavior and Evolution, University of California, San Diego
M.Sc., Science Education (Marine Science emphasis), Oregon State University

Reed M. Ariyoshi
618 Anela Place
Wailuku, HI 96793

December 3, 2015

Land Use Commission
PO Box 2359
Honolulu, HI 96804
Fax: 808 587-3827
E-mail: luc@dbedt.hawaii.gov

Re: Testimony IN FAVOR of Final Environmental Impact Statement
Olowalu Town Master Plan (DKT. NO. A10-786)

Dear Land Use Commissioners,

I am writing to express my support for the approval of the Final Environmental Impact Statement for the Olowalu Town Master Plan; DKT. NO. A10-786. I have reviewed the Final EIS for this project and believe that the document is very concise, thorough and covers all aspects of the proposed project.

It is my understanding that the purpose of a Final Environmental Impact Statement is to analyze and disclose potential impacts for a proposed development. The Olowalu Town Final EIS utilizes the services of many reputable professionals in their various fields of expertise to provide information about the impacts of the Olowalu Town Master Plan.

It is not surprising to find that some members of the community do not agree with everything contained within the document. In fact, it would be nearly impossible to create a document for a project of this magnitude in which there is total agreement within the community. However, it is my opinion that this Final EIS represents a complete disclosure document that is very well prepared and thorough. If this document is deemed not acceptable, I am afraid that the current system will not allow for worthy projects to progress through the review process, which moving forward, will ultimately prove to be detrimental to our State.

It is my hope that you will approve the Olowalu Town Final Environmental Impact Statement.

Very truly yours,

Reed M. Ariyoshi

Olowalu Master Plan (DKT. NO. A10-786)

Stephen Smith to: luc@dbedt.hawaii.gov 12/03/2015 02:39 AM

This is my testimony in favor of final EIS for Olowalu Town Master Plan

Aloha Land Use Commissioners,

I humbly ask for your approval of the Olowalu Master Plan. I grew up on Maui, fourth generation Jamaicans family that grew up in the sixth increment in Kahului. I grew up in a master planned community that was developed for the sugar cane industry on Maui. It was like growing up in a wonderfully planned village. The often repeated phrase it takes a village to raise a child, I grew up in that village. I have wonderful memories living in the plantation style homes in the 60's and 70's.

Looking back at the changes to Maui both good and bad, I wish more people had the vision to create smart plans like this vision for Olowalu. This plan keeps Maui alive by allowing future generations to experience the closeness of growing up around towns like Makawao, Paia, and like the Olowalu of past generations. The Olowalu Master Plan is a great plan to recreate the old town feel that we have been losing on Maui with the modern improvements needed for the area.

Building the right mix of homes will allow a once beautiful town to exist once again. Even more precious is to bring back the old Maui families to the the area and allowing the future generations to grow up in a Maui that we were lucky to experience.

My Dad worked for Waihee Dairy as a delivery driver in the days milk was delivered to your home. We delivered milk all over the island and one of our weekly stops was the Olowalu store. At the time there were more homes in the area, a nice community and the store was the gathering place for everyone. Everyone knew each other and when we came to deliver the milk it was like visiting family.

When my daughter was a youngster, we would get up early during the summer and winter breaks to dive or dawn patrol surf at Olowalu. Some of my fondest memories was heading back to the Olowalu Store before lunch to eat those red hot dogs and shaved ice on the tailgate of my pick up truck to laugh and share stories. Yes, I have many fond memories of this area.

Unfortunately, the ocean and shoreline conditions are progressively deteriorating. The area needs to be modern solutions before the conditions created from centuries of sediment runoff completely destroy the reefs. Hopefully, over time this condition can be reversed by modern drainage options that filter the runoff before entering the ocean. This plan has solutions to stop the current problem from progressing.

The entire roadway along the coast from the Pali to Lahaina needs to be re routed Mauka before it falls into the ocean. Then the area between the road and the ocean can then be returned back to public use. So much of this roadway is in danger to falling in the ocean and during high surf being a danger to motorist.

There was a beautiful area to picnic and bbq at the entrance to Olowalu. The water was always crystal clear and the circular inner reef created almost a lagoon like setting for the kids to swim. It was about 50 yards before the drainage outlet coming into Olowalu. The reef is still there but not as vibrant anymore. But, the beach area is gone. Like many areas of the coast it has been swallowed up by the ocean. The kiawe trees that once created shade for our picnics now lie in the ocean. The ocean is now up to the roadway and like many of the picnic areas along that route it has given way to high tides that splash onto the roadway.

It's time to recreate that beauty of old. The road needs to be moved Mauka allowing for space again for families to enjoy the beachfront. This plan encompasses that restoration of shoreline. It's time to bring Maui people back to the area and restore the town culture that has disappeared not just in Olowalu but on the entire West side.

This plan shows that the developers care about Maui. This plan gives the locals an opportunity to be a part of a beautifully planned community. Everything else along the coast is owned by the rich. Give the locals a chance to be a part of the area and recreate beautifully planned community.

Thank you for this opportunity to submit testimony.

Sincerely,

Stephen E Smith (DePonte and Aikau Ohana)

Sent from my iPad

December 3rd, 2015

To: The State of Hawaii Land Use Commission

Concerning: A10-786 Olowalu Town Testimony on the Final-Environmental Impact Statement

Dear State of Hawaii Land Use Commission,

For the reasons presented in this testimony, please consider the rejection of the Final-Environmental Impact Statement (FEIS) for the proposed development of Olowalu Town on the island of Maui.

The coral reef community (or benthic composition) is under represented:
The benthic composition maps provided by the FEIS are created from models; they are not created from actual data. The area of Olowalu's coral reef that the FEIS attempts to address is approximately 454 acres or ~1.8 million square meters. The area that the FEIS actually covered in the field by the five, 500 meter long transects (and assuming 1 meter wide) is roughly 2500 square meters, or 0.62 acres. Another way to express the FEIS data is that each of their 200 "calibration/validation" sites covered $3.33m^2$ or 4 pixels of remote sensing imagery, providing only 800 pixels of actual data. The number of pixels in the map is not provided, but it is likely much higher than 800. Clearly the area of coral reef actually covered is not sufficient. Furthermore, it is absolutely not possible for this FEIS to serve as a "baseline" for Olowalu's coral reef community prior to the development of Olowalu Town due to the complete lack of actual benthic composition data. Since the benthic composition is poorly represented and the current "ground-truthing" data can not serve as a baseline data set, any benthic surveys conducted after Olowalu Town is developed will have little benthic data for comparison to what existed prior to the developmental process. I recommend that the FEIS establishes more transects to provide more actual benthic composition to serve as a baseline data set for Olowalu's coral reef. It is crucial for the current status of Olowalu's coral reef to be represented accurately and appropriately with real data.

The marine water chemistry is under represented:
The number of marine water samples collected for water chemistry analyses is not sufficient enough to represent accurate values. Marine water chemistry can be highly variable, and it is a scientific standard for the average of three samples per location to be presented with the associated variance as the result. The FEIS only has one sample per location, and only 60 samples total to address the entire 454 acres of Olowalu's coral reef. That is equivalent to 1 sample per 7.5 acres. In addition, Transect 1 has extremely high nitrogen levels at the nearshore sites, the reasoning for which was not addressed by the FEIS. In this same area, the Olowalu Landfill was closed in the early 1990's, and the leachate from this closed landfill might be affecting the nearshore waters. The FEIS failed to even mention the existence of the landfill, and definitely ignored the potential affects of the landfill on the adjacent coastal environment. I recommend that more

marine water samples are collected across the coral reef at Olowalu on the additional transects mentioned above, to represent the water chemistry of the area appropriately. The existing information provides very little information on the current water chemistry.

The current assessment of shoreline groundwater properties is entirely lacking: A number of times the FEIS refers to the emergence of "groundwater at the shoreline" because of a decreasing salinity trend and some elevated nitrogen levels in the nearshore waters, but the FEIS failed to provide actual groundwater samples from the shoreline. I recommend that groundwater samples be taken through standard procedures that often involve a pipe or a piezometer being driven into the ground at the shoreline. The pipe or piezometer is connected with tubing to a peristaltic pump, which extracts the groundwater from the benthos into the collection bottle. Water collection methods such as this were not used in the FEIS so there is currently no baseline for groundwater constituents prior to the development of Olowalu Town. At this time, any shoreline groundwater survey conducted after the development of Olowalu Town will have no data to compare the post developmental results to.

The affects of sedimentation rates and nutrient levels are inaccurately represented: On multiple occasions the FEIS concludes that the development of Olowalu Town will decrease sedimentation rates to the adjacent reef through retention basins. Unfortunately, even with a few retention basins, more sediment will be delivered to the adjacent coral reef when the bare ground of the construction sites is exposed to heavy rains. Once Olowalu Town is built, there will be sustained increased levels of nutrients in the adjacent nearshore coastal water through 5 new major sources: (1) wastewater, (2) fertilizers, (3) leakage at the wastewater treatment plant, (4) 4.7 acre excess R1 leach field, and (5) R1 re-use for irrigation (pg. 22). Unfortunately, in severe contrast to the claims of the FEIS (pg 19, 3rd paragraph), the nutrient responsive algae *Hypnea musciformis* (aka: hook weed) and *Ulva lactuca* (aka: sea lettuce) persist excellently in any high-nutrient reef flat environment regardless of circulation rates. Both species have already formed massive coral-degrading blooms in response to land-based nutrient loading in across Maui, including areas of Kihei, North-West Maui, Maalaea, and from Kahului to Hookipa. In fact, *Ulva sp.* is known to form blooms across the world in response to increased nutrients. I have attached one of my peer-reviewed scientific manuscripts as additional information which investigates the prolific growth of *Hypnea musciformis* and *Ulva lactuca* in response to increased nutrients.

In consideration of the abovementioned issues with the current Final-Environmental Impact Statement for Olowalu Town as well as the complete lack of important land-based assessments (appropriate Hawaiian cultural surveys, traffic issues throughout the developmental process, and traffic issues after the development for West Maui residents, etc.) I respectfully request that it is rejected by your authority.

Thank you for your time and vital thoughts on this important matter,

Meghan Dailer, Marine Researcher
dailer@hawaii.edu, P.O. Box 10816, Lahaina, HI 96761
MSc University of Hawaii, Manoa; BS Long Island University, Southampton College

Harmful Algae 17 (2012) 111–125

Contents lists available at SciVerse ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Responses of bloom forming and non-bloom forming macroalgae to nutrient enrichment in Hawai'i, USA

Meghan L. Dailer[a,*], Jennifer E. Smith[b], Celia M. Smith[a]

[a] University of Hawai'i, Mānoa, Department of Botany, 3190 Maile Way, Honolulu, HI 96822, USA
[b] University of California San Diego, Scripps Institution of Oceanography, 9500 Gilman, Dr. Mail Code 0202, La Jolla, CA 92083-0202, USA

ARTICLE INFO

Article history:
Received 17 December 2011
Received in revised form 20 March 2012
Accepted 21 March 2012
Available online 9 April 2012

Keywords:
Coral reef
Macroalgae
Ulva
Hypnea
Nitrogen
Phosphorus
Wastewater
Hawai'i

ABSTRACT

Macroalgal blooms of *Ulva lactuca* and *Hypnea musciformis* have been problematic in shallow coastal waters around agricultural and urbanized regions of Maui, Hawai'i for decades. Observations have highlighted the correspondence between these blooms and elevated nutrient levels from the adjacent land-use, however little evidence exists regarding the effects of nutrient enrichment on the blooming and non-blooming macroalgae in the area. To determine if elevated nutrient levels influence *H. musciformis* physiology, we conducted a nutrient enrichment (+N, +P, and +N+P) experiment and measured growth, photosynthetic status, and pigment absorbance. Phycobilin pigments were significantly reduced in the no addition and +P treatment and maintained in those with N additions, suggesting that *H. musciformis* can use phycobilins to store N. We conducted a second, larger experiment with additions of secondarily-treated wastewater effluent on the bloom forming species *Acanthophora spicifera*, *H. musciformis*, and *U. lactuca* and the common non-bloom forming species, *Dictyota acutiloba*. All samples were initially depleted of potential N stores and measured for growth, photosynthetic status, and N uptake rates; *H. musciformis* and *U. lactuca* were also assessed for micro nutrient uptake, % tissue N, and $\delta^{15}N$ values. Growth rates of *D. acutiloba*, *H. musciformis*, and *U. lactuca* increased with increasing % wastewater effluent addition and concentrations of TN and NO_3^- and those of the bloom forming species were 2-fold higher. All species increased photosynthetic capacity and saturation irradiance with increasing % wastewater effluent addition and concentrations of TN and NO_3^-. *U. lactuca* was the most sensitive to low N conditions, evidenced by declines in light capturing efficiency. All species utilized a substantial amount of N over 24 h. *H. musciformis* and *U. lactuca* also (1) utilized micro nutrients: iron, manganese, molybdenum, and zinc, (2) decreased % tissue N in low N conditions, (3) increased % tissue N in response to elevated N conditions, and (4) expressed elevated $\delta^{15}N$ values with increasing additions of wastewater effluent. These results demonstrate that in Hawai'i, the bloom forming species *H. musciformis* and *U. lactuca*, have similar physiological responses to decreased and increased nutrient levels.

1. Introduction

Excess anthropogenic nutrients severely impact coastal ecosystems worldwide with two general ecosystem responses (1) declines in original habitat, including seagrass meadows in estuaries (Twilley et al., 1985; Burkholder et al., 1992; Zaitsev, 1992; Fong et al., 1993; Peckol et al., 1994) and benthic structure and composition on coral reefs (Barnes, 1973; Smith et al., 1981; Walker and Ormond, 1982; Bell, 1992; McCook, 1999; Cole et al., 2004) and (2) increases in macroalgal growth and abundance (Lapointe, 1997; Paerl, 1997; Valiela et al., 1997; Stimson et al., 2001; Morand and Merceron, 2005; Viaroli et al., 2005). Although declines in herbivore populations from over-fishing (Jackson et al., 2001; Pandolfi et al., 2003) or disease outbreaks (Hughes, 1994) would likely contribute to increases in the percent cover of macroalgae, the formation of macroalgal blooms in close proximity to urbanized and agricultural areas worldwide suggests that anthropogenic nutrient loading is the dominant factor allowing for excessive biomass production (Goreau, 1992; Peckol et al., 1994; Pedersen and Borum, 1997; Raven and Taylor, 2003).

Most macroalgal blooms consist of one or two species, suggesting that the blooming species are more responsive to excess nutrients than other macroalgae in the area. Anthropogenic nutrient driven blooms of opportunistic macroalgae in the genus *Ulva* (Chlorophyta) (referred to as "green tides") have been well documented in temperate regions of the world (Brittany, France, Briand, 1989; Puget Sound, Washington, USA, Thom and Albright, 1990; Waquoit Bay, Massachusetts, USA, Valiela et al., 1992;

* Corresponding author. Tel.: +1 808 221 2942; fax: +1 808 956 3923.
E-mail address: dailer@hawaii.edu (M.L. Dailer).

1568-9883/$ – see front matter
http://dx.doi.org/10.1016/j.hal.2012.03.008

Venice, Lagoon, Italy, Sfriso et al., 1993; Ythan Estuary, Scotland, UK, Raffaelli et al., 1998; Tancada Lagoon, Ebro Delta, NE Spain, Menendez and Comin, 2000; Yellow Sea and East China, Hu et al., 2010). In temperate and tropical regions, increased eutrophication has led to biomass accumulations of opportunistic Chlorophyceaens with simple morphologies including *Ulva* (bistromatic lamina and monostromatic hollow cylinders), *Codium* (unicellular interwoven filaments), *Cladophora* (branched filament), *Chaetomorpha* (unbranched filament), and *Ulvaria* (monostromatic blades) (Fletcher, 1996; Morand and Briand, 1996; Lapointe, 1997; Valiela et al., 1997; Nelson et al., 2003; Lapointe et al., 2005a; Teichberg et al., 2010). Pedersen and Borum (1996) conclude that opportunistic macroalgae have fast growth and high nutrient uptake rates and are, therefore, able to substantially increase their biomass when exposed to excessive nutrient (nitrogen, N and phosphorus, P) levels. This implies that blooms of opportunistic macroalgae will persist in locations where nutrient levels are sustained above the threshold levels of prolific algal growth (on coral reefs for example: dissolved inorganic $N = 1.0\ \mu M$, soluble reactive $P = 0.1\ \mu M$, Bell, 1992) until such nutrients are reduced to levels that will not promote high algal growth rates.

To decrease macroalgal biomass in areas of persistent blooms it is crucial to verify the response of these species to nutrient enrichment and determine the source(s) of land-based nutrients in the area. This information can assist management officials in the decision making processes of regulating land-based nutrient loading in areas of macroalgal blooms. Globally, over the past few decades, sources of anthropogenic N have been detected by investigating the isotopic signature of N (^{15}N:^{14}N, expressed as $\delta^{15}N$; Eq. 4) (Gartner et al., 2002; Costanzo et al., 2005; Lin et al., 2007; Risk et al., 2009; Dailer et al., 2010, 2012). This is possible because different N sources have distinct $\delta^{15}N$ signatures. Naturally occurring and fertilizer N generally range from 0 to 4‰ and −4 to 4‰, respectively (Macko and Ostrom, 1994) and sewage derived wastewater N ranges from 11 to 38‰ (Kendall, 1998; Gartner et al., 2002; Savage and Elmgren, 2004) depending on the level and type of wastewater treatment. Elevated $\delta^{15}N$ values arise from the denitrification of nitrate and nitrification of ammonia, during which microbial fractionation occurs for the easier to metabolize, lighter isotope (^{14}N) (Heaton, 1986). The volatilization of ^{14}N-ammonia also enriches the sewage N source in ^{15}N relative to ^{14}N (Heaton, 1986). The release of N_2 into the atmosphere has prompted some wastewater treatment facilities (including those on the island of Maui, Hawai'i, S. Parabicoli, pers. comm.) to use a combination of denitrification and nitrification, termed Biological Nitrogen Removal, to reduce N levels of the effluent (Wiesmann, 1994). The wastewater effluent from such facilities likely has highly elevated $\delta^{15}N$ values. Macroalgae take up N from their environment with no evidence of N fractionation (Cohen and Fong, 2005), therefore their $\delta^{15}N$ values likely represent the integration of all available N sources. Macroalgae growing adjacent to sewage outfalls frequently have enriched $\delta^{15}N$ values ranging from 9 to 15‰ (Gartner et al., 2002; Costanzo et al., 2005; Lin et al., 2007). To date, the highest reported macroalgal $\delta^{15}N$ value is 50.1 ‰ from samples of *Ulva lactuca* grown over warm, freshwater seeps on a nearshore reef at Kahekili on Maui (Dailer et al., 2010). Kahekili is located near the Lahaina Wastewater Reclamation Facility (operated by the County of Maui) that utilizes Class V injection wells to dispose of 3–5 million gallons of wastewater effluent daily. The wastewater effluent from this facility has been continuously detected on this reef through high $\delta^{15}N$ values of transplanted and intertidal macroalgae (Dailer et al., 2010, 2012).

Increasing populations and substantial agricultural areas across Hawai'i subject the adjacent estuaries and coral reefs to anthropogenic nutrient loads (Laws, 2003; Stimson et al., 2001; Derse et al., 2007). In the 1970s, the increased abundance and spread of *Dictyosphaeria cavernosa* was documented in Kaneohe Bay, Oahu as a result of nutrient-rich sewage discharge to the southern region of the bay (Soegiarto, 1973; Banner, 1974; Smith et al., 1981; Pastorock and Bilyard, 1985). The abundance of *D. cavernosa* decreased after the sewage was diverted to an offshore outfall (Hunter and Evans, 1995). The role of anthropogenic N in the promotion of opportunistic green macroalgal blooms and often co-occurring red macroalgal blooms has been well documented for temperate (Björnsäter and Wheeler, 1990; Valiela et al., 1992; Fong et al., 1993; Pedersen and Borum, 1997; Fong et al., 1998; Menendez and Comin, 2000; Nelson et al., 2003; Fox et al., 2008; Teichberg et al., 2008; Thornber et al., 2008) and tropical (Smith et al., 1981; Lapointe, 1997; Lapointe et al., 2004, 2005a,b; Barile and Lapointe, 2005) regions. Studies have not specifically linked elevated N and/or P levels to blooms consisting of both *Ulva lactuca* and *Hypnea musciformis* (Rhodophyta) in Hawai'i.

Blooms primarily comprised of *H. musciformis* and *U. lactuca* are problematic in shallow, coastal waters around urbanized and agricultural regions of Maui and annually cost over 20 million dollars in economic losses (Van Beukering and Cesar, 2004). Another species commonly found in these blooms is *Acanthophora spicifera*, which is the most widespread and successful alien invasive alga in Hawai'i (Smith et al., 2002). These macroalgal blooms occur in the following four regions of Maui across the corresponding length of coastline: (1) northwest, ~7.0 km, (2) central-south, ~2.4 km, (3) southwest, ~10.5 km, and (4) central-north, ~11.3 km (blooms in this region occur during summer months and are decimated with large winter swells) (Fig. 1; West Maui Watershed Owners Manual, 1997; MD per. obs.). The co-occurrence of green and red macroalgal blooms suggests that bloom forming species from different algal phyla may respond similarly to increased N and/or P levels even though their pigment composition differs. Typically in low light conditions, red macroalgae assemble dark colored phycobilin pigments phycoerythrin (PE) and phycocyanin (PC), which require more N to construct and absorb more light than chlorophyll complexes (Graham and Wilcox, 2000). However, as documented for *Gracilaria* spp., PC and PE can also be used to store N (Ryther et al., 1981; Lapointe and Duke, 1984; Horrocks et al., 1995). On Maui, blooms of *H. musciformis* consist of plants that are dark purple in high light conditions, suggesting that phycobilin pigments are likely used for N storage.

To investigate the role of N and P on the growth, photosynthetic properties, and pigment composition of *H. musciformis* we performed a preliminary nutrient enrichment experiment with the following treatments: no addition, +NH_4^+, +PO_4^{3-}, and +PO_4^{3-} and +NH_4^+. Based on the results from the preliminary experiment and the detection of wastewater effluent in areas of *H. musciformis*

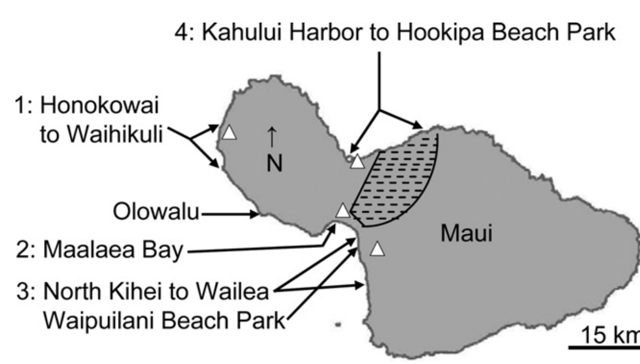


Fig. 1. Long-term (decadal) locations of *Hypnea musciformis* and *Ulva lactuca* blooms on Maui, Hawai'i. Region 1 has fluctuations in macroalgal biomass, regions 2 and 3 have persistent blooms, and region 4 blooms are subject to large winter swells and primarily occur in the summer months. White triangles represent wastewater injection well locations and the dashed area represents ongoing agricultural (sugar cane) operations.

and *Ulva lactuca* blooms on Maui (Dailer et al., 2010), we adjusted our methods and conducted a larger experiment with incremental additions of secondarily-treated wastewater effluent, containing an assortment of micro nutrients and elevated N levels relative to oligotrophic coral reef conditions. These experiments were conducted on the following four species: *Dictyota acutiloba* (non-bloom forming), and the bloom forming species, *Acanthophora spicifera*, *H. musciformis*, and *U. lactuca*. To determine if these species would physiologically respond similarly to increasing nutrient levels, we exposed samples to a gradient of wastewater effluent and measured their growth rates, photosynthetic properties, and N uptake rates. For *H. musciformis* and *U. lactuca*, additional analyses were performed to determine if they (1) also use micro nutrients, (2) decrease % tissue N in low N conditions, (3) increase % tissue N in high N conditions, and (4) would reflect the associated isotopic signatures ($\delta^{15}N$) from the wastewater N source.

2. Materials and methods

2.1. Preliminary experiment: response of Hypnea musciformis to N and P enrichment

Samples of *Hypnea musciformis* were collected in July 2006 from Kaimana Beach Park in Honolulu, Oahu (an urbanized area with blooms of *H. musciformis* and *Ulva lactuca*) and transported to the University of Hawai'i, Mānoa. Samples ($n = 3$ per treatment) were blotted with a towel to remove excess water, trimmed to weigh ~0.400 g, and assessed for initial photosynthetic status with Pulse Amplitude Modulated fluorometry (PAM; see Section 2.3) and pigment composition with *in vivo* absorbance spectra (Shimadzu UV Vis-2101 spectrophotometer with a Shimadzu 150 mm integrating sphere attachment for macroalgal tissues 0.5 cm × 1.0 cm in dimension; Beach et al., 2000). Samples were transported to the Anuenue aquaculture facility (in Honolulu), and randomly placed in 1.0 L glass beakers ($n = 1$ per beaker) with individual aerators. Beakers were housed in a shaded (maximum light levels of 500 μmol m^{-2} s^{-1} PAR, measured with a 4π quantum LiCor light sensor) open air tank with a running seawater bath to prevent the treatment waters from heating. Samples were subjected to one of four treatments for seven days: no addition, +P (~4.5 μmol PO_4^{3-}), +N (~300 μmol NH_4^+) and +N+P (~300 μmol NH_4^+ and ~4.5 μmol PO_4^{3-}). N concentrations were chosen based on levels reported for blooms of *H. musciformis* and *U. lactuca* on Maui (277 DIN; Hunt and Rosa, 2009). P concentrations were based on previous saturation experiments (6–12 μ mol PO_4^{3-}; Björnsäter and Wheeler, 1990). Treatment waters in each 1.0 L beaker were changed daily to maintain nutrient concentrations. Water samples were collected ($n = 3$ per treatment) to verify nutrient additions on days 0 and 7. On the seventh day, samples were assessed for final photosynthetic status with PAM fluorometry (see Section 2.3), weighed, transported to the University of Hawai'i, Mānoa, and analyzed for final pigment composition with *in vivo* absorbance. Growth data are expressed as specific growth rates (% d^{-1}), calculated as follows, with biomass (N) in g and time (t) in days (Lobban and Harrison, 1994):

$$\mu = \frac{100[\ln(N_{final}/N_{initial})]}{t} \quad (1)$$

2.2. Main experiment: responses of Acanthophora spicifera, Dictyota acutiloba, Hypnea musciformis, and Ulva lactuca to a gradient of wastewater effluent

This study was conducted on the following four species during the corresponding month in 2008 at the University of Hawai'i, Lahaina field station on Maui: *Acanthophora spicifera* (September), *Dictyota acutiloba* (October), *Hypnea musciformis* (June), and *Ulva lactuca* (July). Prior to experimental trials, all species were acclimated to low N seawater from Olowalu (a rural area that currently has no anthropogenic nutrient sources) (Fig. 1) to deplete potential internal N stores. Algal samples were collected from Waipuilani Beach Park, transported to the Lahaina field station and randomly placed in 1.0 L beakers with individual aerators ($n = 1$ per beaker) in a shaded (maximum light levels *ca* 500 μ mol m^{-2} s^{-1} PAR, measured with a 4π quantum LiCor light sensor) outdoor aquarium system in water baths to prevent the seawater from heating. Low N acclimation occurred for seven days (Fong et al., 1994), during which the seawater in each beaker was changed every two days.

Low N acclimated samples were assessed for initial photosynthetic status with Pulse Amplitude Modulated fluorometry (PAM; see Section 2.3), blotted with a towel to remove excess water, trimmed to weigh ~0.400 g, photographed, and added to one of the following seven treatments ($n = 6$ per treatment): (1) no addition and wastewater effluent additions of (2) 25 ml (2.5%), (3) 50 ml (5.0%), (4) 75 ml (7.5%), (5) 100 ml (10.0%), (6) 150 ml (15.0%), and (7) 200 ml (20.0%) to create a final volume of 1.0 L. Each sample was housed in a 1.0 L beaker provided with an aerator in the abovementioned Lahaina field station aquarium system. The wastewater effluent was a clear liquid obtained at the beginning of each trial from the Lahaina Wastewater Reclamation Facility where it was secondarily treated and disinfected with chlorine. All treatment waters were changed daily with (1) low N water from Olowalu, (2) the corresponding addition of wastewater effluent, and (3) the appropriate addition of natural sea salt to maintain a constant and representative salinity (35‰; confirmed with a 7-Multi conductivity meter model 8603, Mettler-Toledo, Switzerland, calibrated with Mettler-Toledo conductivity standards). Based on the observations of Naldi and Wheeler (2002) that *U. fenestra* and *Gracilaria pacifica* had the highest growth response to increased nutrients over the first nine days and the preliminary observations of *H. musciformis* in low N conditions for seven days; we elected to run trials for nine days in an attempt to observe a physiologically complete response of the algae to the nutrient gradient. On the ninth day, samples were assessed for final photosynthetic status with PAM fluorometry (see Section 2.3) weighed, and photographed. All growth data are expressed as specific growth rates (% d^{-1}) (Eq. (1)).

2.3. Photosynthetic measurements

Samples were assessed for photosynthetic status with Pulse Amplitude Modulated (PAM) fluorometry (Diving PAM, Walz), which measures *in vivo* chlorophyll fluorescence. Measurements occurred between 1100 h and 1500 h to minimize variation associated with diurnal changes of photosynthetic activity. Rapid Light Curves (RLCs) were used to determine the following photosynthetic parameters (1) relative maximum Electron Transport Rate ($rETR_{max}$; maximum photosynthetic capacity), (2) α, the slope of the light limited region of the curve (proportional to the efficiency of light capture), and (3) minimum photosynthetic saturation irradiance (E_k; optimal irradiance for maximal electron transport), which is determined by finding the interception of α with the maximum photosynthetic rate ($E_k = rETR_{max}/\alpha$) (Ralph and Gademann, 2005). PAM was used to assess samples while connected to a laptop to provide instantaneous observations of the RLCs. The actinic light factor was adjusted to the photosynthetic capacity of the sample to obtain RLCs prior to photoinhibition. All photosynthetic parameters were calculated with the methods provided by Platt et al. (1980), which resulted in reliable parameter estimates (<0.5% variation attributable to error).

2.4. Nutrient concentrations and uptake rates

Nutrient uptake rates were determined over a 24 h period from day eight to nine to obtain rates that would be applicable to ongoing blooms of *Hypnea musciformis* and *Ulva lactuca*. For all species, uptake rates were determined for total organic carbon (TOC), total nitrogen (TN), nitrate (NO_3^-), and nitrite (NO_2^-). For *H. musciformis* and *U. lactuca* additional uptake rates were determined for total phosphorus (TP), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). On days eight and nine, algal samples ($n = 3$ per treatment) were weighed and corresponding water samples were collected with sterile syringes (prior to the return of the algal sample on day eight), filtered through sterile 0.45 μm nylon filters into acid washed bottles and frozen. Frozen water samples were sent to the Analytical Laboratory, University of Hawai'i, Hilo and analyzed with the following instrumentation for the corresponding nutrients: Nutrient AutoAnalyzer, NO_3^- and NO_2^- (Marti and Hale, 1981); Shimadzu TOC/TN, TOC and TN; Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES), TP, Cu, Fe, Mn, Mo, and Zn (Garbarino et al., 1989). TP was measured instead of soluble reactive P because it is applicable to the State of Hawai'i water quality standards. All quality assurance indicators were acceptable (standard curves, lab spikes, certified reference materials, and digestion spikes). Nutrient uptake rates ($g^{-1}\,d^{-1}$) and % change in the nutrient concentrations were calculated as:

$$\text{uptake of nutrient } X = \frac{(X_{D8} - X_{D9})/N_{D9}}{t} \quad (2)$$

$$\%\text{ change nutrient } X = \frac{X_{D8} - X_{D9}}{X_{D8}} \times 100 \quad (3)$$

where X_{D8} = concentration of nutrient X on day eight; X_{D9} = concentration of nutrient X on day nine; N_{D9} = biomass of the algal sample on day nine; t = 1 day.

2.5. % tissue N and $\delta^{15}N$ values of Hypnea musciformis and Ulva lactuca

Samples of *Hypnea musciformis* and *Ulva lactuca* ($n = 3$ per species per condition/treatment) were prepared for the analysis of % tissue N and $\delta^{15}N$ on the day of field collection (initial bloom levels), the first day of the experimental trials (low N acclimated) and on the ninth day of exposure to wastewater effluent additions. Samples were dried at 60 °C to a constant weight, ground with mortar and pestle into a powder, and sent for mass spectrometer analysis of % tissue N and $\delta^{15}N$ to the Biogeochemical Stable Isotope Laboratory, University of Hawai'i, Mānoa. Samples were weighed then analyzed with a Carlo Erba NC 2500 Elemental Analyzer, Finnigan MAT ConFloII, and Finnigan MAT DeltaS (with source upgrade). Ratios of ^{15}N:^{14}N were expressed relative to atmospheric N and calculated as (Peterson and Fry, 1987):

$$\delta^{15}N(‰) = \left\{\frac{R_{sample}}{R_{standard}} - 1\right\} \times 10^3, \quad \text{where } R = \frac{^{15}N}{^{14}N} \quad (4)$$

2.6. Statistical analyses

Preliminary experiment: *T*-tests were used to determine if there were significant differences in nutrient concentrations between the no addition and enrichment treatments. All data were normally distributed and displayed homogeneity of variances. Growth rates (% d^{-1}) were analyzed with a one-way ANOVA. A two-way ANOVA with treatment and day as predictive factors was performed on the initial and final values of $rETR_{max}$, α, E_k, PC, and PE. If a significant result was obtained for the two-way ANOVA, a Tukey's *post hoc* multiple comparisons test was performed to assess differences in final values for each variable between treatments.

Main experiment: All data were normally distributed and displayed homogeneity of variances. Data were examined with regressions (simple, power, and hyperbolic where appropriate) with % wastewater effluent addition and concentrations of total nitrogen (TN) and nitrate (NO_3^-) as predictor variables. TN and NO_3^- concentrations were selected from the other nutrients because they increased the most with increasing wastewater effluent addition for all trials and provide information that is applicable to management officials. The following dependent variables were regressed with % wastewater effluent addition and concentrations of TN and NO_3^-: (1) growth rate (% d^{-1}), $rETR_{max}$, E_k, and α, for all species, and (2) % tissue N and $\delta^{15}N$ values of *Hypnea musciformis* and *Ulva lactuca*. *T*-tests were used to determine significant differences in: (1) initial and final α values of *U. lactuca* in the no addition, (2) day nine wet weights between the no addition and wastewater effluent additions, (3) day eight water chemistry and nutrient uptake rates between the no addition and additions of wastewater effluent, and (4) % tissue N and $\delta^{15}N$ values between field and low N acclimated samples of *H. musciformis* and *U. lactuca*. Statistics were performed with Statistica 6.0 and SigmaPlot 9.0.

3. Results

3.1. Preliminary experiment: response of Hypnea musciformis to N and P enrichment

The nutrient additions significantly increased the concentration of the nutrient provided compared to the no addition (NA) (Table 1). Significant effects (ANOVA, $F = 8.46$, $P = 0.007$) were found between growth rate and nutrient treatment. Growth rates (% d^{-1}) in the +P treatment were significantly lower than those in the +N and +N+P treatments. NA growth rates were statistically similar to all nutrient treatments (Table 1). A significant interaction (two-way ANOVA, $F = 6.52$, $P < 0.00001$) was found with day by treatment. Significant increases in E_k occurred in all treatments (Table 1), the highest E_k values (193 ± 2.8) were

Table 1
Hypnea musciformis nutrient enrichment concentrations (average of initial and final per treatment), growth rate (GR, % d^{-1}), and initial and final values of: photosynthetic capacity ($rETR_{max}$), light capturing efficiency (α), photosynthetic saturation irradiance (E_k), phycoerythrin (PE, 563:680 nm), and phycocyanin (PC, 625:680 nm) (means ± SE). Significant differences between (1) the no addition and nutrient concentration and (2) initial and final values are in bold. Significant ($P < 0.01$) differences in final values between treatments are represented by different letters.

	No Addition	+P	+N	+N+P
NH_4^+ (μM)	0.48 ± 0.22	0.53 ± 0.12	325 ± 34.2**	300 ± 30.5**
PO_4^{-3} (μM)	0.07 ± 0.02	4.6 ± 0.2***	0.12 ± 0.03	4.6 ± 0.1***
GR (% d^{-1})	9.51 ± 0.4[a,b]	8.28 ± 0.2[b]	11.0 ± 0.2[a]	11.2 ± 0.3[a]
$rETR_{max}$				
Initial	27.5 ± 2.0	28.5 ± 4.3	30.6 ± 2.6	26.7 ± 0.5
Final	45.0 ± 0.7	46.1 ± 1.9	39.7 ± 0.6	52.6 ± 0.8**
α				
Initial	0.40 ± 0.02	0.38 ± 0.03	0.40 ± 0.01	0.44 ± 0.02
Final	0.34 ± 0.01	0.33 ± 0.01	0.30 ± 0.02	0.27 ± 0.01*
E_k				
Initial	68.3 ± 3.6	73.4 ± 7.4	77.2 ± 7.7	62.0 ± 2.2
Final	132 ± 5.6**[a]	139 ± 4.0**[a]	133 ± 6.3*[a]	193 ± 2.8***[b]
PE				
Initial	0.98 ± 0.01	0.97 ± 0.003	0.96 ± 0.003	0.98 ± 0.001
Final	0.69 ± 0.03***[a]	0.77 ± 0.02***[a]	0.99 ± 0.001[b]	1.0 ± 0.002[b]
PC				
Initial	0.78 ± 0.01	0.77 ± 0.01	0.77 ± 0.01	0.80 ± 0.01
Final	0.58 ± 0.01***[a]	0.63 ± 0.01***[a]	0.79 ± 0.004[b]	0.82 ± 0.004[b]

* $P < 0.05$.
** $P < 0.005$.
*** $P < 0.0005$.

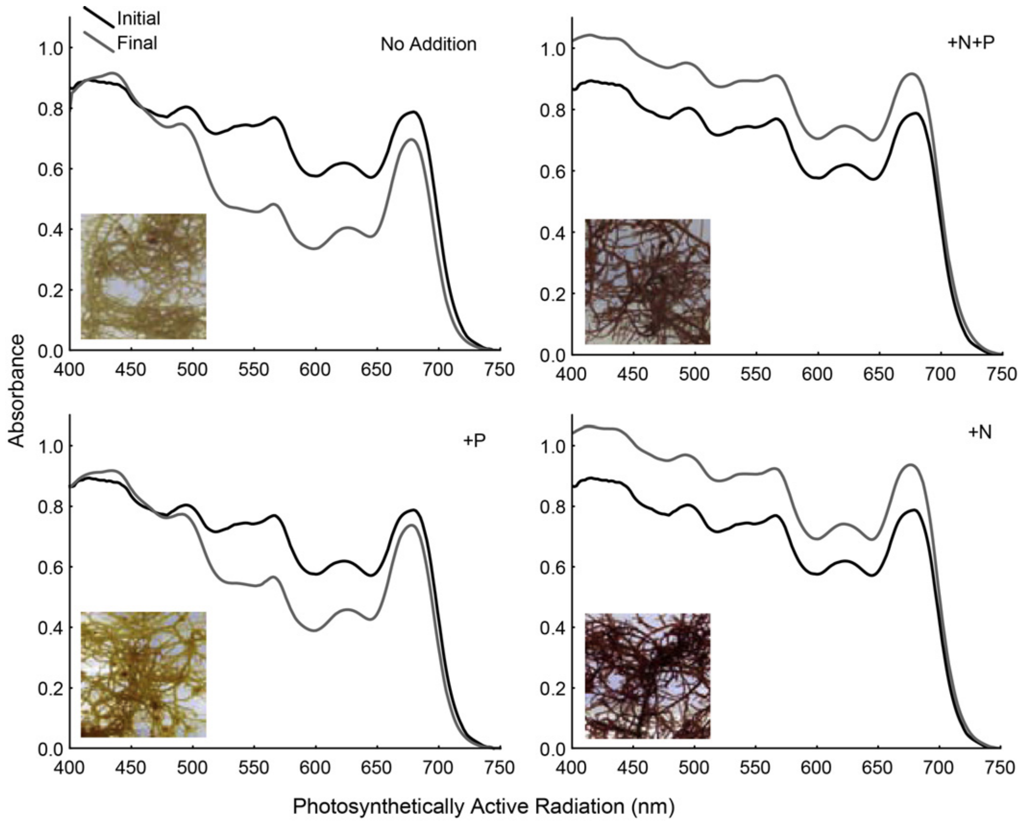


Fig. 2. Initial (black lines) and final (gray lines) *in vivo* absorbance spectra and final photographs of *Hypnea musciformis* in the no addition and enrichment treatments of +P, +N, and +N+P.

observed in the +N+P treatment and were significantly higher than all other treatments (Table 1). Samples in the +N+P treatment also had the only significant increase in $rETR_{max}$ (Table 1). Final *in vivo* absorbance spectra showed that samples in the NA and +P treatments had decreased absorbance levels in the spectra range for phycoerythrin (PE, 563 nm) and phycocyanin (PC, 625 nm) (Fig. 2). Final values of PE and PC absorbance normalized to chlorophyll *a* (680 nm) were significantly decreased from initial values in the NA and +P treatments (Table 1). These values were also significantly lower than those of samples provided with N additions, where no change in PE or PC absorbance occurred (Fig. 2, Table 1).

3.2. Main experiment: response of Acanthophora spicifera, Dictyota acutiloba, Hypnea musciformis, and Ulva lactuca to a gradient of wastewater effluent

3.2.1. Visual and growth response

In nine days, samples of *Acanthophora spicifera*, *Dictyota acutiloba*, *Hypnea musciformis*, and *Ulva lactuca* visibly responded to the gradient of wastewater effluent (and associated increasing concentrations of TN and NO_3^-) with darkened coloration, while no change was observed in the no addition (Fig. 3). No significant relationship was found between the growth rates (% d^{-1}) of *A. spicifera* and increasing % wastewater effluent addition (Fig. 4) or TN concentration (Table 2); however a weak but significant relationship was found with increasing NO_3^- concentration (Table 2). Significant relationships were found between the growth rates of *D. acutiloba*, *H. musciformis*, and *U. lactuca* and increasing % wastewater effluent addition (Fig. 4) and concentrations of TN and NO_3^- (Table 2). The highest growth rates observed were those of *H. musciformis* ($15.8 \pm 0.37\%$ d^{-1}) and *U. lactuca* ($15.5 \pm 0.34\%$ d^{-1}) in wastewater effluent additions of 20.0% and 10.0%, respectively. These growth rates were about 2-fold higher than the highest rates observed of *A. spicifera* ($6.60 \pm 0.40\%$ d^{-1}) and *D. acutiloba* ($7.41 \pm 0.11\%$ d^{-1}), which occurred in wastewater effluent additions of 7.5% and 20.0%, respectively. The lowest growth rates of *H. musciformis* ($3.89 \pm 0.16\%$ d^{-1}) and *U. lactuca* ($4.28 \pm 0.20\%$ d^{-1}) occurred in the no addition. The growth rate of *H. musciformis* depleted of N stores then placed in the no addition was nearly 3-fold lower than that of the no addition in the preliminary experiment ($9.50 \pm 0.41\%$ d^{-1}) and 5-fold lower than treatments with $\geq$10.0% wastewater effluent ($\sim$15% d^{-1}).

3.2.2. Photosynthetic response

The final $rETR_{max}$ values of all species significantly increased with increasing % wastewater effluent addition (Fig. 5a–d) and concentrations of TN and NO_3^- (Table 2). The highest observed $rETR_{max}$ values were those of *Acanthophora spicifera* (67.8 ± 4.67) and *Ulva lactuca* (90.8 ± 3.32) in wastewater effluent additions of 15.0% and 20.0%, respectively. No significant relationships were found between the final α values of *A. spicifera*, *Dictyota acutiloba*, and *Hypnea musciformis* and increasing % wastewater effluent addition (Fig. 5e–g) and concentrations of TN and NO_3^- (Table 2). Significant relationships were found between the final α values of *U. lactuca* with increasing % wastewater effluent addition (Fig. 5h) and concentrations of TN and NO_3^- (Table 2). These significant relationships were primarily due to a significant decline in α (initial: 0.274 ± 0.006, final: 0.172 ± 0.013, $P < 0.01$) in the no addition. Significant relationships were found between the final minimum photosynthetic saturation irradiance (E_k) values of *A. spicifera*, *D. acutiloba*, and *H. musciformis* and increasing % wastewater effluent addition (Fig. 5i–k) and concentrations of TN and NO_3^- (Table 2). The highest final E_k values observed were those of *U. lactuca* in the highest addition of wastewater effluent (346 ± 22.1) and in the no addition (322 ± 19.8) (Fig. 5l). However, the high final E_k values of *U. lactuca* in the no addition were the product of the decline in α rather than an

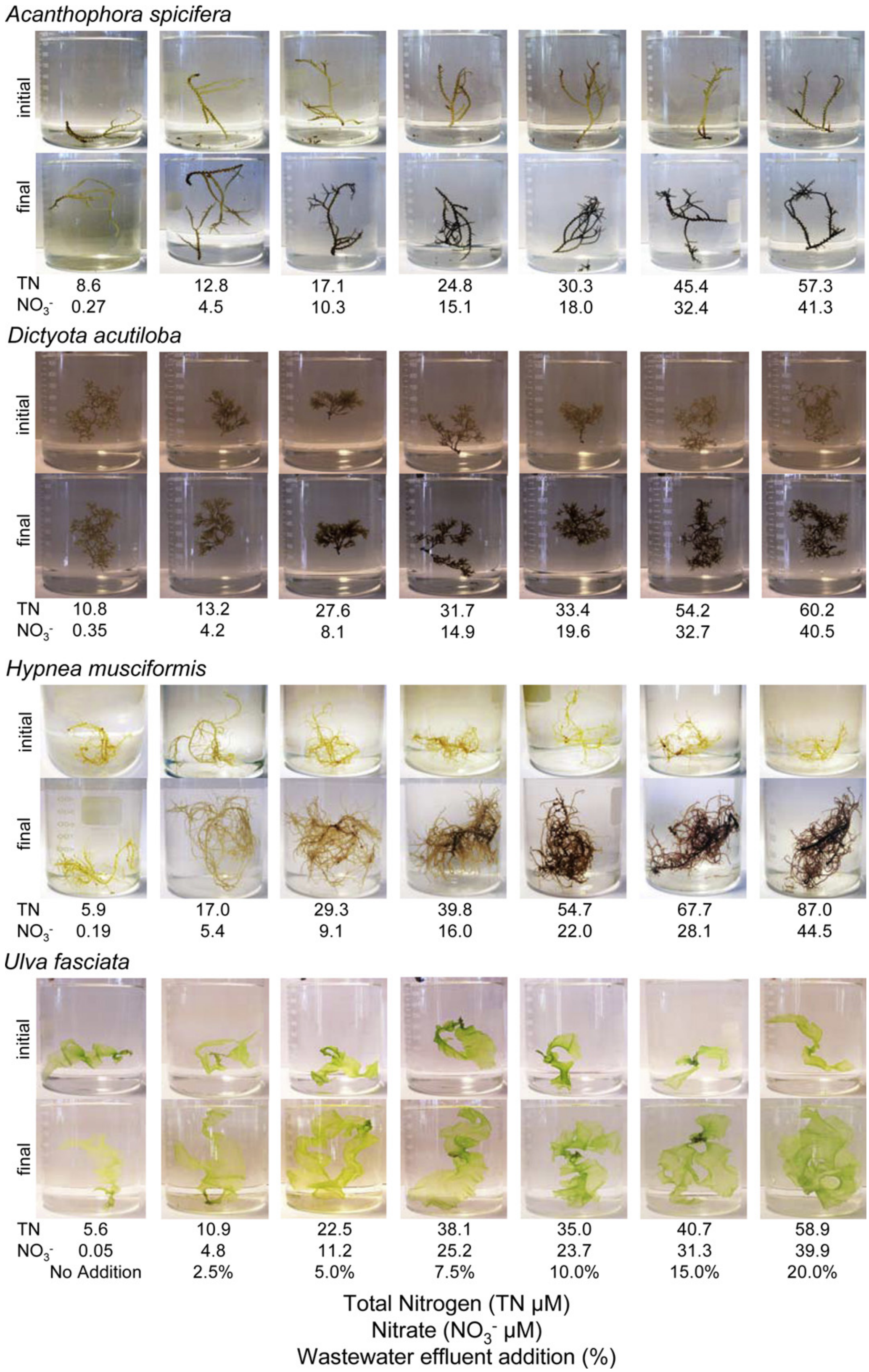


Fig. 3. Initial and final photographs of *Acanthophora spicifera*, *Dictyota acutiloba*, *Hypnea musciformis*, and *Ulva lactuca* with day 8 total nitrogen (TN) and nitrate (NO_3^-) concentrations (μM) for each addition of wastewater effluent (%).

increase in minimum photosynthetic saturation irradiance from initial values. E_k is calculated by dividing $rETR_{max}$ by α and samples in the no addition on day 9 had unchanged $rETR_{max}$ values (initial: 53.2 ± 3.09, final: 54.7 ± 2.89); therefore the decline in α consequently produced misleading, higher E_k values. However, this was the only situation where the calculation of E_k was misleading; therefore, we support the view that using RLCs to assess the photosynthetic status of samples is a successful, robust method.

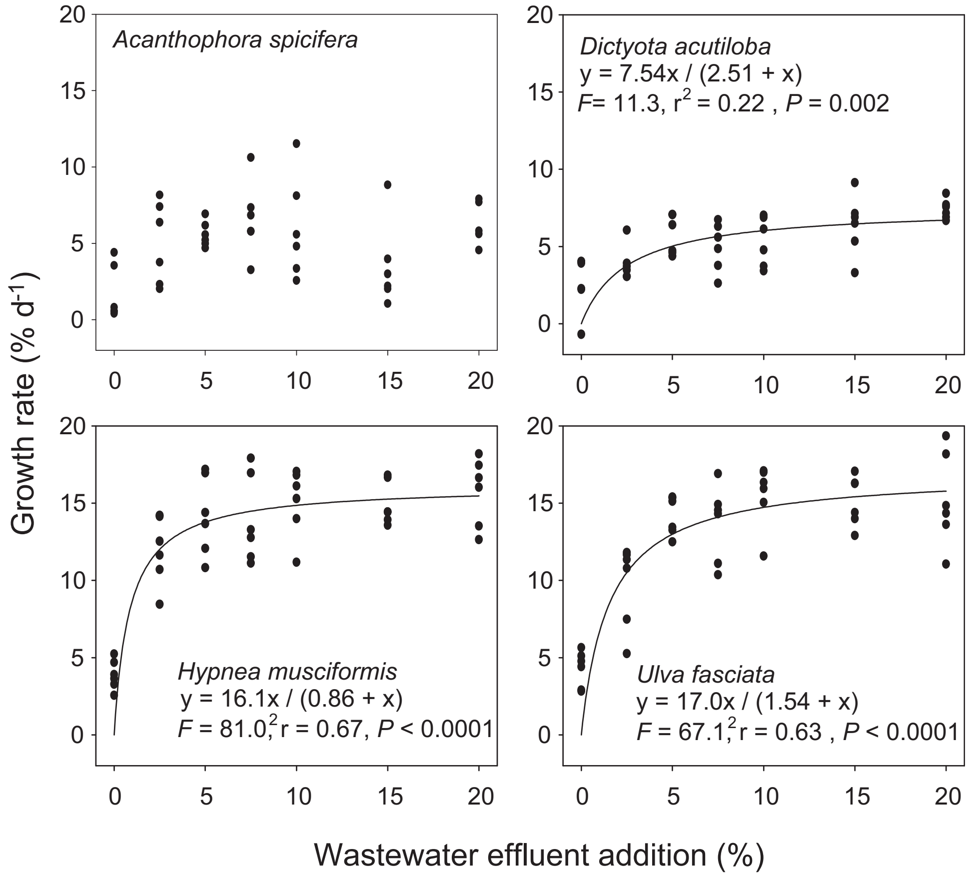


Fig. 4. Growth rate (% d^{-1}) responses of *Acanthophora spicifera*, *Dictyota acutiloba*, *Hypnea musciformis*, and *Ulva lactuca* to increasing wastewater effluent addition (%).

Table 2
Results for *Acanthophora spicifera*, *Dictyota acutiloba*, *Hypnea musciformis*, and *Ulva lactuca* from simple, power, and hyperbolic regression analyses with total nitrogen (TN) and nitrate (NO_3^-) concentration as the predictor variable for growth rate (GR, % d^{-1}), photosynthetic capacity ($rETR_{max}$), light capturing efficiency (α), and photosynthetic saturation irradiance (E_k). *H. musciformis* and *U. lactuca* relationships for % tissue N (% N) and $\delta^{15}N$ values are also presented. Dashed lines represent no significant relationship.

		Acanthophora spicifera				*Dictyota acutiloba*			
		Eq.	*F*	r^2	*P*	Eq.	*F*	r^2	*P*
TN	GR (% d^{-1})	–	–	–	–	$y = 9.79x/(24.8 + x)$	38.5	0.49	<0.0001
	$rETR_{max}$	$y = 14.7x^{0.39}$	25.5	0.44	<0.0001	$y = 30.9 + 27x$	8.51	0.21	0.006
	α	–	–	–	–	–	–	–	–
	E_k	$y = 64.1x^{0.33}$	27.3	0.45	<0.0001	$y = 58.3x^{0.21}$	7.55	0.19	0.010
NO_3^-	GR (% d^{-1})	$y = 5.41x/(0.48 + x)$	7.95	0.17	0.007	$y = 3.09x^{0.22}$	36.0	0.47	<0.0001
	$rETR_{max}$	$y = 30.4x^{0.22}$	34.1	0.51	<0.0001	$y = 34.1 + 0.33x$	7.76	0.19	0.009
	α	–	–	–	–	–	–	–	–
	E_k	$y = 121.9x^{0.18}$	35.7	0.52	<0.0001	$y = 101.2 + 1.03x$	6.84	0.17	0.013
		Hypnea musciformis				*Ulva fasciata*			
		Eq.	*F*	r^2	*P*	Eq.	*F*	r^2	*P*
TN	GR (% d^{-1})	$y = 18.5x/(12.6 + x)$	108.7	0.73	<0.0001	$y = 19.5x/(12.2 + x)$	103.6	0.72	<0.0001
	$rETR_{max}$	$y = 28.7 + 0.30x$	29.9	0.48	<0.0001	$y = 51.4 + 0.66x$	34.8	0.51	<0.0001
	α	–	–	–	–	$y = 0.15x^{0.18}$	20.4	0.38	<0.0001
	E_k	$y = 124.1 + 1.48x$	39.7	0.55	<0.0001	–	–	–	–
	%N	$y = 3.14x/(17.1 + x)$	25.3	0.57	<0.0001	$y = 0.516 + 0.03x$	135.2	0.88	<0.0001
	$\delta^{15}N$	$y = 31.x/(14.8 + x)$	505.5	0.96	<0.0001	$y = 41.5x/(19.8 + x)$	201.7	0.91	<0.0001
NO_3^-	GR (% d^{-1})	$y = 15.2x/(0.74 + x)$	128.4	0.76	<0.0001	$y = 7.93x^{0.19}$	116.3	0.74	<0.0001
	$rETR_{max}$	$y = 31.1 + 0.60x$	34.6	0.51	<0.0001	$y = 55.5 + 0.81x$	30.0	0.48	<0.0001
	α	–	–	–	–	$y = 0.22x^{0.09}$	40.6	0.55	<0.0001
	E_k	$y = 137.1 + 2.82x$	41.7	0.56	<0.0001	–	–	–	–
	%N	$y = 1.24x^{0.20}$	20.9	0.52	0.0002	$y = 0.66 + 0.04x$	215.8	0.92	<0.0001
	$\delta^{15}N$	$y = 12.4x^{0.21}$	306.6	0.94	<0.0001	$y = 11.7x^{0.26}$	536.7	0.97	<0.0001

3.2.3. Nutrient concentrations, final wet weights, and uptake rates

In all trials, significant increases in N concentrations of day 8 water samples occurred with increasing additions of wastewater effluent for total nitrogen (TN), nitrate (NO_3^-), and nitrite (NO_2^-; with the exception of the *Acanthophora spicifera* trial, where NO_2^- was not detected) (Tables 3–5). The day 8 water chemistry for the *Hypnea musciformis* and *Ulva lactuca* trials also had significant increases in concentrations of total phosphorous (TP)

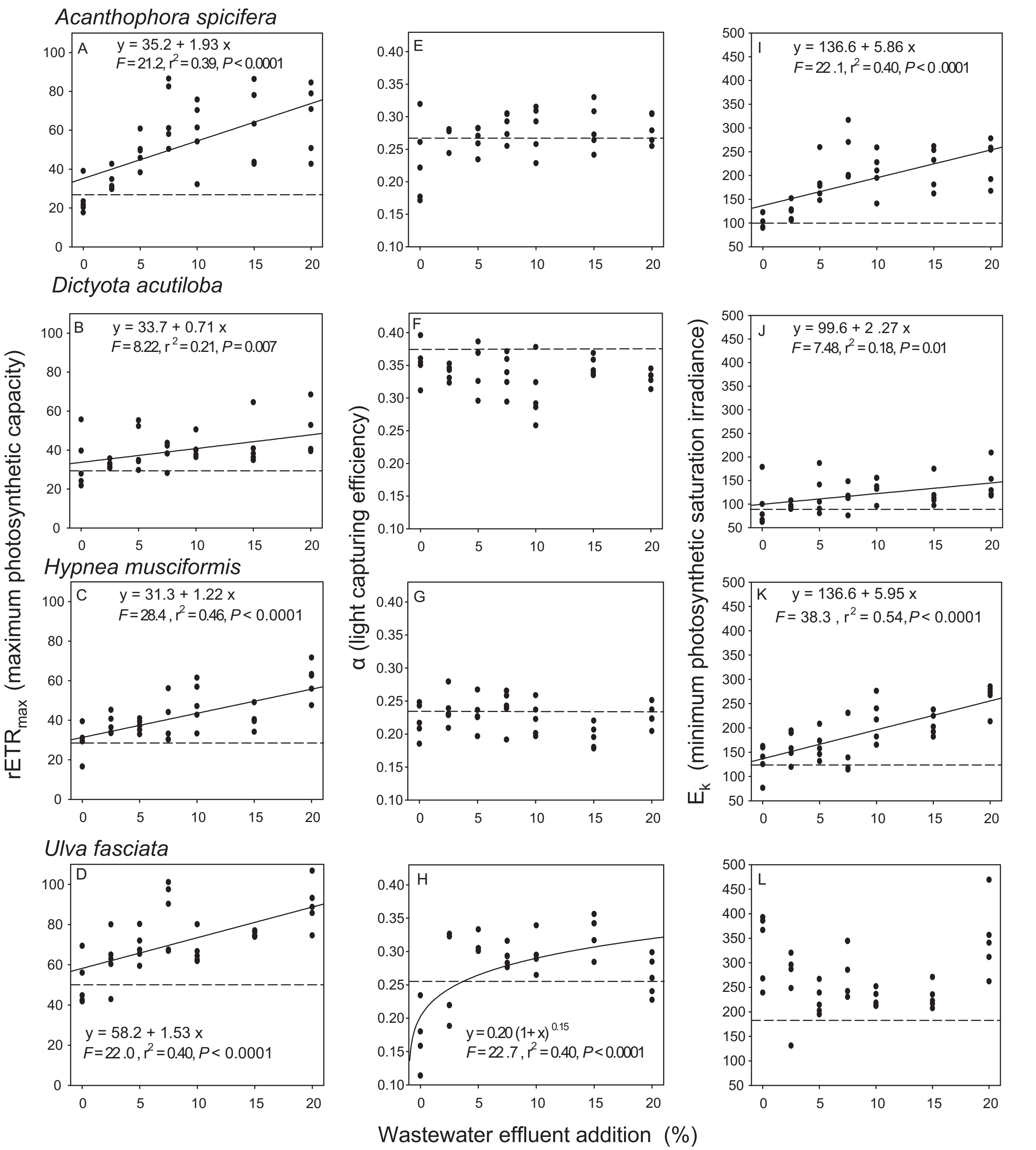


Fig. 5. Final photosynthetic parameters $rETR_{max}$ (a–d), α (e–h) and E_k (i–l) for *Acanthophora spicifera*, *Dictyota acutiloba*, *Hypnea musciformis*, and *Ulva lactuca* in response to increasing wastewater effluent addition (%); dashed lines represent average initial values.

(*H. musciformis* trial only), iron (Fe), and manganese (Mn) with increasing additions of wastewater effluent (Tables 4 and 5). No significant difference was found between the no addition and additions of wastewater effluent in day 8 nutrient concentrations of copper (Cu), molybdenum (Mo), and zinc (Zn) (Tables 4 and 5). In the *U. lactuca* trial, TP was only detected in the two highest treatments, Cu was detected in 4 treatments, and Mo and Zn were not detected in any treatment (Table 5).

Significant differences in final wet weights of *Acanthophora spicifera* and *Dictyota acutiloba* were found between the no addition and wastewater effluent additions of 2.5–10.0% and 5.0–20.0%, respectively (Table 3). Significant differences were found in the final wet weights of *Hypnea musciformis* and *Ulva lactuca* between the no addition and all wastewater effluent additions (Tables 4 and 5). Furthermore, the final wet weights of *H. musciformis* and *U. lactuca* in the no addition (0.56 ± 0.03 and 0.56 ± 0.01, respectively) were 2-fold lower than those provided with the lowest wastewater effluent addition of 2.5% (1.19 ± 0.05 and 1.10 ± 0.03, respectively) (Tables 4 and 5). The highest final wet weights of *A. spicifera* (0.85 ± 0.08), *D. acutiloba* (0.78 ± 0.03), *H. musciformis* (1.73 ± 0.07),

Table 3
Final wet weight (ww), day 8 nutrient concentrations, nutrient uptake rates ($g^{-1} d^{-1}$) (means ± SE), and % change in nutrient concentration from day 8 to 9 per treatment for *Acanthophora spicifera* and *Dictyota acutiloba*. Significant differences between the no addition and wastewater effluent additions are in bold, n.d. = not detected.

	No addition	2.5%	5.0%	7.5%	10.0%	15.0%	20.0%
Acanthophora spicifera							
Final ww (g)	0.42 ± 0.01	**0.77 ± 0.02***	**0.70 ± 0.03****	**0.78 ± 0.06****	**0.85 ± 0.08***	0.63 ± 0.06	0.77 ± 0.03
Total organic carbon (TOC)							
Day 8 (μM)	128 ± 11	99.5 ± 6.9	90.8 ± 2.6	112 ± 7.6	190 ± 41	126 ± 3.7	157 ± 2.7
TOC uptake ($\mu M g^{-1} d^{-1}$)	−0.71 ± 40	−25.0 ± 16	−25.6 ± 3.7	−44.8 ± 6.6	16.1 ± 16	−45.7 ± 17	−24.3 ± 15
% Change	−6.67	−24.2	−20.8	−33.4	−0.24	−24.1	−11.3
Total nitrogen (TN)							
Day 8 (μM)	8.6 ± 0.2	**12.8 ± 0.5***	**17.1 ± 0.5****	**24.8 ± 0.9****	**30.3 ± 1.8****	**45.4 ± 1.1*****	**57.3 ± 0.8*****
TN uptake ($\mu M g^{-1} d^{-1}$)	−2.2 ± 1.2	2.3 ± 0.8	**7.9 ± 0.5***	4.8 ± 2.5	**15.5 ± 0.3****	**36.9 ± 2.4****	**32.5 ± 1.7*****
% Change	−13.0	13.9	32.1	15.3	44.7	51.1	43.6
Nitrate (NO_3^-)							
Day 8 (μM)	0.27 ± 0.11	**4.5 ± 0.03*****	**10.3 ± 0.3*****	**15.1 ± 0.2*****	**18.0 ± 1.0*****	**32.4 ± 0.4*****	**41.3 ± 0.2*****
NO_3^- uptake ($\mu M g^{-1} d^{-1}$)	0.21 ± 0.07	**5.6 ± 0.1*****	**14.7 ± 0.4*****	**19.1 ± 0.4*****	**20.8 ± 1.1*****	**42.4 ± 3.9****	**31.8 ± 0.8*****
% Change	57.8	94.3	98.7	98.7	98.9	81.6	59.4
Dictyota acutiloba							
Final ww (g)	0.53 ± 0.02	0.53 ± 0.01	**0.67 ± 0.01***	**0.71 ± 0.02***	**0.64 ± 0.02***	**0.72 ± 0.01***	**0.78 ± 0.03*****
Total organic carbon (TOC)							
Day 8 (μM)	111 ± 10	128 ± 8.8	162 ± 37	150 ± 9.6	254 ± 45	149 ± 47	173 ± 9.2
TOC uptake ($\mu M g^{-1} d^{-1}$)	−185 ± 31	−90.1 ± 28	−148 ± 111	−157 ± 68	**178 ± 64***	25.6 ± 38	**−14.2 ± 14***
% Change	−86.9	−41.6	−110	−66.2	30.4	3.64	−7.81
Total nitrogen (TN)							
Day 8 (μM)	10.8 ± 1.2	13.2 ± 0.5	27.6 ± 3.6	31.7 ± 5.0	**33.4 ± 2.4****	**54.2 ± 2.0*****	**60.2 ± 1.4*****
TN uptake ($\mu M g^{-1} d^{-1}$)	−1.97 ± 2.8	6.6 ± 2.8	16.4 ± 5.7	**17.7 ± 0.5***	19.2 ± 8.0	**56.2 ± 4.2****	**58.9 ± 1.6*****
% Change	−21.0	28.5	32.9	45.0	42.2	76.1	76.1
Nitrate (NO_3^-)							
Day 8 (μM)	0.35 ± 0.03	**4.2 ± 0.3****	**8.1 ± 0.5*****	**14.9 ± 0.5*****	**19.6 ± 0.9*****	**32.7 ± 0.7*****	**40.5 ± 0.6*****
NO_3^- uptake ($\mu M g^{-1} d^{-1}$)	0.09 ± 0.03	**6.8 ± 1.2***	**11.9 ± 0.5****	**20.8 ± 0.8*****	**29.5 ± 0.9*****	**45.1 ± 1.2*****	**50.6 ± 0.9*****
% Change	42.2	80.0	97.8	98.0	96.8	99.4	97.0
Nitrite (NO_2^-)							
Day 8 (μM)	n.d.	**0.47 ± 0.05****	**0.90 ± 0.06****	**1.72 ± 0.09*****	**2.2 ± 0.1*****	**3.9 ± 0.1*****	**4.8 ± 0.1*****
NO_2^- uptake ($\mu M g^{-1} d^{-1}$)	–	**0.89 ± 0.09****	**1.35 ± 0.10*****	**2.4 ± 0.1*****	**3.4 ± 0.2*****	**5.3 ± 0.1*****	**4.4 ± 0.5*****
% Change	–	100	100	100	100	100	100

* $P < 0.05$.
** $P < 0.005$.
*** $P < 0.0005$.

and *U. lactuca* (1.40 ± 0.11) were observed in treatments of 10.0–20.0% (Tables 3–5).

TN uptake rates of *Acanthophora spicifera*, *Hypnea musciformis*, and *Ulva lactuca* in treatments ≥5.0% wastewater effluent were significantly increased from those of the no addition (Tables 3–5). The highest TN uptake rates ($\mu mol\ TN\ g^{-1} d^{-1}$) of *A. spicifera* (36.9 ± 2.40), *Dictyota acutiloba* (58.9 ± 1.56), *H. musciformis* (28.1 ± 3.84), and *U. lactuca* (31.4 ± 3.44) were observed in wastewater effluent additions of 15.0–20.0% (Tables 3–5). The % change in TN for all species was lower than 100%. NO_3^- uptake rates of all species in treatments ≥2.5% wastewater effluent were significantly increased from those of the no addition and *U. lactuca* removed 100% of NO_3^- in all treatments (Tables 3–5). The highest NO_3^- uptake rates ($\mu mol\ NO_3^-\ g^{-1} d^{-1}$) of *A. spicifera* (42.4 ± 3.90), *D. acutiloba* (50.6 ± 0.91), *H. musciformis* (24.9 ± 2.81), and *U. lactuca* (28.5 ± 0.21) occurred in wastewater effluent additions of 15.0–20.0% (Tables 3–5). *H. musciformis* removed 100% of TP, Fe, Mo, and Zn in all treatments (with the exception of Fe in the 10.0% wastewater effluent addition and Mo in the no addition) (Table 4). The highest Mn uptake rates of *H. musciformis* (5.79 ± 0.93 ppb $g^{-1} d^{-1}$) and *U. lactuca* (2.32 ± 0.73 ppb $g^{-1} d^{-1}$) occurred in wastewater effluent additions of 20.0% and 7.5%, respectively (Tables 4 and 5). Mn uptake rates of *H. musciformis* in wastewater effluent additions of 7.5, 10.0, and 20.0% were significantly higher than those of the no addition (Table 4). For all species, in all treatments, the total organic carbon concentrations of the incubation water generally increased from day 8 to 9 (Tables 3–5).

3.2.4. % tissue N and $\delta^{15}N$ values of Hypnea musciformis and Ulva lactuca

The low N acclimated % tissue N of *Hypnea musciformis* (1.02 ± 0.03) and *Ulva lactuca* (1.14 ± 0.29) were significantly ($P < 0.0001$) decreased from bloom levels (2.81 ± 0.70 and 3.31 ± 0.31, respectively). The final % tissue N of *H. musciformis* and *U. lactuca* significantly increased with increasing % wastewater effluent addition (Fig. 6) and concentrations of TN and NO_3^- (Table 2). The $\delta^{15}N$ values of *H. musciformis* and *U. lactuca* after low N acclimation and in the no addition were not significantly changed from initial bloom levels. The final $\delta^{15}N$ values of *H. musciformis* and *U. lactuca* significantly increased with increasing % wastewater effluent addition (Fig. 6) and concentrations of TN and NO_3^- (Table 2). The highest $\delta^{15}N$ values observed were those of *U. lactuca* (30.3 ± 0.3 ‰) in the highest wastewater effluent addition.

4. Discussion

Opportunistic macroalgae in the genus *Ulva* are known to form blooms in response to excess anthropogenic nutrients worldwide (Briand, 1989; Thom and Albright, 1990; Sfriso et al., 1993; Raffaelli et al., 1998; Menendez and Comin, 2000; Hu et al., 2010). Blooms of *Hypnea musciformis* have been documented in nutrient enriched areas of Florida (Avery, 1997; Lapointe and Bedford, 2007), but nutrient driven blooms consisting of both *H. musciformis* and *U. lactuca* have not been documented. This study shows that *H. musciformis* is an opportunistic macroalga capable of physiologically responding to excess nutrients at rates equal to the world renowned *Ulva* spp. in nearshore regions of Maui that are affected by anthropogenic nutrient enrichment.

4.1. N storage of Hypnea musciformis

The preliminary N and P experiment on *H. musciformis* confirmed that this species responds to high N conditions by

Table 4
Final wet weight (ww), day 8 nutrient concentrations, nutrient uptake rates ($g^{-1}\,d^{-1}$) (means ± SE), and % change in nutrient concentrations from day 8 to 9 per treatment for *Hypnea musciformis*. Significant differences between the no addition and wastewater effluent additions are in bold, n.d. = not detected.

	No addition	2.5%	5.0%	7.5%	10.0%	15.0%	20.0%
Final ww (g)	0.56 ± 0.03	**1.19 ± 0.05*****	**1.41 ± 0.08*****	**1.38 ± 0.07*****	**1.73 ± 0.07*****	**1.54 ± 0.08*****	**1.54 ± 0.11*****
Total organic carbon (TOC)							
Day 8 (μM)	69.8 ± 4.7	77.1 ± 1.2	73.8 ± 4.4	88.6 ± 3.6	**103 ± 1.0***	104 ± 21	**119 ± 4.9***
TOC uptake ($\mu M\,g^{-1}\,d^{-1}$)	−40.5 ± 13	−13.9 ± 0.9	−24.5 ± 5.5	−24.0 ± 2.3	−7.34 ± 2.7	−16.4 ± 6.5	−22.1 ± 6.2
% Change	−37.5	−21.6	−49.6	−36.8	−12.6	−28.7	−30.3
Total nitrogen (TN)							
Day 8 (μM)	5.9 ± 0.1	**17.0 ± 0.6*****	**29.3 ± 2.8****	**39.8 ± 2.3*****	**54.7 ± 2.0*****	**67.7 ± 17****	**87.0 ± 4.0*****
TN uptake ($\mu M\,g^{-1}\,d^{-1}$)	2.7 ± 0.2	**9.3 ± 0.3*****	**15.5 ± 2.0***	**23.0 ± 1.4****	**26.9 ± 1.1*****	**28.1 ± 3.8***	**25.7 ± 1.1*****
% Change	25.6	65.0	73.4	79.6	85.2	62.0	45.6
Nitrate (NO_3^-)							
Day 8 (μM)	0.19 ± 0.08	**5.4 ± 0.3*****	**9.1 ± 1.2***	**16.0 ± 1.0*****	**22.0 ± 1.0*****	**28.1 ± 7.2****	**44.5 ± 4.9****
NO_3^- uptake ($\mu M\,g^{-1}\,d^{-1}$)	−0.08 ± 0.12	**4.3 ± 0.3****	**6.1 ± 0.9***	**11.5 ± 0.8****	**12.4 ± 0.5*****	**16.4 ± 1.5****	**24.9 ± 2.8****
% Change	21.5	93.4	93.6	98.3	97.8	89.6	85.7
Nitrite (NO_2^-)							
Day 8 (μM)	n.d.	**7.2 ± 0.1*****	**12.6 ± 0.7*****	**19.6 ± 0.6*****	**31.0 ± 1.3*****	**40.8 ± 14****	**54.7 ± 2.2*****
NO_2^- uptake ($\mu M\,g^{-1}\,d^{-1}$)	–	**6.1 ± 0.04*****	**8.9 ± 0.5*****	**14.0 ± 0.5*****	**17.0 ± 0.7*****	**13.2 ± 3.3*****	**11.7 ± 0.3*****
% Change	–	100	99.7	98.3	94.7	43.4	33.2
Ammonium (NH_4^+)							
Day 8 (μM)	n.d.	0.90 ± 0.21	**1.6 ± 0.3***	**2.8 ± 0.4***	**5.9 ± 0.17*****	**8.1 ± 0.51*****	**7.8 ± 1.1***
NH_4^+ uptake ($\mu M\,g^{-1}\,d^{-1}$)	–	0.75 ± 0.17	**1.2 ± 0.2***	**2.0 ± 0.3***	**3.4 ± 0.1*****	**5.3 ± 0.3*****	**5.1 ± 0.7***
% Change	–	100	100	100	100	100	100
Total phosphorous (TP)							
Day 8 (μM)	0.29 ± 0.06	0.52 ± 0.06	**0.81 ± 0.04****	**1.0 ± 0.1****	**1.7 ± 0.04*****	**2.1 ± 0.3*****	**2.6 ± 0.1*****
TP uptake ($\mu M\,g^{-1}\,d^{-1}$)	0.34 ± 0.11	0.44 ± 0.05	0.58 ± 0.03	0.75 ± 0.04	**0.95 ± 0.02***	**1.3 ± 0.1***	**1.8 ± 0.03****
% Change	100	100	100	100	100	100	100
Copper (Cu)							
Day 8 (ppb)	0.99	2.2 ± 0.2	2.1 ± 0.2	1.86	1.7 ± 0.6	2.6 ± 1.7	**3.1 ± 0.3***
Cu uptake ($ppb\,g^{-1}\,d^{-1}$)	0.77	0.45 ± 0.05	−0.41 ± 0.09	0.04	0.41 ± 0.26	1.0 ± 0.54	0.70 ± 0.01
% Change	26.5	21.4	−31.3	2.59	39.0	46.3	33.7
Iron (Fe)							
Day 8 (ppb)	n.d.	**1.2 ± 0.1*****	1.68	**1.3 ± 0.1****	**1.7 ± 0.1****	**1.6 ± 0.4****	2.0 ± 0.06
Fe uptake ($ppb\,g^{-1}\,d^{-1}$)	–	**1.0 ± 0.04*****	1.19	**0.97 ± 0.07****	0.59 ± 0.18	**1.0 ± 0.1****	**1.3 ± 0.04*****
% Change	–	100	100	100	54.0	100	100
Manganese (Mn)							
Day 8 (ppb)	0.39 ± 0.06	**3.6 ± 0.5***	**5.4 ± 0.8***	**6.6 ± 0.2*****	**12.3 ± 0.2*****	**16.0 ± 3.2****	**22.8 ± 0.9*****
Mn uptake ($ppb\,g^{-1}\,d^{-1}$)	0.69 ± 0.11	2.7 ± 0.5	3.0 ± 0.6	**3.1 ± 0.4***	**5.5 ± 0.2*****	2.8 ± 1.2	**5.8 ± 0.9***
% Change	100	85.9	73.1	65.2	78.1	23.5	38.2
Molybdenum (Mo)							
Day 8 (ppb)	6.4 ± 0.2	**8.9 ± 0.3****	7.0 ± 0.5	6.3 ± 0.1	7.2 ± 0.3	5.4 ± 0.3	7.3 ± 0.3
Mo uptake ($ppb\,g^{-1}\,d^{-1}$)	9.8 ± 0.9	7.4 ± 0.2	**5.0 ± 0.4***	**4.6 ± 0.04***	**4.2 ± 0.2***	**3.5 ± 0.2***	**4.7 ± 0.2***
% Change	85.7	100	100	100	100	100	100
Zinc (Zn)							
Day 8 (ppb)	7.4 ± 3.7	5.1 ± 1.4	1.6 ± 0.2	5.0 ± 1.0	5.8 ± 1.1	8.9 ± 1.0	**7.9 ± 0.9*****
Zn uptake ($ppb\,g^{-1}\,d^{-1}$)	13.2 ± 6.6	4.3 ± 1.2	1.2 ± 0.1	3.6 ± 1.2	3.4 ± 0.7	5.8 ± 0.7	5.2 ± 0.6
% Change	100	100	100	100	100	100	100

* $P < 0.05$.
** $P < 0.005$.
*** $P < 0.0005$.

forming dark purple phycobilin pigments (PE and PC) and acclimates to low N conditions by utilizing PE and PC, subsequently lightening in color. Utilization of PE and PC in low N conditions temporarily allowed for sustained growth and photosynthetic rates similar to samples provided with N additions. These findings are comparable to the increased PE and PC levels observed of *Ahnfeltiopsis concinna* in acclimation to low from high light conditions (Beach et al., 2000). In agreement with several studies, these results document the ability of macroalgae to store N which can be used to temporarily maintain growth rates in low N conditions (Lapointe and Tenore, 1981; Björnsäter and Wheeler, 1990; Fong et al., 1998). Therefore, without a low N acclimation period prior to nutrient enrichment experiments conducted on *H. musciformis*, growth rates of samples in the no addition will be reflective of this species utilizing N stores for growth (as those reported by Vermeij et al., 2009).

4.2. Nutrient effects on growth rates

All species visually responded to increasing additions of wastewater effluent (and increased N supply) with darkened coloration. These observations agree with those of Lapointe et al. (1976), where *Hypnea musciformis* responded to increased wastewater N supplies (140 mg/l) with dark brown, almost black pigmentation. All species also increased growth rates when provided with additional N, however, the bloom forming species, *H. musciformis* and *Ulva lactuca*, were more responsive in terms of building biomass than *Acanthophora spicifera* (another bloom forming species) and *Dictyota acutiloba* (non-bloom forming). Although *A. spicifera* is known to form blooms in Hawai'i (Smith et al., 2002) and responded to increased nutrients with increased growth, it was not as responsive as *H. musciformis* and *U. lactuca*. This may be because of the morphological differences between the species, as *A. spicifera* is polysiphonous, *H. musciformis* is *pseudoparenchymatous* and *U. lactuca* is distromatic. *H. musciformis* and *U. lactuca* responded to the increased nutrient levels in the smallest wastewater effluent addition of 2.5% with 2-fold higher biomass than those in the no addition. In addition, the growth rate of *H. musciformis* depleted of N stores and then subjected to the no addition was nearly 3-fold lower than that of the no addition in the preliminary experiment and 5-fold lower than treatments of 10.0% wastewater effluent and above. The maximum growth rates of *H.*

Table 5
Final wet weight (ww), day 8 nutrient concentrations, nutrient uptake rates (g^{-1} d^{-1}) (means ± SE), and % change in nutrient concentrations from day 8 to 9 per treatment for *Ulva lactuca*. Significant differences between the no addition and wastewater effluent additions are in bold. n.d. = not detected.

	No addition	2.5%	5.0%	7.5%	10.0%	15.0%	20.0%
Final ww (g)	0.56 ± 0.01	**1.10 ± 0.03****	**1.27 ± 0.04*****	**1.16 ± 0.04*****	**1.19 ± 0.11*****	**1.31 ± 0.01*****	**1.40 ± 0.11*****
Total organic carbon (TOC)							
Day 8 (μM)	71.1 ± 2.8	104 ± 15	94.6 ± 9.9	138 ± 24	105 ± 13	69.7 ± 9.4	102 ± 7.3
TOC uptake (μM g^{-1} d^{-1})	−73.1 ± 27	27.4 ± 13	−37.4 ± 9.6	28.3 ± 16	−1.49 ± 6.3	−74.1 ± 13	−62.7 ± 22
% Change	−57.2	17.8	−48.5	8.90	−6.41	−159	−104
Total nitrogen (TN)							
Day 8 (μM)	5.6 ± 0.7	10.9 ± 1.1	**22.5 ± 0.6*****	**38.1 ± 5.4***	**35.0 ± 2.7****	**40.7 ± 5.4***	**58.9 ± 4.7****
TN uptake (μM g^{-1} d^{-1})	0.43 ± 1.9	5.1 ± 0.8	**11.7 ± 0.4***	**26.7 ± 4.5***	**21.9 ± 1.4*****	**21.4 ± 2.6***	**31.4 ± 3.4***
% Change	5.35	49.5	66.3	79.8	74.9	69.1	73.6
Nitrate (NO_3^-)							
Day 8 (μM)	0.05 ± 0.03	**4.8 ± 0.3***	**11.2 ± 1.5***	**25.2 ± 2.6****	**23.7 ± 0.4*****	**31.3 ± 2.8****	**39.9 ± 0.3*****
NO_3^- uptake (μM g^{-1} d^{-1})	0.27	**4.4 ± 0.3*****	**8.8 ± 1.2***	**21.8 ± 2.2****	**19.9 ± 0.3*****	**23.6 ± 2.0****	**28.5 ± 0.2*****
% Change	100	100	100	100	100	99.0	100
Nitrite (NO_2^-)							
Day 8 (μM)	0.02 ± 0.01	**0.19 ± 0.01****	**0.62 ± 0.01*****	**0.85 ± 0.07****	**0.98 ± 0.07****	**1.08 ± 0.14***	**1.54 ± 0.13****
NO_2^- uptake (μM g^{-1} d^{-1})	0.10	**0.17 ± 0.01***	**0.49 ± 0.01*****	**0.74 ± 0.06****	**0.82 ± 0.06****	**0.83 ± 0.10***	**1.10 ± 0.09****
% Change	100	100	100	100	100	100	100
Ammonium (NH_4^+)							
Day 8 (μM)	1.59 ± 0.11	n.d	1.67	3.75	1.72	0.82	0.57
NH_4^+ uptake (μM g^{-1} d^{-1})	2.8 ± 0.20	–	1.31	3.23	1.45	0.63	0.41
% Change	100	–	100	100	100	100	100
Total Phosphorous (TP)							
Day 8 (μM)	n.d	n.d	n.d	n.d	n.d	0.05	0.13 ± 0.06
TP uptake (μM g^{-1} d^{-1})	–	–	–	–	–	0.03	0.09 ± 0.04
% Change	–	–	–	–	–	100	100
Copper (Cu)							
Day 8 (ppb)	2.7 ± 0.3	1.28 ± 0.37	2.4 ± 0.2	3.0 ± 0.8	1.66 ± 0.21	1.33 ± 0.39	3.4 ± 0.3
Cu uptake (ppb g^{-1} d^{-1})	0.20 ± 0.89	−1.28 ± 0.81	0.66 ± 0.54	0.79 ± 0.78	−1.08 ± 0.11	−1.24 ± 0.15	0.13 ± 0.14
% Change	−6.26	−74.0	21.3	−6.09	−84.7	−83.5	2.98
Iron (Fe)							
Day 8 (ppb)	1.89	n.d	n.d	1.20 ± 0.17	1.54 ± 0.34	2.2	2.5 ± 0.4
Fe uptake (ppb g^{-1} d^{-1})	3.4	–	–	0.12 ± 0.33	1.30 ± 0.29	1.67	1.75 ± 0.25
% Change	100	–	–	26.4	100	100	100
Manganese (Mn)							
Day 8 (ppb)	1.09 ± 0.05	2.4 ± 0.3	**7.5 ± 0.2*****	**12.1 ± 0.8****	**15.5 ± 1.2****	**22.4 ± 2.1****	**32.5 ± 2.5****
Mn uptake (ppb g^{-1} d^{-1})	1.05 ± 0.44	−0.14 ± 0.34	0.54 ± 0.32	1.44 ± 1.35	2.32 ± 0.73	0.22 ± 1.3	2.2 ± 1.7
% Change	59.8	−10.3	8.38	9.72	16.1	−2.42	6.95

* $P < 0.05$.
** $P < 0.005$.
*** $P < 0.0005$.

musciformis and *U. lactuca* in this study were approximately 0.24 g d^{-1}, which is slightly slower than 0.34 g d^{-1} reported for *U. lactuca* in the Roskilde Fjord (Pedersen and Borum, 1996). However, in the summer months, these northern fjords receive 16 h of sunlight (Pedersen and Borum, 1996) compared to 12 h in Hawai'i. These results are similar to those of Larned (1998) where samples of *U. lactuca* provided with additions of N and NP grew significantly faster than those in the control or P addition, suggesting that *U. lactuca* is N limited in Hawai'i. The high growth rates of *H. musciformis* and *U. lactuca* (~15% d^{-1}) are comparable to those observed for the bloom forming *U. lactuca* in Waquoit Bay from *in situ* N and P enrichment experiments (over 13 d) (Teichberg et al., 2008). Our findings are also consistent with those of other studies on *Ulva* that report increased growth rates with increased nutrient supplies (Björnsäter and Wheeler, 1990; Pedersen and Borum, 1996, 1997; Fox et al., 2008).

4.3. Nutrient effects on photosynthetic properties

All bloom forming species tested in this study responded to increased nutrients with increased photosynthetic performance ($rETR_{max}$) and saturation irradiance (E_k). These findings are consistent with those of Valiela et al. (1997) where elevated maximum photosynthetic rates were characteristic of bloom forming macroalgae in increased nutrient conditions. These results also agree with those of Pedersen and Borum (1996) who found that out of 12 species tested in laboratory N enrichment experiments, *U. lactuca* had the highest growth rates and suffered the most from N limitation. In this study, *U. lactuca* was the only species to show substantial declines in photosynthetic properties when deprived of nutrients. The photosynthetic efficiency (α) and % tissue N of *U. lactuca* were significantly decreased after a total of 16 days in low N conditions (seven days of low N acclimation followed by nine days in the no addition). These results (1) support the findings of Rosenberg and Ramus (1982) which conclude that N pools in *Ulva* consist mainly of chlorophyll-protein complexes, (2) agree with those of Henley et al. (1991) (for *U. rotundata* over seven days) that the light capturing efficiency of *U. lactuca* is negatively affected by low N conditions, and (3) verify that chlorophyll–protein complexes are utilized in *U. lactuca* when subjected to low N conditions for extended periods of time.

4.4. Nutrient uptake rates and total organic carbon release

All species were able to take up high levels of TN, NO_3^-, and NO_2^- (with the exception of the *A. spicifera* trial where NO_2^- was not detected) and uptake rates increased with increasing wastewater effluent additions. These results are similar to those of other studies where bloom forming macroalgae increased nutrient uptake rates in response to increased nutrient supplies (Peckol et al., 1994; Pedersen and Borum, 1997; Valiela et al., 1997). The % change in TN for all species was lower than 100%, indicating that the samples were not likely N-limited. The TN uptake rates observed in this study are comparable to those

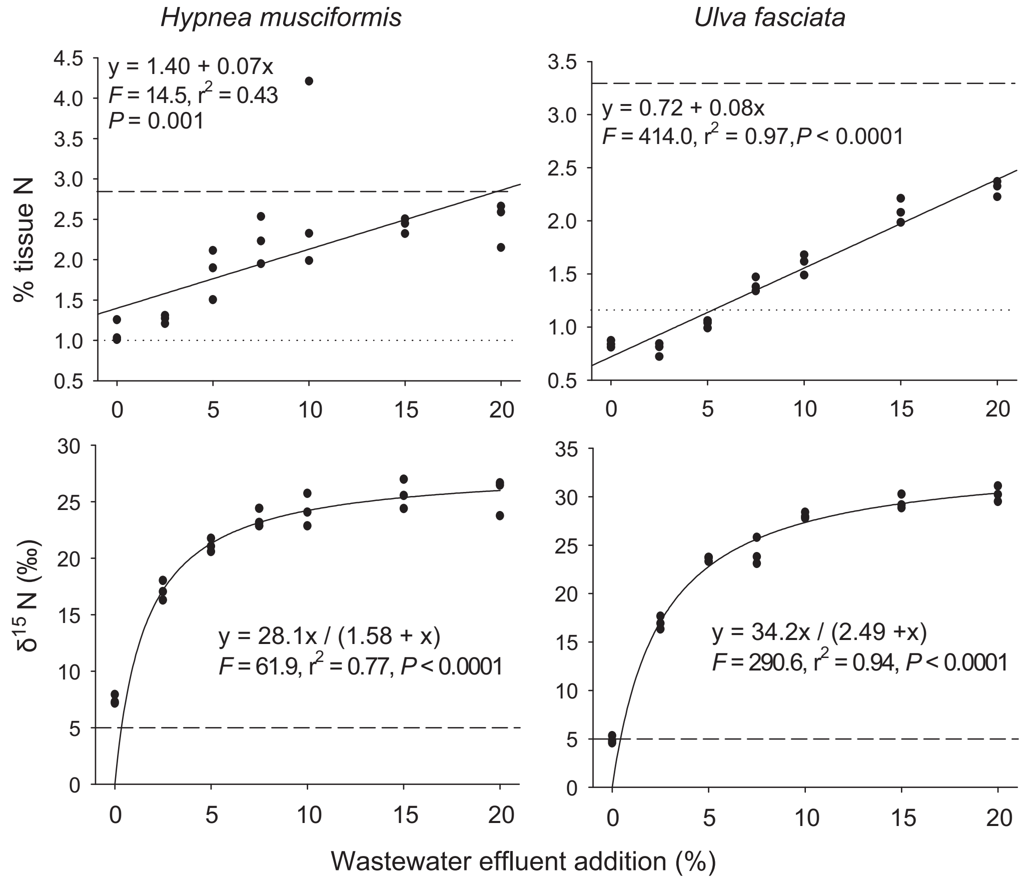


Fig. 6. Final % tissue N and δ^{15}N values of *Hypnea musciformis* and *Ulva lactuca* in response to increasing wastewater effluent addition (%). Average field (bloom) and low N acclimated levels are represented by dashed and dotted lines, respectively (no change occurred in δ^{15}N values during the low N acclimation period).

reported by Björnsäter and Wheeler (1990) for *U. fenestrata* under N-enriched and P-limited conditions (27.1 ± 6.9 μmol TN g^{-1} d^{-1}), which were significantly lower than those in the N and P enriched treatment (133.7 ± 9.3 μmol TN g^{-1} d^{-1}). Björnsäter and Wheeler (1990) suggested from these findings that algae regulate N and P uptake to maintain a balanced internal N:P ratio, which indicates that the species tested in this study might have higher N uptakes rates when provided with higher P concentrations. *H. musciformis* and *U. lactuca* acquired Mn and all available Fe from the surrounding media. *H. musciformis* also acquired all available P, Mo, and Zn confirming that micro nutrients such as Fe, Mn, Mo, and Zn are vital for growth and photosynthetic properties.

H. musciformis NO_3^- uptake might have been affected by limited NO_3^- reductase activity because of the presence of NH_4^+ (Thomas and Harrison, 1985; Young et al., 2005). Another, more likely, possibility is that NO_3^- uptake was limited by Fe because NO_3^- utilization depends on Fe-containing enzymes and requires high cellular Fe quotes (Viaroli et al., 2005). In the highest wastewater effluent addition, all available Fe was utilized but the nitrate was only decreased by 85%. However, Maui soils are derived from intermediate-weathering of basalt and are rich in Fe and other nutrients (Chorover et al., 2004); therefore it is unlikely that the blooms of *H. musciformis* and *U. lactuca* are Fe limited.

For all species, in all treatments, the total organic carbon of the incubation water generally increased over 24 h, which is consistent with the observations of Khailov and Burlakava (1969) that macroalgae release large amounts of organic matter. Generally, macroalgae frequently fix carbon in excess of metabolic needs for growth and subsequently release the unused dissolved organic carbon (DOC) (Alber and Valiela, 1994). In bloom situations, this is likely to further alter ecosystem properties as substantial quantities of DOC enter the microbial food web (Alber and Valiela, 1994). Furthermore, Smith et al. (2006) document that the dissolved organic matter released from macroalgae promotes microbial growth and subsequently causes coral mortality. The vast majority of coral disease incidences occur on reefs with moderate to high anthropogenic impacts (Green and Bruckner, 2000). DOC loading caused significant coral mortality and increased (by an order of magnitude) growth rates of microbes associated with coral mucus (Kline et al., 2006), which suggests that these microbial assemblages are carbon limited. These findings in the combination with other studies (Pantos et al., 2003; Sutherland et al., 2004) further indicate that increased levels of DOC in wastewater (and other organic sources) from coastal developments could contribute to the high incidence of coral disease on adjacent reefs. Future work on Maui should therefore include efforts in bloom and non-bloom areas to identify microbial communities in terms of composition and abundance in disturbed and natural states.

4.5. % tissue N and δ^{15}N values

The % tissue N of *Hypnea musciformis* and *Ulva lactuca* decreased from bloom levels when acclimated to low N conditions, then significantly increased with increasing wastewater addition and concentrations of TN and NO_3^-. These results are similar to those of Lapointe et al. (1976) where *H. musciformis* increased % tissue N in high N (3.4%; 140 mg/l) compared to low N (2.5%; 49 mg/l) conditions. In agreement with other studies, these findings confirm that both species are opportunistic, because they are capable of rapidly building N stores when exposed to increased N supplies

(Björnsäter and Wheeler, 1990; Fong et al., 1994; Pedersen and Borum, 1996; Fong et al., 1998; Cohen and Fong, 2005).

McClelland et al. (1997) found that elevated $\delta^{15}N$ values in groundwater from wastewater infiltration act as a ^{15}N enriched tracer in polluted estuaries. Gartner et al. (2002) confirmed that the method of using macroalgal $\delta^{15}N$ values to trace wastewater dispersal in well-mixed oceanic environments is more sensitive (in terms of detection) than conventional techniques. In Moreton Bay Australia, macroalgal $\delta^{15}N$ values have been used to map the reduced impact of sewage outfalls after wastewater treatment facilities were upgraded (Costanzo et al., 2005). In agreement with these studies (and references therein), this study shows that the tissue $\delta^{15}N$ values of *Hypnea musciformis* and *Ulva lactuca* are reflective of the percent of wastewater N exposure. This demonstrates the potential of using *H. musciformis* and *U. lactuca* in transplantation studies to assess the N source in the marine environment over short time periods. Field studies on Maui have confirmed that the $\delta^{15}N$ values of low N acclimated and transplanted *U. lactuca* samples can be used to map wastewater effluent plumes from underground injection wells emerging onto a nearshore reef (Dailer et al., 2010, 2012).

5. Summary and conclusions

This study confirms that in elevated N conditions, *Hypnea musciformis* stores N by building dark colored phycobilin pigments. This study also confirms that *H. musciformis* and *Ulva lactuca* are opportunistic macroalgae capable of exploiting elevated nutrient levels to rapidly generate substantial amounts of biomass. It is also apparent from this study that *H. musciformis* and *U. lactuca* blooms on Maui will collapse if their resources are depleted. The nutrient enhanced accelerated growth rates of these blooming species suggests, in agreement with numerous other studies from temperate and tropical regions (Littler et al., 1991, 1993; Hunter and Evans, 1995; Fletcher, 1996; Morand and Briand, 1996; Lapointe, 1997; Valiela et al., 1997; Menendez and Comin, 2000; Nelson et al., 2003; Lapointe et al., 2005a,b; Lapointe and Bedford, 2007, 2010; see DeGeorges et al., 2010 for a review), that these blooms will proliferate where land-based nutrients are improperly disposed of. Therefore the interception of land-based nutrients is likely the most effective way for resource managers to diminish bloom formations on Maui. Improved control of land-based nutrients entering the nearshore marine environment could be achieved in various ways, including, reducing nitrogen levels in the injected wastewater effluent, eliminating cesspools in coastal areas, and managing runoff from massive active and inactive agricultural regions. Even secondarily treated wastewater effluent has levels of nitrogen and phosphorus that can drive macroalgal bloom formation in coastal areas with long residence times (US EPA, 1972; DeGeorges, 1990). Cesspools can potentially leech elevated nutrients and bacteria into the adjacent coastal area (US EPA, 1972). Agricultural practices have been known to enrich coastal regions worldwide, including those on Maui, for decades (Soicher and Peterson, 1997; Goreau, 2003). Regulating these and other land-based nutrient sources will greatly improve the health of the remaining coral reefs on Maui and throughout the Hawaiian islands.

Acknowledgements

This work was funded by the Hawai'i Coral Reef Initiative grant # NA07NOS4000193. We thank the County of Maui, Division of Environmental Management former Director C. Okuma, S. Parabicoli and staff of the Lahaina Wastewater Reclamation Facility for their cooperation and assistance, C. Bird for experimental design and statistical guidance, and many anonymous reviewers whose comments improved earlier versions of this manuscript.[SS]

References

Alber, M., Valiela, I., 1994. Production of microbial organic aggregates from macrophyte-derived dissolved organic material. Limnol. Oceanogr. 39, 37–50.

Avery, W., 1997. Distribution and abundance of macroalgae and seagrass in Hillsborough Bay, Florida, from 1986 to 1995. In: Treat, S.F. (Ed.), Proceedings, Tampa Bay Area Scientific Information Symposium 3, Text, Tampa, FL, pp. 151–165.

Banner, A.H., 1974. Kaneohe Bay, Hawai'i: urban pollution and a coral reef ecosystem. In: 2nd International Symposium Coral Reefs, Brisbane, pp. 685–702.

Barile, P.J., Lapointe, B.E., 2005. Atmospheric nitrogen deposition from a remote source enriches macroalgae in coral reef ecosystems near Green Turtle Cay, Abacos, Bahamas. Mar. Poll. Bull. 50, 1265–1272.

Barnes, E.S., 1973. Sewage pollution from tourist hotels in Jamaica. Mar. Poll. Bull. 4, 102–105.

Beach, K., Smith, C.M., Okano, R., 2000. Experimental analysis of rhodophyta photoacclimation to PAR and UV radiation using *in vivo* absorbance spectroscopy. Bot. Mar. 43, 525–536.

Bell, P., 1992. Eutrophication and coral reefs- some examples in the Great Barrier Reef Lagoon. Water Res. 26, 553–568.

Björnsäter, B.R., Wheeler, P.A., 1990. Effect of nitrogen and phosphorus supply on growth and tissue composition of *Ulva fenestrata* and *Enteromorpha intestinalis* (Ulvales, Chlorophyta). J. Phycol. 26, 603–611.

Briand, X., 1989. Proliferation de l'algue verte *Ulva* sp. en baie de Lannion (France): etude d'une nuisance et de son taitement par fermentation anaerobe, vol. VII. University of Lille I.

Burkholder, J.M., Mason, K.M., Glasgow Jr., H.B., 1992. Water-column nitrate enrichment promotes decline of eelgrass *Zostra marina*: evidence from seasonal mesocosm experiments. Mar. Ecol. Prog. Ser. 81, 163–178.

Chorover, J., Amistadi, M.K., Chadwick, O.A., 2004. Surface charge evolution of mineral–organic complexes during pedogenesis in Hawaiian basalt. Geochim. Cosmochim. Acta 68, 4859–4876.

Cohen, R., Fong, P., 2005. Experimental evidence supports the use of $\delta^{15}N$ content of the opportunistic green macroalga *Enteromorpha intestinalis* (Chlorophyta) to determine nitrogen sources to estuaries. J. Phycol. 41, 287–293.

Cole, M.L., Valiela, I., Kroeger, K.D., Tomasky, G.L., Cebrian, J., Wigand, C., McKinney, R.A., Grady, S.P., Carvalho da Silva, M.H., 2004. Assessment of an ^{15}N method to indicate anthropogenic eutrophication in aquatic ecosystems. J. Environ. Qual. 33, 124–132.

Costanzo, S.D., Udy, J., Longstaff, B., Jones, A., 2005. Using nitrogen stable isotope ratios ($\delta^{15}N$) of macroalgae to determine the effectiveness of sewage upgrades: changes in the extent of sewage plumes over four years in Moreton Bay, Australia. Mar. Poll. Bull. 51, 212–217.

Dailer, M.L., Knox, R.S., Smith, J.E., Napier, M., Smith, C.M., 2010. Using $\delta^{15}N$ values in algal tissue to map locations and potential sources of anthropogenic nutrient inputs on the island of Maui, Hawai'i, USA. Mar. Poll. Bull. 60, 655–671.

Dailer, M.L., Ramey, H.L., Saephan, S., Smith, C.M., 2012. Algal $\delta^{15}N$ values detect a wastewater effluent plume in nearshore and offshore surface waters and three-dimensionally model the plume across a coral reef on Maui, Hawai'i, USA. Mar. Poll. Bull. 64, 207–213.

DeGeorges, A., 1990. Land-based Pollution and its Impact on Coral Reefs and Related Ecosystems, The Caribbean Experience Implications for East African Coastal Tourism; Regional Environmental Advisor. U.S. Agency for International Development, Washington, DC, USA.

DeGeorges, A., Goreau, T.J., Reilly, B., 2010. Land-sourced pollution with an emphasis on domestic sewage: lessons from the Caribbean and implications for coastal development on Indian Ocean and Pacific coral reefs. Sustainability 2, 2919–2949.

Derse, E., Knee, K.L., Wankel, S.D., Kendall, C., Berg Jr., C.J., Paytan, A., 2007. Identifying sources of nitrogen to Hanalei Bay, Kauai, utilizing the nitrogen isotope signature of macroalgae. Environ. Sci. Technol. 41, 5217–5223.

Fletcher, R.L., 1996. The occurrence of "green tides" – a review. In: Schramm, W., Nienhuis, P.H. (Eds.), Marine Benthic Vegetation: Recent Changes and the Effects of Eutrophication. Springer, Berlin, pp. 7–43.

Fong, P., Zedler, J.B., Donohoe, R.M., 1993. Nitrogen vs phosphorus limitation of algal biomass in shallow coastal lagoons. Limnol. Oceanogr. 38, 906–923.

Fong, P., Donohoe, R.M., Zedler, J.B., 1994. Nutrient concentration in tissue of the macroalga *Enteromorpha* as a function of nutrient history: an experimental evaluation using field microcosms. Mar. Ecol. Prog. Ser. 106, 273–281.

Fong, P., Boyer, K.E., Zedler, J.B., 1998. Developing an indicator of nutrient enrichment in coastal estuaries and lagoons using tissue nitrogen content of the opportunistic alga, *Enteromorpha intestinalis* (L. Link). J. Exp. Mar. Biol. Ecol. 231, 63–79.

Fox, S.E., Stieve, E., Valiela, I., Hauxwell, J., McClelland, J., 2008. Macrophyte abundance in Waquoit Bay: effects of land-derived nitrogen loads on seasonal and multi-year biomass patterns. Estuar. Coast 3, 532–541.

Garbarino, J.R., Taylor, H.E., Batie, W.C., 1989. Simultaneous determination of major and trace elements by inductively coupled plasma mass spectrometry/optical emission spectrometry. Anal. Chem. 61, 793–796.

Gartner, A., Lavery, P., Smit, A.J., 2002. Use of $\delta^{15}N$ signatures of different functional forms of macroalgae and filter feeders to reveal temporal and spatial patterns in sewage dispersal. Mar. Ecol. Prog. Ser. 235, 63–73.

Goreau, T.J., 1992. Bleaching and reef community change in Jamaica: 1951–1991. Symposium on long term dynamics of coral reefs. Am. Zool. 32, 683–695.

Goreau, T.J., 2003. Case study: waste nutrients: impacts on coastal coral reefs and fisheries, and abatement via land recycling. In proceeding of the United Nations expert meeting on waste management in small island developing states, Havana, Cuba October 1 November 2003; Small Island Developing States Network of the United Nations Department of Economic and Social Affairs (UN-DESA): New York, NY, USA, 2003. Available from: http://www.sidsnet.org/docshare/other/20040310124457_case_study_by_Thomas_J_Goreau_on_waste_mgmt_2003.pdf (accessed 06.06.11).

Graham, L.E., Wilcox, L.W., 2000. Algae. Prentice-Hall, Inc., New Jersey.

Green, E.P., Bruckner, A.W., 2000. The significance of coral disease epizootiology for coral reef conservation. Biol. Conserv. 96, 347–361.

Heaton, T.H.E., 1986. Isotopic studies of nitrogen pollution in the hydrosphere and atmosphere: a review. Chem. Geol. 59, 87–102.

Henley, W.J., Levavasseur, G., Franklin, L.A., Osmond, C.B., Ramus, J., 1991. Photoacclimation and photoinhibition in *Ulva rotundata* as influenced by nitrogen availability. Planta 184, 235–243.

Horrocks, J.L., Stewart, G.R., Dennison, W.C., 1995. Tissue nutrient content of *Gracilaria* spp. (Rhodophtya) and water quality along an estuarine gradient. Mar. Freshw. Res. 46, 975–983.

Hu, C., Li, D., Chen, C., Ge, J., Muller-Karger, F.E., Liu, J., Yu, F., He, M.X., 2010. On the recurrent *Ulva prolifera* blooms in the Yellow Sea and East China Sea. J. Geophys. Res. 115, C05017, http://dx.doi.org/10.1029/2009JC005561.

Hughes, T.P., 1994. Catastrophes, phase shifts, and large scale degradation of a Caribbean coral reef. Science 265, 1547–1551.

Hunt Jr., C.D., Rosa, S.N., 2009. A multitracer approach to detecting wastewater plumes at Kihei and Lahaina, Maui, Hawai'i. USGS Scientific Investigations Report, 2009-5253.

Hunter, C.L., Evans, C.W., 1995. Coral reefs in Kaneohe Bay, Hawai'i: two centuries of western influence and two decades of data. Bull. Mar. Sci. 57, 501–515.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629–637.

Kendall, C., 1998. Tracing nitrogen sources and cycling in catchments. In: Kendall, C., McDonnell, J.J. (Eds.), Isotope tracers in catchment hydrology. Elsevier, Amsterdam, pp. 519–576.

Khailov, K.M., Burlakava, Z.P., 1969. Release of dissolved organic matter from seaweeds and distribution of their total organic production to inshore communities. Linmol. Oceanogr. 14, 521–527.

Kline, D.L., Kuntz, N.M., Breitbart, M., Knowlton, N., Rohwer, F., 2006. Role of elevated organic carbon levels and microbial activity in coral mortality. Mar. Ecol. Prog. Ser. 314, 119–125.

Lapointe, B.E., Lavergne, W.D., Goldman, J.C., Ryhter, J.H., 1976. The mass outdoor culture of macroscopic marine algae. Aquaculture 8, 9–21.

Lapointe, B.E., Tenore, K.R., 1981. Experimental outdoor studies with *Ulva fasciata* Delile. I. Interactions of light and nitrogen on nutrient uptake, growth and biochemical composition. J. Exp. Mar. Biol. Ecol. 53, 135–152.

Lapointe, B.E., Duke, C.S., 1984. Biochemical strategies for growth of *Gracilaria tikvahiae* (Rhodophyta) in relation to light intensity and nitrogen availability. J. Phycol. 20, 488–495.

Lapointe, B.E., 1997. Nutrient thresholds for bottom-up control of macroalgal blooms on coral reefs in Jamaica and southeast Florida. Limnol. Oceanogr. 42, 1119–1131.

Lapointe, B.E., Barile, P.J., Yentsch, C.S., Littler, M.M., Littler, D.S., Kakuk, B., 2004. The relative importance of nutrient enrichment and herbivory on macroalgal communities near Norman's Pond Cay, Exumas Cays, Bahamas: a "natural" enrichment experiment. J. Exp. Mar. Biol. Ecol. 298, 275–301.

Lapointe, B.E., Barile, P.J., Littler, M.M., Littler, D.S., Bedford, B.J., Gasque, C., 2005a. Macroalgal blooms on southeast Florida coral reefs: I. Nutrient stoichiometry of the invasive green alga Codium isthmocladum in the wider Caribbean indicates nutrient enrichment. Harmful Algae 4, 1092–1105.

Lapointe, B.E., Barile, P.J., Littler, M.M., Littler, D.S., 2005b. Macroalgal blooms on southeast Florida coral reefs: II. Cross-shelf discrimination of nitrogen sources indicates widespread assimilation of sewage nitrogen. Harmful Algae 4, 1106–1122.

Lapointe, B.E., Bedford, B.J., 2007. Drift rhodophyte blooms emerge in Lee County, Florida, USA: evidence of escalating coastal eutrophication. Harmful Algae 6, 421–437.

Lapointe, B.E., Bedford, B.J., 2010. Stormwater nutrient inputs favor growth of non-native macroalgae (Rhodophyta) on O'ahu, Hawaiian Islands. Harmful Algae 10, 310–318.

Larned, S.T., 1998. Nitrogen-versus phosphorus-limited growth and sources of nutrients for coral reef macroalgae. Mar. Biol. 132, 409–421.

Laws, E.A., 2003. Human impacts on fluxes of nutrients and sedimentation in Waimanalo stream, Oahu, Hawaiian Islands. Pac. Sci. 57, 119–140.

Lin, H.J., Wu, C.Y., Kao, S.J., Meng, P.J., 2007. Mapping anthropogenic nitrogen through point sources in coral reefs using $\delta^{15}N$ in macroalgae. Mar. Ecol. Prog. Ser. 335, 95–109.

Littler, M.M., Littler, D.S., Titlyanov, E.A., 1991. Comparisons of N- and P-limited productivity between high granitic islands versus low carbonate atolls in the Seychelles Archipelago: a test of the relative dominance paradigm. Coral Reefs 10, 199–209.

Littler, M.M., Littler, D.S., Lapointe, B.E., 1993. Modification of tropical reef community structure due to cultural eutrophication: The southwest coast of Martinique. Proc. 7th Int. Coral Reef Symp. 1, 335–343.

Lobban, C.S., Harrison, P.J., 1994. Seaweed Ecology and Physiology. Cambridge University Press, New York, NY.

Macko, S.A., Ostrom, N.E., 1994. Pollution studies using stable isotopes. In: Lajtha, K., Michener, R.H. (Eds.), Stable Isotopes in Ecology. Blackwell Scientific, pp. 45–62.

Marti, V.C., Hale, D.R., 1981. Comparison of automated segment flow and discrete analyzers for the determination of nutrients in water. Environ. Sci. Technol. 15, 711–713.

McClelland, J.W., Valiela, I., Michener, R.H., 1997. Nitrogen-stable isotope signatures in estuarine food webs: a record of increasing urbanization in coastal watersheds. Limnol. Oceanogr. 42, 930–937.

McCook, L.J., 1999. Macroalgae, nutrients and phase shifts on coral reefs: scientific issues and management consequences for the Great Barrier Reef. Coral Reefs 18, 357–367.

Menendez, M., Comin, F.A., 2000. Spring and summer proliferation of floating macroalgae in a Mediterranean coastal lagoon (Tancada lagoon, Ebro Delta, NE Spain). Estuar. Coast. Shelf. Sci. 51, 215–226.

Morand, P., Briand, X., 1996. Excessive growth of macroalgae: a symptom of environmental disturbance. Bot. Mar. 39, 491–516.

Morand, P., Merceron, M., 2005. Macroalgal population and sustainability. J. Coast. Res. 21, 1009–1020.

Naldi, M., Wheeler, P.A., 2002. ^{15}N measurements of ammonium and nitrate uptake by *Ulva fenestrata* (Chlorophyta) and *Gracilaria pacifica* (Rhodophyta): comparison of net nutrient disappearance, release of ammonium and nitrate and ^{15}N accumulation in algal tissue. J. Phycol. 38, 135–144.

Nelson, T.A., Nelson, A.V., Tjoelker, M., 2003. Seasonal and spatial patterns of "green tides" (Ulvoid algal blooms) and related water quality parameters in the coastal waters of Washington State, USA. Bot. Mar. 46, 263–275.

Paerl, H., 1997. Coastal eutrophication and harmful algal blooms: Importance of atmospheric deposition and groundwater as 'new' nitrogen and other nutrient sources. Limnol. Oceanogr. 42, 1154–1165.

Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, G., Jackson, J.B.C., 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science 301, 955–958.

Pantos, O., Cooney, R., Le Tissier, M., Barer, M., O'Donnell, A., Bythell, J., 2003. The bacterial ecology of a plague-like disease affecting the Caribbean coral *Montastraea annularis*. Environ. Microbiol. 5, 370–382.

Pastorock, R.A., Bilyard, G.A., 1985. The effects of sewage pollution on coral reef communities. Mar. Ecol. Prog. Ser. 99, 137–151.

Peckol, P., DeMeo-Anderson, B., Rivers, J., Valiela, I., Maldonado, M., Yates, J., 1994. Growth, nutrient uptake capacities and tissue constituents of the macroalgae, *Cladophora vagabunda* and *Gracilaria tikvahiae*, related to site specific nitrogen loading rates. Mar. Biol. 121, 175–185.

Pedersen, M.F., Borum, J., 1996. Nutrient control of algal growth in estuarine waters. Nutrient limitation and the importance of nitrogen requirements and nitrogen storage among phytoplankton and macroalgae. Mar. Ecol. Prog. Ser. 142, 261–272.

Pedersen, M.F., Borum, J., 1997. Nutrient control of estuarine macroalgae: growth strategy and the balance between nitrogen requirements and uptake. Mar. Ecol. Prog. Ser. 161, 155–163.

Peterson, B.J., Fry, B., 1987. Stable isotopes in ecosystem studies. Ann. Rev. Ecol. Syst. 18, 293–320.

Platt, T., Gallegos, C.L., Harrison, W.G., 1980. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. J. Mar. Res. 38, 687–701.

Raffaelli, D.G., Raven, J.A., Poole, L.J., 1998. Ecological impact of green macroalgal blooms. Oceanogr. Mar. Biol. Annu. Rev. 36, 97–125.

Ralph, P., Gademann, R., 2005. Rapid light curves: a powerful tool to assess photosynthetic activity. Aquat. Bot. 82, 222–237.

Raven, J.A., Taylor, R., 2003. Macroalgal growth in nutrient enriched estuaries: a biogeochemical and evolutionary perspective. Water Air Soil Poll. Foc. 3, 7–26.

Risk, M.J., Lapointe, B.E., Sherwood, O.A., Bedford, B.J., 2009. The use of $\delta^{15}N$ in assessing sewage stress on coral reefs. Mar. Poll. Bull. 58, 793–802.

Rosenberg, G., Ramus, J., 1982. Ecological growth strategy in the seaweeds *Gracilaria foliifera* (Rhodophyceae) and *Ulva* sp. (Chlorophyceae): soluble nitrogen and reserve carbohydrates. Mar. Biol. 66, 251–259.

Ryther, J.H., Corwin, N., DeBusk, T.A., Williams, L.D., 1981. Nitrogen uptake and storage by the red alga *Gracilaria tikvahiae* (McLachlan 1979). Aquaculture 26, 107–115.

Savage, C., Elmgren, R., 2004. Macroalgal (*Fucus vesiculosus*) $\delta^{15}N$ values trace decrease in sewage influence. Ecol. Appl. 14, 517–526.

Sfriso, A., Marcomini, A., Pavoni, B., Orio, A.A., 1993. Species composition, biomass and net primary production in shallow coastal waters: the Venice Lagoon. Biores. Tech. 44, 235–250.

Smith, S.V., Kimmerer, W.J., Laws, E.A., Brock, R.E., Walsh, T.W., 1981. Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation. Pac. Sci. 35, 279–402.

Smith, J.E., Hunter, C.L., Smith, C.M., 2002. Distribution and reproductive characteristics of nonindigenous and invasive marine algae in the Hawaiian Islands. Pac. Sci. 56, 299–315.

Smith, J.E., Shaw, M., Edwards, R.A., Obura, D., Pantos, O., Sala, E., Sandin, S.A., Smriga, S., Hatay, M., Rohwer, F., 2006. Indirect effects of algae on coral: algae-mediated, microbe-induced coral mortality. Ecol. Lett. 9, 835–845.

Soegiarto, A., 1973. Benthic algae of the bay. In: Smith, S.V., Chav, K.E., Kam, D.T.O. (Eds.), Atlas of Kaneohe Bay: a reef ecosystem under stress. University of Hawai'i Sea Grant Program, Honolulu, pp. 67–90.

Stimson, J., Larned, S., Conklin, E., 2001. Effects of herbivory, nutrient levels and introduced algae on the distribution and abundance of the invasive macroalga *Dictyosphaeria cavernosa* in Kaneohe Bay, Hawai'i. Coral Reefs 19, 343–357.

Sutherland, K.P., Porter, J.W., Torres, C., 2004. Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals. Mar. Ecol. Prog. Ser. 266, 273–302.

Soicher, A.J., Peterson, F.L., 1997. Terrestrial nutrient and sediment fluxes to the coastal waters of west Maui. Hawai'i. Pac. Sci. 51, 221–232.

Teichberg, M., Fox, S.E., Aguila, C., Olsen, Y.S., Valiela, I., 2008. Macroalgal responses to experimental nutrient enrichment in shallow coastal waters: growth, internal nutrient pools, and isotopic signatures. Mar. Ecol. Prog. Ser. 368, 117–126.

Teichberg, M., Fox, M.T., Olsen, Y.O., Valiela, I., Martinetto, P., Iribarne, O., Muto, E.Y., Petti, M.A.V., Corbisier, T.N., Soto-Jiménez, M., Páez-Osuna, F., Castro, P., Freitas, H., Zitelli, A., Cardinaletti, M., Tagliapietra, D., 2010. Eutrophication and macroalgal blooms in temperate and tropical coastal waters: nutrient enrichment experiments with *Ulva* spp. Glob. Change Biol. 16, 2624–2637.

Thomas, T.E., Harrison, P.J., 1985. Effect of nitrogen supply on nitrogen uptake, accumulation and assimilation in *Porphyra perforata* (Rhodophyta). Mar. Biol. 84, 267–274.

Thom, R.M., Albright, R.G., 1990. Dynamics of benthic vegetation standing stock, irradiance and water properties in central Puget Sound. Mar. Biol. 104, 129–141.

Thornber, C.S., DiMilla, P., Nixon, S.W., McKinney, R.A., 2008. Natural and anthropogenic nitrogen uptake by bloom-forming macroalgae. Mar. Poll. Bull. 56, 261–269.

Twilley, R.R., Kemp, W.M., Staver, K.W., Stevenson, J.C., Boynton, W.R., 1985. Nutrient enrichment of estuarine submerged vascular plant communities. I. Algal growth and effects on production of plants and associated communities. Mar. Ecol. Prog. Ser. 23, 179–191.

United States Environmental Protection Agency, 1972. Water Quality Criteria "Blue Book" A Report of the Committee on Water Quality Criteria. U.S. Government Printing Office, Washington, DC, USA.

Valiela, I., Foreman, K., LaMontagne, M., Hersh, D., Costa, J., Peckol, P., DeMeo-Anderson, B., D'Avanzo, C., Babione, M., Sham, C., Brawley, J., Lajtha, K., 1992. Couplings of watersheds and coastal waters: Sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts. Estuar. Coast 15, 443–457.

Valiela, I., McClelland, J., Hauxwell, J., Behr, P.J., Hersh, D., Foreman, K., 1997. Macroalgal blooms in shallow estuaries: controls and ecophysiological and ecosystem consequences. Limnol. Oceanogr. 42, 1105–1111.

Van Beukering, P., Cesar, H., 2004. Ecological, economic modeling of coral reefs: evaluating tourist overuse at Hanauma Bay and algae blooms at the Kihei Coast, Hawai'i. Pac. Sci. 58, 243–260.

Viaroli, P., Bartoli, M., Azzoni, R., Giordani, G., Mucchino, C., Naldi, M., Nizzoli, D., Taje, L., 2005. Nutrient and iron limitation to *Ulva* blooms in a eutrophic coastal lagoon (Sacca di Goro, Italy). Hydrobiologia 550, 57–71.

Vermeij, M.J.A., Dailer, M.L., Smith, C.M., 2009. Nutrient enrichment promotes survival and dispersal of drifting fragments in an invasive topical macroalga. Coral Reefs 28, 429–435.

Walker, D., Ormond, R.F.G., 1982. Coral death from sewage and phosphate pollution at Aqaba, Red Sea. Mar. Poll. Bull. 13, 21–25.

West Maui Watershed Owners Manual, 1997. Prepared by: West Maui Watershed Advisory Committee. Available from: http://hawaii.gov/health/environmental/water/cleanwater/prc/pdf/WestMauiWatershedOwnersManual_bookmarked.pdf.

Wiesmann, U., 1994. Biological nitrogen removal from wastewater. In: Fiechter, A. (Ed.), Advances in Biochemical Engineering/Biotechnology, vol. 51. Springer, Berlin, Heidelberg, pp. 113–154.

Young, E.B., Lavery, P.S., van Elven, B., Dring, M.J., Berges, J.A., 2005. Nitrate reductase activity in macroalgae and its vertical distribution in macroalgal epiphytes of seagrasses. Mar. Ecol. Prog. Ser. 288, 103–114.

Zaitsev, Y.P., 1992. Recent changes in the trophic structure of the Black Sea. Fish Oceanogr. 1, 180–189.

2,322 signers: #SaveOlowalu: Please Testify To The State Of Hawaii LUC, Reject The Olowalu EIS petition
John Fitzpatrick
to:
State Land Use Commision, Members of the Land Use Commision
12/03/2015 12:25 PM
Hide Details
From: "John Fitzpatrick" <petitions@moveon.org>
To: "State Land Use Commision, Members of the Land Use Commision" <luc@dbedt.hawaii.gov>
Security:
To ensure privacy, images from remote sites were prevented from downloading. Show Images

Dear State Land Use Commision,

I started a petition to you titled *#SaveOlowalu: Please Testify To The State Of Hawaii LUC, Reject The Olowalu EIS*. So far, the petition has 2,322 total signers.

You can post a response for us to pass along to all petition signers by clicking here:
http://petitions.moveon.org/target_talkback.html?tt=tt-102740-custom-64216-20251203-jkawvl

The petition states:

> "On November 18th we need to let the Hawaii State Land Use Commission know that we reject the plan for an Olowalu town development and we reject the Environmental Impact Statement (EIS) that Frampton and Ward are presenting in order to build their 1700-home city at Olowalu. This city will increase the West Maui population by over 4,000 residents and 3,000 more cars on an already overcrowded infrastructure. In addition, marine biologists from around the world have said it will likely kill our largest, oldest and extremely priceless coral reef ecosystem that house 700+ year old coral colonies, endangered monk seals, sea turtles, fish, invertebrates and other endemic species. What's at stake? • Our ocean, reef eco-system (700 year old kupuna coral), limu and fish • Existing roads and traffic are already horrible; imagine 3,000 more cars • Our streams and aquifers • Over-crowded schools • Loss of prime agricultural land • Public access to the coastline • Traditional and customary use of Olowalu lands and waters Please sign the petition and, if possible, show up to testify on Wednesday, Nov. 18, 2015 at 9:30 AM. We only have seven days to get the word out. #saveolowalu facebook event to get instructions. https://www.facebook.com/events/1517489378544315/"

To download a PDF file of all your constituents who have signed the petition, including their addresses, click this link: http://petitions.moveon.org/deliver_pdf.html?job_id=1679957&target_type=custom&target_id=64216

To download a CSV file of all of your constituents who have signed the petition, including their addresses, click this link: http://petitions.moveon.org/deliver_pdf.html?job_id=1679957&target_type=custom&target_id=64216&csv=1

Thank you.

--John Fitzpatrick

If you have any other questions, please email petitions@moveon.org.

The links to download the petition as a PDF and to respond to all of your constituents will remain available for the next 14 days.

This email was sent through MoveOn's petition website, a free service that allows anyone to set up their own online petition and share it with friends. MoveOn does not endorse the contents of petitions posted on our public petition website. If you don't want to receive further emails updating you on how many people have signed this petition, click here: http://petitions.moveon.org/delivery_unsub.html?e=soBXfUW3mIZGl5GGesCKzSBsdWNAZGJlZHQuaGF3YWlpLmdvdg--&petition_id=102740.

Ali Martin
808 Olowalu Village Road,
Olowalu, HI 96761

December 2, 2015

Land Use Commission
PO Box 2359
Honolulu, HI 96804
Fax: 808 587-3827
E-mail: luc@dbedt.hawaii.gov

Re: Testimony IN FAVOR of Final Environmental Impact Statement
Olowalu Town Master Plan (DKT. NO. A10-786)

Dear Land Use Commissioners,

I was born and raised on Maui and I live in Olowalu. And, I deeply love and care about Olowalu. I am writing to provide my support for the approval of the Final Environmental Impact Statement for the Olowalu Town Master Plan; DKT. NO. A10-786. I have reviewed the Final EIS for this project and believe that the document is very thorough.

It is my understanding that a Final Environmental Impact Statement is utilized to disclose potential impacts for a proposed development. The Olowalu Town Final EIS utilizes many professionals in their various fields of expertise to provide information about the impacts of the Olowalu Town Master Plan.

It is not surprising that some members of the community do not agree with everything within the document. In fact, it would be impossible to create a document in which someone would not disagree. However, this Final EIS is a complete disclosure document that is well prepared and thorough. If this document is not acceptable, I fear that the system will not allow for worthy projects to progress through the review system which will be detrimental to Hawaii moving forward.

Olowalu is a special place. I deeply love and care about Olowalu and Maui. For this reason I strongly support the Olowalu Town Master Plan.

Please approve the Olowalu Town Final Environmental Impact Statement.

Sincerely,

Ali Martin

Fergus & Company
A LIMITED LIABILITY COMPANY

360 PAPA PLACE SUITE 101
KAHULUI, HAWAII 96732
TELEPHONE (808) 545-1700 x40
FAX (808) 871-8773

December 2, 2015

Land Use Commission
PO Box 2359
Honolulu, HI 96804
Fax: 808 587-3827
E-mail: luc@dbedt.hawaii.gov

Re: Testimony IN FAVOR of Final Environmental Impact Statement
Olowalu Town Master Plan (DKT. NO. A10-786)

Dear Land Use Commissioners,

I am writing to provide my support for the approval of the Final Environmental Impact Statement for the Olowalu Town Master Plan; DKT. NO. A10-786. I believe the EIS is thorough and utilized many professionals in their various fields of expertise to provide information about the impacts of the project.

The implementation of the Olowalu Town Master Plan will improve ocean access for fishermen, beachgoers, divers, and surfers. The Final EIS addresses existing and future traffic concerns with the relocation of Honoapiʻilani Highway within the project to a more mauka location. The relocation of the highway will remove the high volume, high speed highway away from the ocean activities which will improve the ocean activities experience. The plan calls for large parks at key recreational areas including the Olowalu surf site on the north side of the project.

By allowing limited housing on the lands makai of the existing Honoapiʻilani Highway, the plan will establish new large parks and open public space within these existing private lands. These parks makai of the existing highway will provide a direct connection of the Olowalu community to the ocean which will create a wonderful place for Maui's families to live, work, and play.

It is not surprising that some members of the community do not agree with everything within the document. In fact, it would be impossible to create a document in which someone would not disagree. However, this Final EIS is a complete disclosure document that is well prepared and thorough. If this document is not acceptable, I fear that the system will not allow for worthy projects to progress through the review system which will be detrimental to Hawaii moving forward.

Please approve the Olowalu Town Final Environmental Impact Statement.

Very truly yours,

FERGUS & COMPANY
A Limited Liability Company

Alexander L. Fergus
Manager

Please Reject FEIS Olowalu Town
margaret Akana
to:
luc@dbedt.hawaii.gov
12/03/2015 11:04 PM
Cc:
"saveolowalu@gmail.com"
Hide Details
From: margaret Akana <margaret.akana@yahoo.com>
To: "luc@dbedt.hawaii.gov" <luc@dbedt.hawaii.gov>
Cc: "saveolowalu@gmail.com" <saveolowalu@gmail.com>
Please respond to margaret Akana <margaret.akana@yahoo.com>

Aloha Land Use Committee Members,
My name is Margaret Akana, I am a Native Hawaiian living in West Maui and I am very concerned about the proposed Olowalu Town and after reviewing the Final EIS submitted by the developer, my conclusion is that it is incomplete, inaccurate and flawed.

The many testifiers at your last public hearing raised many valid concerns - I have seen endangered nene at Olowalu, why is there no mitigation plan to address the threat development poses to this Endangered Species which is in fact our State bird.

Traffic Impacts are a major concern of everyone I know that currently lives in West Maui. When Launiupoko was approved and a new traffic light was installed it added half and hour plus to the commute from West Maui to the rest of the island. After 5 years of the EIS process, the traffic analyses are still incomplete, there is no clear timeline when the highway will be relocated and a four lane highway is the primary mitigation offered for the huge increase in traffic in an already congested area (ask most residents of West Maui, almost every weekend traffic is backed up for hours on the way to the West side), also the TIAR refers to a future hotel in all its calculations and the text of the FEIS does not mention this?

As a Native Hawaiian I would like to emphasize the point that our cultural practices can not be confined to a cultural reserve area, many areas in Olowalu are important to our history and cultural use may be restricted but no mention of this is made in the FEIS. The shoreline buffer of 150' is not enough to protect cultural practices and we are already experiencing erosion and sea level rise, which is also a reason that the wastewater treatment plant is much too close to the shoreline. Hawaiians know the importance of fresh water springs to support limu, fish and coral populations, this is traditional knowledge handed down for generations, the FEIS marine report is thus flawed saying that it is not important. Mauka to makai streamflow is essential to healthy ahupuaa and yet the FEIS sets no restoration goals, doesn't propose amending Instream flow standards and does nothing to address this protected use except to use R1 water for irrigation which may or may not happen.

I'm very concerned that the current cultural site preservation plan has not been implemented, I believe this goes to show the developers commitment to our cultural sites and burial areas, it is a telling foreshadow of worse things to come. The relocated Honoapiilani Highway realignment will place a apps 200' high speed highway just below Puu Kilea a traditional burial ground and between two heiau and there has been no coordination with the Federal/State government or the Army Core of Engineers as the developers were advised to do after filing their draft EIS leading me to believe they have not done their due diligence and do not take their responsibilities serious enough.

I am asking you to reject the developers FEIS and listen to our community not those who have financial gain riding on this development or even those employed by the landowner and the developers. Our general plan update states this would be excessive amount of housing for West Maui's projected needs given all the developments that already have entitlements and the distance from infrastructure makes it the opposite of LEED smart location, it actually makes it sprawl with tax payers shouldering the burden of police, fire, medic, school and ocean safety services.

In closing, I'm not saying that this project should not go forward, but in deference to our community that lives here and our many concerns in the glaring gaps and the minimizing of environmental, cultural and traffic concerns by the developer, I'm asking that you reject this version of a Final EIS let them go back and correct the inadequacies, address all the concerns, develop plans for mitigation and they can always come back before your commission with a complete and accurate FEIS. Do not accept this FEIS we have already endured too many flawed EIS just look to the results of Launiupoko majority of the houses in that subdivision are for sale, they are diverting water from Kauaula valley at the expense of lo'i kalo and especially when the light malfunctions which seems to happen almost every weekend it creates a nightmarish traffic situation for the entire West District, look to the results of Mahana Ridge part of the Kapalua Mauka project district and the report by the same Marine Consultants who stated there would be no negative downstream effects and yet despite their use of best management practices by the project manager (above and beyond what was required) they were unable to keep sediment and green waste on their project sites, the sediment retention basins were inadequate and for the past few years this project has had a significant documented negative impact on downstream nearshore environment. We are not willing to take this chance with Olowalu. Do not accept this FEIS.

Mahalo,
Margaret "Mugs" Akana
Honokowai Villas
Lahaina, HI 96761
808-276-3853

Jennifer and Philip Schettewi
PO Box 791540
Paia, HI 96779

December 2, 2015

Land Use Commission
PO Box 2359
Honolulu, HI 96804
Fax: 808 587-3827
E-mail: luc@dbedt.hawaii.gov

Re: Testimony **IN FAVOR** of Final Environmental Impact Statement
Olowalu Town Master Plan (DKT. NO. A10-786)

Dear Land Use Commissioners,

We are writing to provide our support and encouragement for the approval of the Final Environmental Impact Statement for the Olowalu Town Master Plan; DKT. NO. A10-786.

Based on our experience and knowledge of living in Hawaii and after a thorough review of the Olowalu Master Plan, the implementation of the Olowalu Town Master Plan will improve ocean access for fishermen, beachgoers, divers, as well as surfers. The Final EIS addresses existing and future traffic concerns with the relocation of Honoapi'ilani Highway within the project to a more mauka location. The relocation of the highway will remove the high volume, high speed highway away from the ocean activities which will improve the ocean activities experience. The plan calls for large parks at key recreational areas including the Olowalu surf site on the north side of the project.

By allowing limited housing on the lands makai of the existing Honoapi'ilani Highway, the plan will establish new large parks and open public space within these existing private lands that will benefit all. These parks makai of the existing highway will provide a direct connection of the Olowalu community to the ocean which will create a wonderful place for Maui's families to live, work, and play.

As residents of Hawaii, we strongly urge you to approve the Olowalu Town Final Environmental Impact Statement.

Sincerely,

Philip Schettewi
Philip Schettewi

Jennifer Schettewi