FINAL REPORT

NEIWPCC Job Code:	0348-008
Project Code:	S-2021-016
Contractor:	Cornell Cooperative Extension of Suffolk County (CCE)
Prepared By:	Kristin Kraseski, Environmental Analyst III
Project Period:	10/01/2020 to 09/30/2021
Date Submitted:	April 2022
Date Approved:	April 2022

***Saccharina Latissima* (Sugar Kelp) Fertilizer Pilot Study, Year 2**

CONTACT INFORMATION

New York State DEC Region 1
SUNY at Stony Brook
50 Circle Rd, Stony Brook, NY 11790
P: 631-941-7205

This is a US EPA funded project.

This project was funded by an agreement awarded by US Environmental Protection Agency (US EPA) to NEIWPCC in partnership with New York State Department of Environmental Conservation (NYS DEC).

Although the information in this document may have been funded wholly or in part by the United States Environmental Protection Agency (under agreement LI-00A00688), it has not undergone the Agency's publications review process and therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

The viewpoints expressed here do not necessarily represent those of NYS DEC, NEIWPCC, or US EPA, nor does mention of trade names, commercial products, or causes constitute endorsement or recommendation for use.

EXECUTIVE SUMMARY

Nitrogen pollution is a critical issue in the Long Island Sound watershed. Although reduction targets from wastewater treatment plants have been met, non-point sources, in addition to legacy pollutants traveling with groundwater into coastal embayments, ensure that there is a steady supply of excess nitrogen entering our waterways in many areas. Seaweed cultivation and harvest has the potential to reduce nitrogen concentrations in impaired waterbodies, because as it grows, it incorporates nutrients into its tissue. Removing seaweed from the water removes nitrogen from the system, through a process called bioextraction.

The purpose of this project was to evaluate the efficacy of nutrient bioextraction using *Saccharina latissima,* a native, winter species of brown seaweed, or kelp, as a nutrient management strategy, by providing data on nutrient, metal and pathogen removals, and an examination of kelp growth at different sites and under different conditions. Because bioextraction is in relatively early stages of development as a usable nitrogen management/mitigation strategy, this type of information is vital in understanding the potential and limitations of using *Saccharina latissima* for this purpose.

Saccharina latissima grown at three sites within the Long Island Sound in New York State: Rye, NY, Bronx, NY and Northport, NY in the winter and spring of 2021, working with Save the Sound, SUNY Maritime College, and Cornell Cooperative Extension of Suffolk County and the Village of Northport, respectively. Kelp lines were deployed at these sites in January 2021 and collected in May or June of 2021; water quality and kelp growth were measured, and kelp tissue was analyzed, when available. There were issues with kelp growth at two of the three sites, but kelp grown at the East River, Bronx site, gave vital data on contaminant levels, as well as nutrient data. Field data was also compared to data collected in the Spring of 2020 at three sites on the south shore of Long Island, in a companion study to this one. Some pathogen and PAH levels were found to be higher in the East River than on the south shore of Long Island, but most other analytes at the East River site were comparable or lower than those seen at the south shore sites.

The kelp harvested from the East River was used in a fertilizer amendment study, completed by Cornell Cooperative Extension of Suffolk County. A field trial was conducted to evaluate the impact of different application rates of locally produced kelp meal and extract, compared to commercial kelp products, on field-grown tomato yield and quality, and two trials were conducted on greenhouse plants to evaluate the possible effects of locally grown sugar kelp extract applied as an amendment: one on tomato germination and seedling growth, and another on plant growth and drought stress in tomato and petunia transplants. There were no appreciable improvements in germination rates for tomato seedlings, or growth or drought tolerance for transplants; but tomatoes grown in the field trial that were treated with sugar kelp were not significantly different in yield or quality from those treated with commercially available seaweed products, suggesting that locally produced kelp amendments perform similarly to the commercially available products.

CONTENTS

1. PROJECT SYNOPSIS

Nitrogen pollution is a significant problem in the Long Island Sound, with non-point sources of pollution, including onsite wastewater treatment systems, stormwater, and fertilizer runoff, being major contributors to water quality impairments. Although reduction targets from wastewater treatment plants have been met, these non-point sources, in addition to legacy pollutants traveling with groundwater into coastal embayments, ensure that there is a steady supply of excess nitrogen entering our waterways in many areas. Common impairments due to excess nitrogen include eutrophication, hypoxic "dead zones," and increased occurrences of harmful algal blooms.

Seaweed cultivation and harvest has the potential to reduce nitrogen concentrations in impaired waterbodies, because as it grows, it incorporates nutrients into its tissue. Removing seaweed from the water removes nitrogen from the system, through a process called bioextraction. *Saccharina latissima* (sugar kelp) is a native, cold-water species of brown algae, or kelp. It has been of interest as a food product for a long time, and now is being considered as a 'bioextractor' and an in-water nitrogen mitigation strategy. Previous work in Long Island Sound has estimated that *Saccharina* could remove 38 to 180 kg of nitrogen per hectare in a growing season (Kim et al. 2015).

Saccharina latissima is a winter species of kelp, and the kelp was grown at three sites within the Long Island Sound in New York State: Rye, NY, Bronx, NY and Northport, NY in the winter and spring of 2021, working with Save the Sound, SUNY Maritime College, and Cornell Cooperative Extension of Suffolk County and the Village of Northport, respectively. In addition to monitoring kelp growth, water quality monitoring was done, and kelp samples were collected to test not only for nitrogen content, but also carbon, micronutrients, heavy metals, organic contaminants, pesticides, and pathogens. This supplied data to determine bioextraction potential, but also whether the kelp picked up any other contaminants that would limit the use of the kelp for other purposes after harvest.

It should be noted here that commercial bioextraction is not yet a reality in New York State due to current regulatory and other barriers. Even in Connecticut, where cultivation and sale of *Saccharina* is allowed, it is still only allowed in shellfish permitted waters, and not in the impaired areas where bioextraction is most needed.

The purpose of this project was to evaluate the efficacy of nutrient bioextraction using *Saccharina latissima* as a nutrient management strategy, by providing data on nutrient, metal and pathogen removals, and an examination of kelp growth at different sites and under different conditions. Because bioextraction is in relatively early stages of development as a usable nitrogen management/mitigation strategy, this type of information is vital in understanding the potential and limitations of using *Saccharina latissima* in such a way. This project also looked at the potential uses of harvested sugar kelp as a fertilizer amendment for locally significant crops. If the seaweed harvested for bioextraction in our coastal areas could be used for a commercial purpose, that would move bioextraction operations beyond just research and restoration/mitigation projects into a more self-sustaining and profitable endeavor.

2. TASKS COMPLETED

The following tasks were completed during this project:

Quality Assurance Project Plan Preparation and Approval – this task included the development and finalization of project objectives, experimental design, and sampling methodology with all participants. This task was completed in March 2021, prior to the collection of any data

Sugar Kelp (*Saccharina latissima*) field cultivation

Deployment of Kelp Seed Lines – this task included the out-planting of kelp seedlings at open-water and near-shore grow-out sites in January of 2021. The deployment sites were located in open water in Rye, NY adjacent to Hen Island, at a near-shore site at the mooring fields of SUNY Maritime College in Bronx, NY, and in Northport, NY (Figures 1-4, and see deployment photos in Appendix).

Figure 1. Project area – red stars indicate kelp cultivation locations

Figure 2. Milton Harbor, Rye, NY (WC) site, indicated by yellow box

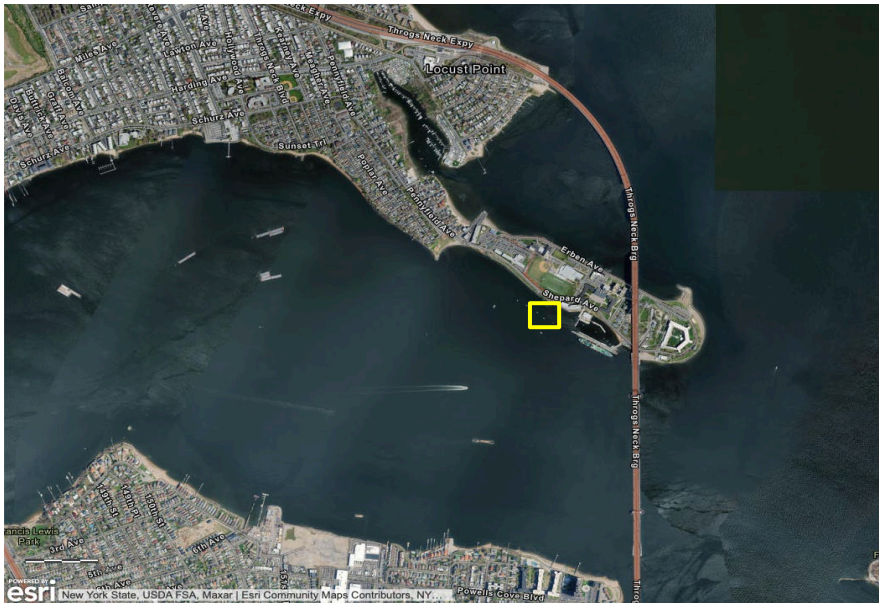


Figure 3. East River, Bronx (Bx) site, indicated by yellow box

Figure 4. Northport Harbor (NH) site location, indicated by yellow box

Water Quality Monitoring – this task included discrete monthly water quality monitoring at kelp grow-out sites. Monitoring began once the QAPP was approved, and continued until the harvest date.

Kelp Growth Monitoring – On each sampling/monitoring date, kelp blades were examined, counted (in cases where growth was limited or sporadic), and blade lengths were measured and recorded.

Kelp Tissue Sampling – this task originally included the monthly collection of tissue samples for nitrogen, phosphorus, carbon, and pathogens, and every-other-month collection of tissue samples for pathogens. Due to slow and/or sporadic growth of kelp at all sites, the number of sampling dates was unavoidably reduced, as collecting the amount of tissue needed for analysis in many cases would have cleared the lines, and made it impossible to collect samples at harvest. NEIWPCC and EPA Project Managers were made aware of this issue early in the growing season, and alerted at early sampling dates that there would have to be changes in the schedule.

Analysis of Kelp Tissue Samples – Kelp tissue samples, when available, were collected, weighed, packaged, and sent to laboratories for analysis, based on the sampling schedule above.

Kelp Harvest – Kelp was harvested from the East River site in early June, 2021. The kelp was placed in bins, transported to Riverhead, NY, where it was weighed, rinsed, and processed/dried by Cornell Cooperative staff for inclusion in the sugar kelp fertilizer amendment study. There were not enough blades at the Milton Harbor or Northport Harbor sites, so the kelp from those sites was placed in sample bags and sent to the laboratories for the analyses described above.

Sugar Kelp (*Saccharina latissima*) Fertilizer Pilot Study

Kelp Drying and Processing – Kelp was delivered to the Long Island Horticulture Research

and Extension Center on June 3, 2021, rinsed with fresh water and line-dried in a greenhouse. The line-dried kelp was then crushed by hand, dried in an oven, and ground into a coarse meal. A portion of the meal was then made into an extract. See Appendix for details on materials and methods.

Evaluation of Soil and Foliar Applied Kelp on Field Grown Tomaotes – A field trial was completed to evaluate the impact of different application rates of locally produced kelp meal and extract, compared to commercial kelp products, on field grown tomato yield and quality. See Appendix for experimental design, materials and methods.

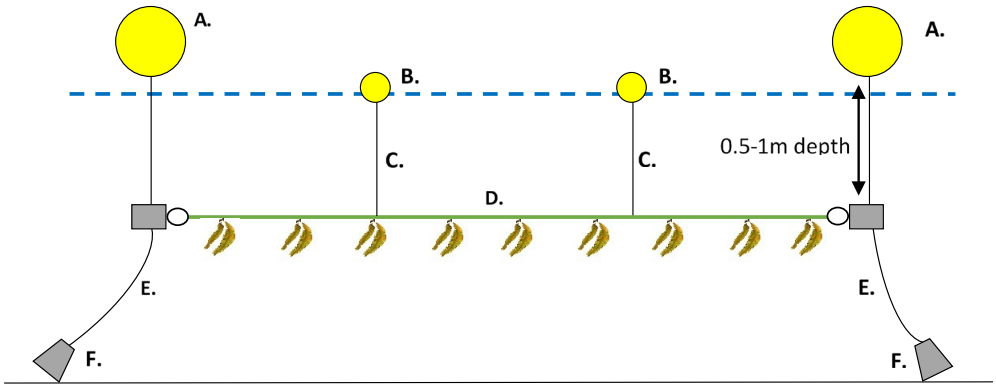
Evaluation of Application of Sugar Kelp Extract to Greenhouse-Grown Tomato Seedlings and Petunia and Tomato Transplants – Two greenhouse trials were completed to evaluate the possible effects of locally grown sugar kelp extract as an amendment: one to study the effects of sugar kelp extract on tomato germination and seedling growth, and another to study the effects of kelp extract on two common greenhouse crops, tomato and petunia, grown using different fertilizer rates. See Appendix for experimental design, materials and methods.

3. METHODOLOGY

Sugar Kelp (*Saccharina latissima*) Cultivation

Juvenile sporophytes were acquired from the Town of Hempstead, and seed spools were transported to the field in small, sealed containers placed in a cooler to minimize exposure and movement. Due to slow growth in the nursery, the sporophytes were not considered to be large enough to be transferred until mid-January 2021, though they were originally planned to be deployed in mid-December of 2020.

Saccharina was suspended from long-lines, approximately 0.5-1.0 meter below the surface of the water, using the following technique: the end of the seed string was tied off to the horizontal line, and the seed string was then ‘spooled-off’ in a spiral fashion onto the line, and tied at the other end. Because the seed spools were more sparse than desired, two seed spools were used for each line in an attempt to increase sporophyte density on the lines. Floats and/or weights were placed at intervals along the lines, as. Needed, to ensure that they were held at approximately the correct depth in the water column.



A. Mooring buoys
B. Floats
C. ¼" line for floats
D. ½" sink line for kelp
E. Anchor line (½" or 5/8" sinking line)
F. Weight

Figure 5. Kelp grow-out system diagram

These long-line systems were monitored monthly to track growth, and measurements began when growth became visible, using the following methodology: the line was pulled up from the water, blades were counted, and a ruler was used to measure blade lengths with minimal disturbance. This method varied slightly from the method described in the Quality Assurance Project Plan, as it was determined that no blades should be discarded in order to obtain the tissue needed for lab analysis. This variation was needed in all cases, except for the harvest date at the East River site. No kelp was removed from the line, or weighed, at the Milton and Northport Harbor sites on any of the sampling dates, except for the final harvest.

Water quality sampling methodology and reporting was conducted in accordance with the Great Cove Citizen Science Monitoring Project QAPP, prepared by Seatuck Environmental Association (effective date: June 1, 2019). Discrete water quality monitoring was conducted on a monthly basis at each grow out site, starting from the point that kelp growth was first seen, and after the QAPP was approved. Parameters included depth, temperature, salinity/conductivity, dissolved oxygen (DO), and pH, and were measured using a YSI EXO1 multiparameter sonde at each site at a location approximately 10 ft away from the kelp long line.

Kelp tissue sampling occurred two times at the East River site, but only once (at harvest) for the Milton and Northport Harbor sites. Samples were collected using sharp scissors, cleaned with isobutyl alcohol between each grow-out site. Sample weights were taken at each site, using a battery-operated bench scale, to ensure that enough biomass was collected for lab analysis. Kelp tissue was placed in sample bags and put on ice for transport. Kelp sample bags were labeled, according to the specifications required by the analytical laboratories, and shipped overnight with required documentation to the labs in insulated shipping boxes packed with ice packs in order to keep temperatures low until they could be processed.

Kelp biomass measurements were taken at final harvest. The original procedure for biomass estimates was to include the monthly collection of length and weight measurements for random blades for use in a regression analysis in addition to measurements of full harvested biomass, however as there was little growth on most lines, no blades were removed from the lines at earlier sampling dates, only at final harvest. Fresh weight biomass measurements from the Milton and Northport Harbor sites were taken using a small bench scale (AWS® AMW-13 Precision Bench Scale), and the more substantial harvest from the East River site was weighed using a digital

platform scale by Cornell Cooperative Extension of Suffolk County staff.

Sugar Kelp (*Saccharina latissima*) Fertilizer Pilot Study
Kelp was delivered to the Long Island Horticulture Research and Extension Center on June 3, 2021, rinsed with fresh water and line-dried in a greenhouse. The line-dried kelp was then crushed by hand, dried in an oven, and ground into a coarse meal. A portion of the meal was then made into an extract. The processed kelp was used in a field trial with tomatoes, and two greenhouse trials using tomatoes and petunias. The development of the experimental design and methodology, and all work for this portion of the project was completed by Cornell Cooperative Extension of Suffolk County. Please see the Appendix which includes a final report from Cornell Cooperative Extension of Suffolk County, with all relevant methodologies used in this pilot study.

4. Quality Assurance Tasks Completed

Project Management

Each project partner ensured that staff were trained on the proper protocol and sampling methods, and New York State Department of Environmental Conservation personnel completed the New York State online Boating Safety training course. All analytical laboratories ensured that staff were trained on the methods of analysis and met the training/certification requirements specified by their laboratory. The most current copy of the approved Quality Assurance Project Plan was distributed to all project partners in PDF format via email. The Quality Assurance Project Plan is and was maintained by the Project Lead in electronic format throughout the length of the project. All data was recorded in appropriate data sheets, and sample custody and instrument calibration forms completed and retained. Although less than expected kelp growth necessitated changes to the sampling schedule and the number of tissue samples analyzed, there were no significant changes in the experimental design of the project and no QAPP amendments were needed. All data for this project is being stored on the DEC server.

Data Generation and Acquisition

The sampling schedule planned for this project used a Systematic Random Sampling (SRS) method, which involves taking samples according to a pre-established schedule rather than in relation to particular conditions, such as weather or rainfall, and has been approved by the National Shellfish Sanitation Program (NSSP).

Data collection instruments were prepared in accordance with guidance in EPA's Generic Guide to Statistical Aspects of Developing an Environmental Results Program (Crow et al. 2003), specifically following a checklist, as developed for this project's Quality Assurance Project Plan. Calibration of the YSI was performed before leaving for the field in accordance with the manufacturer's instructions, with information recorded in a calibration data sheet. There were no issues identified regarding the instrument, and no data that did not meet the manufacturer-developed acceptance criteria.

Field sampling data sheets were completed by field staff at each sampling date, and were collected and retained by the Project Lead. Following NYSDEC's Vibrio Control Plan, kelp tissue samples were immediately placed into sterile plastic bags under temperature control using gel packs and maintained between 33ºF and 45ºF. All samples were handled using plastic gloves to minimize the risk of contamination. Tags were affixed to the sample bags with the time of harvest and the sampling location and Chain of Custody forms completed, and used

as a control document to track samples from harvest through analysis. Kelp tissue samples were shipped to the appropriate laboratory, within their listed hold times, and laboratory staff notified of sampling schedule to ensure timely refrigeration/processing of the samples after receipt.

Records and raw data including handwritten field notes, data sheets, field logs, analysis logs and results of instrument calibrations have been scanned into electronic format, with raw data entered into an Excel database. Computer-entered data was cross-referenced with field data and sample analysis results to confirm accuracy.

The following steps were taken to measure/estimate the effect of data errors, consistent with the NYSDEC Division of Water's Quality Management Plan (2016): Duplicate YSI profiles were taken at each sampling location per sampling event, with duplicate readings in conformance with listed YSI sensitivity criteria. For kelp tissue analysis, every batch run by Eurofins Food Integrity & Innovation had a validated control or a blank spike set with the batch. At least ten percent of the samples analyzed by UC Davis Analytical Laboratory were duplicated, with duplicate values falling within 8% of each other, and at least one standard reference material as analyzed with each set of samples. Data discrepancies or anomalies, if they had occurred, would have been flagged and brought to the attention of the Project Lead. No data points from the laboratory analysis were found to be high or low enough to necessitate re-analysis or re-sampling, nor was it expected that samples could be re-analyzed due to holding times or amounts of biomass submitted to the laboratories. During the project period, laboratory equipment was maintained by Certified Laboratories, Inc., Eurofins Food Integrity & Innovation, UC Davis Analytical Laboratory, and Brookside Laboratories, Inc. following their laboratory quality manuals. All instruments and equipment used within Certified Laboratories, Inc., Eurofins Food Integrity & Innovation, and UC Davis Analytical Laboratory are/were routinely calibrated by laboratory personnel throughout the project period.

Field equipment was inspected prior to use for cleanliness and needed repairs or adjustments. Equipment was rinsed with ambient water at each sampling site prior to use. After use at each sampling site, field equipment was cleaned according to the manufacturer's instructions, and then rinsed with ambient water prior to use at the next site. Water quality instruments were inspected before each use following the manufacturer's recommendations and protocols. The YSI sensor was calibrated prior to each sampling event according to the manufacturer's directions. There were no calibration failures to report during this study, but if there were, they would have been flagged so that affected parameters could be removed from the data and any reporting.

Project field team members were responsible for coordinating with the Project Lead to ensure maintenance of adequate supplies for kelp cultivation and water quality monitoring. The Project Lead was in attendance for most of the sampling dates, with additional supplies in hand. The Project Lead was also responsible for YSI equipment calibration for the sonde used at the East River and Northport Harbor sites, and Save the Sound handled YSI calibration for the Milton Harbor site. The Project lead was present at all tissue sampling dates and ensured that sterile sample bags, coolers, and all other sampling supplies were prepared, and also inspected for cleanliness and potential contamination prior to use. All laboratory supplies and materials were provided by Certified Laboratories, Inc., Eurofins Food Integrity & Innovation, UC Davis Analytical Laboratory, and Brookside Laboratories, Inc., with all supplies and materials washed and visually inspected for cleanliness and potential contamination by lab staff prior to use.

Field collected data was recorded on paper forms in the field, and once sampling events were completed, in cases where the Project Lead was not present, the field team reviewed the data

sheets and submitted them to the Project Lead. The Project Lead then scanned all hard copies and stored them electronically and maintained the original data sheets. Raw data was entered into a database by the Project Lead, and computer-entered data was then cross-referenced with field sheets at a later date for accuracy. Laboratory data and results were delivered electronically to NEIWPCC and the Project Lead, and were saved electronically to the NYSDEC server. Raw data from these reports were entered by the Project Lead into an Excel database. Computer-entered data was then cross-referenced with lab reports at a later date to ensure accuracy. The NYSDEC server is backed-up daily, and the data will be available upon the release of this report to other government agencies, researchers, and the general public upon request. Any third-party users will be informed of their restricted rights for using and editing the data.

Assessment and Oversight

Assessment and response actions and reports to management

The Project Lead thoroughly briefed project implementation staff before and after beginning their respective implementation tasks to identify any emerging/unanticipated problems. This was done through virtual meetings, and presence at significant field workdays (line deployment, tissue sampling, final harvest); identification of potential problems was also done through email correspondence and phone calls. Corrective actions or significant changes to the project were reported to the NEIWPCC QA Program Manager and the EPA Project Officer, and also reported in quarterly reports to the EPA – for this project, these changes/issues were limited to difficulties with kelp growth. Meetings were held with the NEIWPCC QA Program Manager and the EPA Project Officer, and after some discussion, these issues were not found to be severe enough to necessitate any QAPP amendments, though changes were noted and acknowledged.

At each sampling date, the Project Lead ensured that sampling occurred as planned, that there was sufficient written commentary and supporting photographs taken, that all necessary forms were properly completed, and that samples were kept under the needed conditions through shipment to analytical laboratories. The Project Lead was present at most sampling and monitoring dates, and in cases where they were not present, email updates with photos were sent to the Project Lead by project partners. No issues were encountered that required a suspension of work or any corrective actions.

There was an audit ordered by NEIWPCC in the Fall of 2021, which occurred during the fertilizer field trials, to assess conformance and compliance to the Quality Assurance Project Plan in accordance with the NEIWPCC Quality Management Plan. No compliance issues were found.

The Project Lead prepared quarterly progress reports during the course of the study. Quarterly progress reports from project partners were submitted to the NYSDEC Project Manager and the NEIWPCC Project Manager, and included the current status of ongoing work, accomplishments, and problems encountered. Quarterly reports were submitted to, and retained by, the EPA Project Officer by the NEIWPCC Project Manager.

Data Review and Evaluation

Field data was reviewed monthly during the kelp growing season to ensure quality, and data was examined for accuracy prior to inclusion in this report. Data verification and validation included check on existence and completion of all fields on data sheets, completeness of sampling events (which reflected changes necessitated by the limitation of kelp growth), completeness of Quality Control checks.

In addition to the review conducted by Certified Laboratories, Inc., Eurofins Food Integrity & Innovation, and UC Davis Analytical Laboratory staff to verify laboratory data quality, data was examined for accuracy prior to inclusion in this report. This included a review of laboratory-flagged data and outlier evaluation.

5. DELIVERABLES COMPLETED

Tissue Analysis and Related Data

The tables in this section of the report represent all data collected throughout the project period. Because there was limited tissue analysis data for two of the three sites, an emphasis was made here to compare data to the 2020 report to the Long Island Community Foundation, which was an earlier phase of this project, and used the same methodology. Data is presented in tables, or within the narrative, as statistical analyses were limited due to growth issues at the Milton Harbor and Northport Harbor sites, allowing for qualitative comparisons only No ANOVA could be done on tissue analysis data or growth rates across the three grow-out sites because there was little to no growth at the Milton Harbor and Northport Harbor sites. Only the following information will be compared among the sites: site information, water quality parameters, and nutrient content (Tables 1-4). Figures 6-8 also offer a visual comparison of the kelp between the three Long Island Sound sites.

Table 1. Site Characteristics and Information

Site ID	WC	NH	Bx
Location Description	Milton Harbor, adjacent to Hen Island	Northport Harbor, adjacent to Bird Island	East River, off Throggs Neck
Latitude	40.93718	40.89809	40.80698
Longitude	-73.7063	-73.36011	-73.8025
Project Partner(s)	Save the Sound and Hen Island	Cornell Cooperative Extension of Suffolk Count, Village of Northport	SUNY Maritime College
Depth at Mean Low Tide	7 ft	5 ft	40 ft
Length of Long Line	100 ft	100 ft	150 ft
Installation Date	1/14/21	1/13/21	1/14/21
Harvest Date	5/27/2021	5/27/2021	6/3/2021
# of Days for Cultivation	134	135	141

Table 2. Water Quality Measurements, 0.5 m from surface

Site ID	Time of Measurement	Temperature (C)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	Specific Conductance (uS/cm)	pH
WC							
April	3:30 pm	9.2	11.5	26.21	28.62	41039	8.18
May	4:00 pm	11.28	9.33	26.07	30.12	40874	7.95
May	4:00 pm	14.75	7.81	28.73	35.83	44464	7.75

NH							
April	11:20 am	11.56	7.12	25.6	29.813	40778	7.65
May	10:15 am	19.47	7.33	27.88	38.612	43184	7.65
Bx							
April	10:20 am	9.59	8.75	25	27.802	40191	7.92
June	9:30 am	14.65	6.53	27.21	33.967	42310	7.5

Table 3. Water Quality Measurements, at depth

Site ID	Time of Measurement	Temperature (C)	Dissolved Oxygen (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	Specific Conductance (uS/cm)	pH
WC							
April	3:30 pm	8.3	10.81	26.43	28.32	41591	8.11
May	4:00 pm	10.43	9.31	26.56	30.022	41592	7.96
May	4:00 pm	13.015	7.36	28.81	34.428	44629	7.74
NH							
April	11:20 am	11.561	7.41	25.9	30.138	41217	6.9
May	10:15 am	19.036	7.02	27.91	38.1314	43243	7.62
Bx							
April	10:20 am	8.54	8.12	26.5	28.587	42637	7.9
June	9:30 am	14.09	6.57	27.86	34.236	43237	7.6

Table 4. Nitrogen and Carbon Data

Site ID	Total Nitrogen	Total Carbon
WC		
May	3.01	22.1
NH		
May	1.23	31.3
Bx		
April	3.29	31.7
June	4.16	32.1

*Results reported on a 100% dry weight basis

Of the three sites, the East River site was the deepest, but water quality measurements fell within the range of the Milton Harbor and Northport Harbor sites, and appeared to have conditions that would be conducive to kelp growth (e.g., based on salinity, pH, etc.). This indicates that differences in the water quality parameters measured may not have been solely responsible for differences in the kelp growth between the sites. It should be noted that point measurements of parameters such as temperature and dissolved oxygen, which vary during the day, may not give the full picture. Although not measured during the course of the study, there were differences in current speed between the sites, with the East River having the fastest currents, followed by Milton Harbor, and the location within Northport Harbor being more or less stagnant, at least at the times of the site visit. It may be likely that differences in growth were due to differences in spool quality, but possible that the East River site also had some benefits over the other sites, as nitrogen and carbon content were also the highest in blades grown at the East River site. It is unclear what those beneficial differences were.

Tables 5-9 show data from the East River, Bronx site, as well as comparisons to 2020 data from the south shore of Long Island. Note again that there was not enough kelp biomass present at the Milton Harbor and Northport Harbor sites to allow for tissue analysis beyond nitrogen and carbon content. Note that the highest values for each parameter are in bold for emphasis. There were no pesticides detected at the East River site, so no table is included here. Eurofins Food Integrity & Innovation completed the metal, nutrient, organic pollutant and pesticide analysis, Certified Laboratories, Inc. completed the pathogen analysis, and the University of California, Davis Analytical Laboratory completed the nitrogen and carbon analysis for this project.

Table 5. Pathogen Data at two dates in the East River, and compared to 2020 Long Island, South Shore data

*Note that only the East River site had enough biomass to allow for these analyses

	East River, Bronx	East River, Bronx	Site A5, 2020	Site A12, 2020	Site NS, 2020
Parameter	4/21/21	6/4/21			
Aerobic Plate Count	**1200 CFU/g**	150 CFU/g	190 CFU/g	290 CFU/g	90 CFU/g
Coliform	**460 MPN/g**	3.6 MPN/g	Not available	Not available	<0.3 MPN/g
E. Coli O157:H7	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
Enterococcus	<10 CFU/g	<10 CFU/g	<10 CFU/g	<10 CFU/g	<10 CFU/g
Fecal Coliform	**9.3 MPN/g**	<3.0 MPN/g	Not available	Not available	<0.3 MPN/g
Salmonella	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
Shigella	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
Shiga-Toxin Producing E. Coli					
E. Coli O121	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
E. Coli O103	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
E. Coli O111	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
E. Coli O145	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
E. Coli O45	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
E. Coli O26	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g	NEGATIVE/25g
Vibrio Species	NEGATIVE/25g	PRESENT/25g	PRESENT/25g	PRESENT/25g	PRESENT/25g
Bacterial Identification	N/A	*Vibrio alginolyticus*	Not available	Not available	Not available

*Highest level for each parameter is in bold.

Table 6. PCB Tissue Analysis in the East River, compared to 2020 Long Island, South Shore data

Parameter/Site	East River, 2021	Site A5, 2020	Site A12, 2020	Site NS, 2020
Total PCBs (ng/kg)	328	194	155	**484**
Monochloro Biphenyls (ng/kg)	**17.3**	9.54	6.76	6.97
Dichloro Biphenyls (ng/kg)	**106**	44.8	34.1	95.3
Trichloro Biphenyls (ng/kg)	45.2	16.7	13.1	**79.5**
Tetrachloro Biphenyls (ng/kg)	39.8	16.8	15.5	**58.4**

Pentachloro Biphenyls (ng/kg)	49.4	22.7	11.2	**81.9**
Hexachloro Biphenyls (ng/kg)	45	25.2	21.3	**108**
Heptachloro Biphenyls (ng/kg)	18.4	21	26.4	**48.3**
Octochloro Biphenyls (ng/kg)	2.68	**11.5**	8.92	6.33
Nonachloro Biphenyls (ng/kg)	**1.33**	ND	1.16	ND
Decachloro Biphenyls (ng/kg	2.08	**26**	16.4	ND

*Highest level for each parameter is in bold.

Table 7. Micronutrient Analysis in the East River, compared to 2020 Long Island, South Shore data

Parameter/Site	East River, 2021	Site A5, 2020	Site A 12, 2020	Site NS, 2020
Boron (B), ppm	19.9	18.2	21.9	**26.3**
Calcium (Ca), ppm	1690	2690	**3120**	2860
Copper (Cu), ppm	0.826	**3.79**	1.73	1.75
Iron (Fe), ppm	73.4	**194**	159	138
Magnesium (Mg), ppm	**1000**	827	892	897
Manganese (Mn), ppm	6.76	**21.4**	14.8	7.42
Potassium (K), ppm	8960	11900	10300	**13800**
Sulfur (S), ppm	**1180**	857	**1180**	1100
Zinc (Zn), ppm	**10.2**	4.41	3.77	6.1

*Highest level for each parameter is in bold.

Table 8. Heavy Metal Analysis in the East River, compared to 2020 Long Island, South Shore data

Parameter/Site	East River, 2021	Site A5, 2020	Site A12, 2020	Site NS, 2020
Cadmium, ppb	30.5	30	**48.7**	Not reported
Chromium, ppb	190	270	568	**777**
Nickel, ppb	125	140	202	**347**
Total Heavy Metals, ppm	<5	<5	<5	<5

*Highest level for each parameter is in bold.

Table 9. Polycyclic Aromatic Hydrocarbons (PAH) Analysis in the East River, compared to 2020 Long Island, South Shore data

Parameter/Site	East River, 2021	Site A5, 2020	Site A12, 2020	Site NS, 2020
Benz(a) anthracene, ppb	**0.348**	<0.250	<0.250	<0.250
Benzo(a)pyrene, ppb	**0.414**	<0.250	<0.250	<0.250
Chrysene, ppb	**0.686**	<0.250	0.313	<0.250
Sum of PAH analytes	**1.93**	<1.00	0.648	Not reported

*Highest level for each parameter is in bold.

The East River site, compared to 2020 south shore of Long Island sites, had the highest aerobic plate count, Coliform and Fecal Coliform levels in April, but as with the 2020 sites, were non-detectable for E. coli, Shiga toxin-producing E. coli, Enterococcus,

Salmonella, and Shigella. However, these levels appeared to decrease somewhat at the time of harvest (June). Similar to the 2020 sites, Vibrio species were found at the harvest date, but not the earlier sampling date. The species identified was *Vibrio alginolyticus*. Micronutrient and PCB analysis comparison to the 2020 sites did not show any information to indicate that there were any noteworthy differences between the sites, but heavy metal readings at the East River site appeared to be lower than, or quite similar to, the 2020 south shore sites. The other result of note here was that PAH levels in the East River were higher than at any of the 2020 south shore sites, and this is something that may warrant further study, and have an effect on uses of the harvested kelp tissue.

There are no limitations that should be placed on the use of this data. No data points needed to be flagged, and all data complied with the quality assurance planning done prior to the start of the project

Sugar Kelp Growth Information

There were 10 blades present on the line at Northport Harbor at the time of harvest. Their average length was 19.4 cm, with a total biomass weight of 70 g. There were approximately 30 blades of kelp on the line at Milton Harbor at the time of harvest. Their average length was 17.6 cm, with a total biomass weight of 120 g. The final biomass weight at harvest for the East River site was 178 pounds, or 80.74 kg. The average blade length at harvest at the East River site was 64.6 cm, or 2.12 ft. Figures 6-8 are examples of blades collected at the East River, Northport Harbor, and Milton Harbor sites, respectively. As can be seen in these photos, the Milton Harbor site had the lightest-colored blades, and they were significantly less-fouled than the Northport Harbor site.

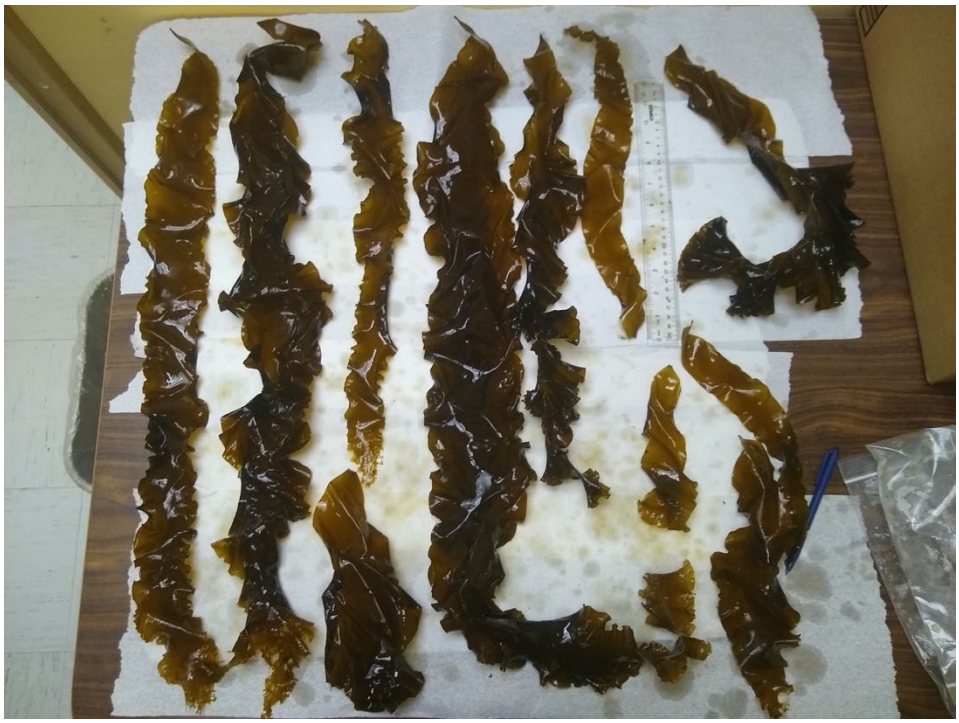


Figure 6. East River kelp at final harvest (photo credit: Kristin Kraseski)

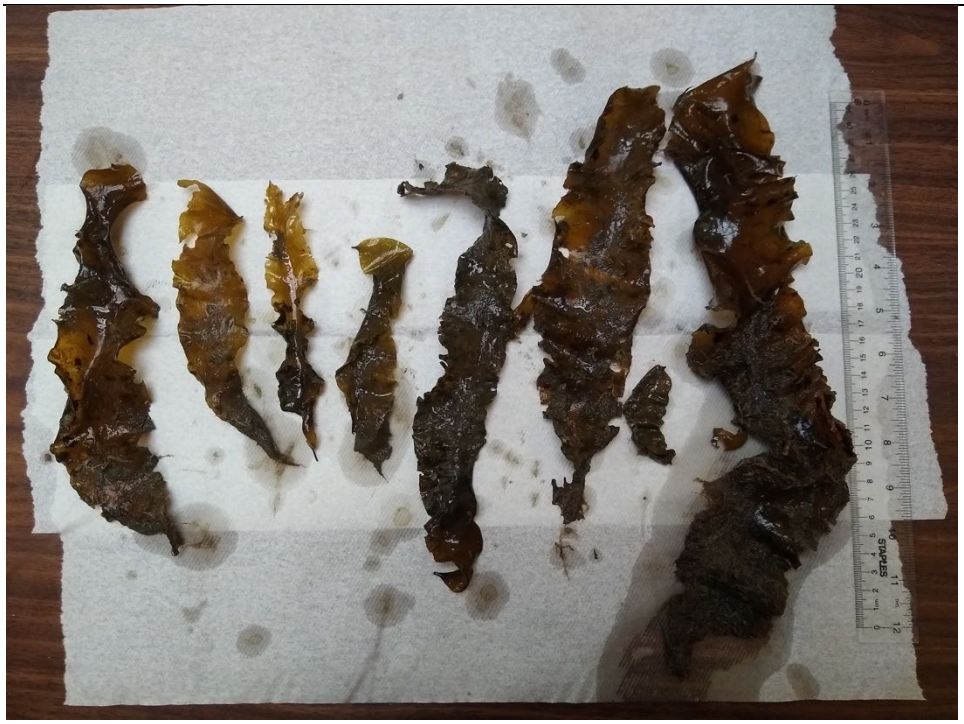


Figure 7. Northport Harbor kelp at final harvest (photo credit: Kristin Kraseski)

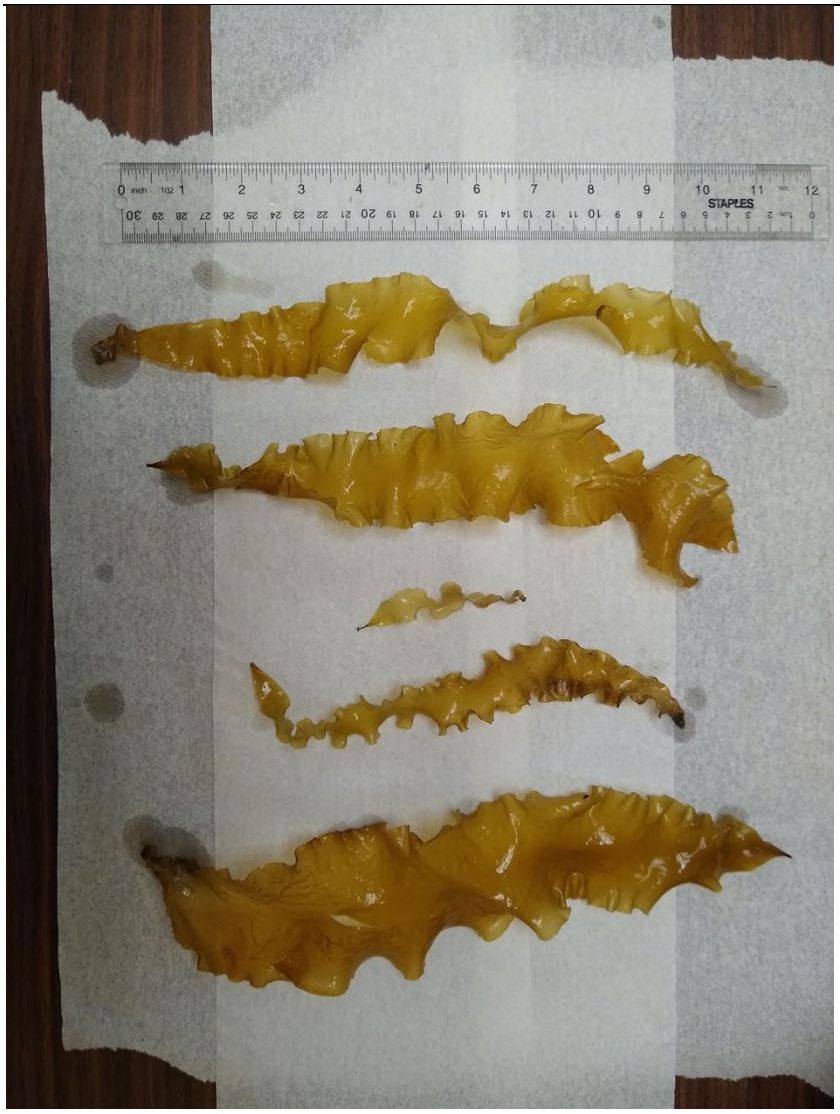


Figure 8. Milton Harbor kelp at final harvest (photo credit: Kristin Kraseski)

Estimates of Nitrogen and Carbon Removal Through Bioextraction

The following section shows calculations for determining the amount of nitrogen and carbon removed by this pilot study, as well as estimates of how much nitrogen and carbon would be removed if this pilot had been scaled up to a one-acre or five-acre plot, using the East River site data.

Using the length of line at the East River site, and the biomass harvested from that site, it is estimated that there was 1.79 kg of kelp per meter of the line, as fresh weight

$$80.74\ kg/45\ m = 1.79 kg/m$$

The carbon and nitrogen content results were based on dry weight, so our fresh weight measurements, taken on the day of harvest need to be converted to dry weight. This can be done using an equation given by Gavaert et al.

$$Dry\ weight(DW) = 0.113 \times Fresh\ weight$$

$$DW = 0.113 \times 1.79 kg/m = 0.2 kg/m$$

The dry weight of the entire East River line at harvest would then be 9.12 kg.

The Total Nitrogen content (% of dry weight) at the time of harvest in the East River was 4.16%, so the mass of nitrogen removed from the water during the growing season from the whole line was,

$$9.12\ kg \times 0.0416 = 0.38\ kg$$

And the mass of nitrogen per meter of line was,

$$0.2kg \times 0.0416 = 0.00832\ kg\ TN$$

The Carbon content (% of dry weight) at the time of harvest in the East River was 32.1%, so the mass of carbon removed from the water during the growing season from the whole line was,

$$9.12\ kg \times .321 = 2.93kg$$

And the mass of carbon per meter of line was,

$$0.2kg \times .321 = 0.0642kg\ C$$

To estimate the nitrogen and carbon removal rates using this East River data, scaled up to a one- and five-acre farm are as follows, assuming 250 ft long lines with 15 ft between the lines. This implies that there would be 11 lines in each acre farm, with a total line length of 838 meters.

Nitrogen removal over one growing season for a one-acre farm:

$$0.00832kg\ N/m \times 838m = 6.97kg\ N$$

For a five-acre farm, that would be 34.85kg of nitrogen removed over one growing season.

Carbon removal over one growing season for a one-acre farm:

$$0.0642kg\ N/m \times 838m = \ 53.8kg\ C$$

For a five-acre farm, that would be 269 kg of carbon removed over one growing season.

These numbers are considerably lower than were reported in 2020, from the south shore of Long Island, again due to growth issues this year. For the 2020 south shore, Long Island project, the nitrogen removal from a one-acre farm were in the range of 17.9 – 39 kg. In Kim, et al. 2015, the numbers were in the range of 44.2 – 96.3 kg of N removal per acre. Compared to the 2020 south shore Long Island sites, there was considerably less biomass at the East River site in 2021, and this appears to be due to differences in blade length, but also differences in density on the line. In fact, there was sections of the line in the East River that were almost completely bare.

Results from the fertilizer portion of this study are contained in the Appendix, in a final report written by partners at Cornell Cooperative Extension of Suffolk County.

6. CONCLUSIONS

Project Accomplishments

The data from this project provides some baseline information necessary to assess the effectiveness of nutrient bioextraction using *Saccharina latissima* as a management strategy and contributes to the critical data needs of an emerging industry by providing data on nutrient removal rates, public health concerns and state and federal health/sanitation standards. The success at the East River site contributed data on the nutrient content, and therefore nutrient removal rates, of sugar kelp, as well as important micronutrient and contaminant data, that may have impacts on how the harvested kelp could be used in commercial settings. Additionally, sugar kelp fertilizer amendments were found to be comparable to other commercially available seaweed amendments in a field setting for tomatoes.

Lessons Learned

As there were issues with kelp growth at two of the three sites, an important lesson learned was that there needs to be a way to ensure consistent and reliable kelp spools at the start of the growing season. This was a pilot project, that should be considered an early stage of determining the technical feasibility of using *Saccharina latissima* as a commercial crop and a nutrient mitigation strategy, and the results from this study point out effective kelp spool production as one of the most vital components of such projects.

Possible Future Work

Future work using *Saccharina latissima* for bioextraction could be done within the Long Island Sound to contribute additional data for the emerging industry, as there were issues in growth that may have been related to the viability of the kelp spools used, rather than some inherent characteristics of the sites used. The issue of kelp spool viability could also be addressed by a systematic assessment of the nursery methods used, and why there might have been differences between nurseries, or between years at the same nursery. Spore releases in the nursery may base their success partly on the timing of kelp reproductive tissue collection, and water temperatures at the time of collection. This issue has the potential to be addressed by attempting to gain some control over the timing of the reproductive process. This may be done through conditioning of kelp reproductive tissue to induce spore release in the nursery, or perhaps even long-term storage of successfully released spores. Either of these methods may lead to more consistently reliable seed spools, with the ultimate goal of supporting an industry that will remove nitrogen from coastal waters.

7. REFERENCES

Crow, Michael et al. Generic Guide to Statistical Aspects of Developing an Environmental Results Program. United States Environmental Protection Agency OPEI, 2003.

Gavaert, F. et al. “Carbon and nitrogen content of Laminaria saccharina in the eastern English Channel: biometrics and seasonal variations.” J. Mar. Biol. Assoc. U.K. Vol. 81, 2001, pp. 727-734.

Kim, Jang K. et al. “Use of sugar kelp aquaculture in Long Island Sound and the Bronx River Estuary for nutrient extraction.” Marine Ecology Progress Series. Vol. 531, 2015, pp.155-166.

NEIWPCC. Utilizing Seaweed Aquaculture to Improve Water Quality in the Long Island Sound Quality Assurance Project Plan, Version 2. NEIWPCC, 2021.

NEIWPCC. Utilizing Seaweed Aquaculture to Improve Water Quality in new York’s Coastal Waters Quality Assurance Project Plan, Version 3.1. NEIWPCC 2020.

New York State Department of Environmental Conservation. Quality Assurance Management Plan for the Division of Water. Revision No. 14 - 02, 2016, http://internal.dec.state.ny.us/docs/dowdocs/2019_qamp.pdf

Seatuck Environmental Association. The Great Cove Citizen Science Monitoring Project QAPP. South Shore Bays, NY: Seatuck Environmental Association, 2019.

8. APPENDICES

Saccharina latissima (Sugar Kelp) Fertilizer Pilot Study Final Report

Saccharina Latissima (Sugar Kelp) Fertilizer Pilot Study, Year 2
Final Report

NEI Job Code: 0348-008
Project Code: S-2021-016
Contractor: Cornell Cooperative Extension of Suffolk County (CCE)
Contact: Nora Catlin, (631) 727-7850 x 214, nora.catlin@cornell.edu

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement (LI-00A00384) to NEIWPCC. The contents of this document do not necessarily reflect the views and policies of NEIWPCC or the EPA, nor does NEIWPCC or the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

Evaluation of Soil and Foliar Applied Kelp on Field Grown Tomatoes – Year 2
Sandra Menasha, Vegetable/Potato Specialist, Cornell Cooperative Extension – Suffolk County
Deborah Aller, Agriculture Stewardship Specialist, Cornell Cooperative Extension – Suffolk County

Introduction:

The project was conducted to evaluate the potential for using sugar kelp (*Saccharina latissima*) grown in and harvested from Long Island waters as an amendment for local agricultural crops. Kelp and other marine plants have long been used by farmers to improve soil nutrient levels, crop yields and quality. Kelp fertilizer is valued for its ability to provide needed micronutrients to crops, as it is not a significant source of macronutrients (nitrogen (N), phosphorus (P), and potassium (K)). Additionally, numerous research studies have focused on the biostimulant effects of various types of kelp or seaweed (in the 2018 Farm Bill a biostimulant is described as "a substance or micro-organism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield"). Numerous kelp and seaweed fertilizer products are currently available to growers, but if kelp can be grown, harvested, processed, and utilized locally the sustainability of both the marine and agricultural industries on Long Island may improve. Specifically, this project investigated the impact of two different types of kelp amendments and application methods on plant and soil properties. This report discusses results from year 2 of a two-year project.

Materials & Methods:

Kelp meal produced in 2020 was used both as the soil applied kelp meal and to produce the kelp extract used in 2021. For the kelp meal, locally harvested sugar kelp was delivered on May 19, 2020 to the Long Island Horticulture Research and Extension Center (LIHREC) in Riverhead, NY. The kelp was rinsed thoroughly with fresh water and line dried in a greenhouse for 3 days. The kelp was then cut off the growing lines, crushed into smaller pieces by hand into paper bags, and the paper bags were placed in a drying oven at 160 °F for 48 hours. After drying, the kelp was crushed and ground into a coarse meal using a Meadow Mills steel burr commercial grain mill (Meadow Mills, North Wilkesboro, NC). The extra meal not used in 2020 was stored in plastic lined paper bags in a greenhouse. It was concluded that little to no changes in the kelp meal occurred during storage and it was acceptable to use in 2021 for the experimental treatments. To prepare the extract for foliar applications, the meal was ground into smaller particles using a handheld coffee/spice grinder. Kelp extract was prepared for each application by boiling 10g of finely ground dried kelp, in 100 ml of distilled water for 30 minutes. The solution was then pre-filtered through a cheesecloth and then filtered through #4 Whatman paper.

In May 2021, a field trial was established to evaluate the impact different application rates of locally produced kelp meal and extract compared to commercial kelp products had on field grown tomato yield and quality. The experiment was arranged as a randomized complete block design with four replications per treatment in a Haven loam soil. A standard fertilizer (10-10-10) was applied to each treatment at either a high (1000 lbs/A) or low (800 lbs/A) rate. The standard fertilizer and kelp meal soil applications were applied prior to planting (Image 1). The kelp extract foliar applications were applied four times using a CO_2 backpack sprayer and continued every two weeks until harvest (Image 2). Commercially available products were applied according to label rate recommendations. A total of 12 treatments were evaluated:

1. Sugar kelp meal at 75 lbs/A plus standard fertilizer at 1000 lbs/A (10-10-10)
2. Sugar kelp meal at 150 lbs/A plus standard fertilizer at 1000 lbs/A (10-10-10)
3. Sugar kelp meal at 75 lbs/A plus standard fertilizer at reduced rate (20% reduction) at 800 lbs/A
4. Sugar kelp meal at 150 lbs/A plus standard fertilizer at reduced rate at 800 lbs/A
5. Commercial kelp meal A (Fertrell) at 150 lbs/A plus standard fertilizer at 1000 lbs/A
6. Commercial kelp meal B (Neptune Harvest) at 435 lbs/A plus standard fertilizer at 1000 lbs/A
7. Sugar kelp extract, plus standard fertilizer rate at 1/3 oz/gal plus standard fertilizer at 1000 lbs/A
8. Commercial kelp extract A (Fertrell) at 1/3 oz/gal plus standard fertilizer at 1000 lbs/A
9. Commercial kelp extract B (Neptune Harvest) at 1 oz/gal plus standard fertilizer at 1000 lbs/A
10. Control; standard fertilizer rate only at 1000 lbs/A 10-10-10
11. Standard fertilizer rate at 1000 lbs/A 10-10-10 plus sugar kelp at 300 lbs/A
12. Reduced fertilizer rate at 800 lbs/A 10-10-10 plus sugar kelp at 300 lbs/A

Treatment plots consisted of a single row or bed of 8 tomato plants. Plants were spaced 24" apart within the bed and beds were spaced 5.67 feet apart on center. Fertilizer and kelp meal applications were made by hand onto each bed and incorporated into the top three inches of the soil. Beds were then fitted with black plastic mulch and drip irrigation. Transplants of 'BHN 589' tomato were started in the greenhouse on April 19, 2021 in 50-cell tray flats, allowed to harden prior to planting and field set on May 28, 2021. Kelp foliar applications were applied 4 times on July 1, 16, 29 and August 19, 2021. Leaf samples were collected from each treatment plot at harvest and sent to Brookside Labs (Ohio) for % total nitrogen analysis. Tomatoes were harvested three times on August 26, September 2 and 9, 2021. Fruit were counted, weighed, and sorted into five different size classes (Image 3). Data on Brix levels (% soluble sugars) were also recorded. Fruit from each treatment plot were collected at the

2nd harvest and also sent to Brookside Labs (Ohio) for nutrient analysis. Pre- and post-trial soil samples were collected and analyzed to evaluate differences in nutrient levels and pH between treatments. Soil samples were sent to Pace Analytical Laboratories (NY). All data collected from the field trial were analyzed using one-way ANOVA in SUPERANOVA. Statistical significance was assessed at the 5% alpha level.

Results and Discussion:

Yield results from the trial were not significantly different among the treatments evaluated; early and total marketable yields were as well as the size distribution of the fruit (Table 1). There were also no significant differences in Brix levels of the fruit among the different treatments. A nutrient analysis of the fruit revealed no significant differences in micronutrient levels and at harvest, a leaf analysis showed no significant differences in N levels (Tables 3 and 4). These results are similar to year 1 where there were no significant differences in yield, fruit quality, or tissue N levels found. These results suggest that locally harvested sugar kelp performs similarly to commercially available kelp products and can be used as a soil and foliar applied amendment in tomato production on Long Island.

No significant differences were found between treatments on any of the soil parameters measured (Table 2). After year 1 of the experiment, we hypothesized that no differences in soil nutrient levels and foliar nitrogen content were found because of kelp application rates. However, this year, two high sugar kelp application rate treatments (300 lbs/A) were added, and no differences were found. This supports that sugar kelp meal and extracts do not need to be applied to crops above the current recommended application rates for commercial products. Also, it is important to mention that growing conditions in 2020 and 2021 differed. According to the US Drought Monitor, the summer of 2020 was abnormally dry from mid-June through July and then moved into a moderate drought for the entire month of August. Meanwhile, there was adequate rainfall throughout summer 2021 and no abnormally dry or drought periods were observed. As previously discussed, sugar kelp has been shown to have a biostimulant effect on plant growth, thus the resiliency of the tomato plants to other potential stresses including more variable weather may have been improved, but quantifying these changes is difficult particularly in a field setting.

Image 1. Soil applied sugar kelp meal. Photo taken on May 27, 2021 during trial setup.

Image 2. Foliar kelp applications. Photo taken on August 19, 2021.

Image 2. Sizing tomatoes during the 2nd harvest on September 2, 2021.

Table 1. Kelp and fertilizer effects on the yield of 'BHN 589' tomato grown in Riverhead, NY- 2021

			Marketable		Size Distribution					Avg.	
	10-10-10[1]	Kelp[2]	Early[3]	Total[4]	Boxes/A[5]					Wt./Fruit	Brix[6]
Treatment	lbs/A	lbs/A	(boxes/A)	(boxes/A)	2"	2.5"	3"	3.5"	>3.5"	(lbs)	(%)
Low rate sugar kelp meal	1000	75	744	2,716	0	179	754	1,265	518	0.50	5.1
High rate sugar kelp meal	1000	150	757	2,526	1	157	705	1,124	539	0.50	5.2
Low rate sugar kelp meal +20% standard reduction	800	75	628	2,365	1	103	657	1,003	601	0.52	5.0
High rate sugar kelp meal +20% standard reduction	800	150	583	2,304	1	170	584	1,045	504	0.51	5.0
Fertrell commercial kelp meal	1000	150	776	2,661	3	157	741	1,108	652	0.52	5.3
Neptune's commercial kelp meal	1000	435	705	2,507	0	128	747	1,141	490	0.52	5.3
Sugar kelp extract	1000	Foliar	728	2,283	1	98	503	1,068	613	0.55	5.3
Fertrell commercial kelp extract	1000	Foliar	808	2,510	0	109	597	1,251	553	0.51	5.2
Neptune commercial kelp extract	1000	Foliar	600	2,408	0	126	587	1,128	566	0.51	5.0
Standard fertilizer	1000		797	2,462	0	110	562	1,179	612	0.53	5.1
Standard fertilizer + high rate sugar kelp meal	1000	300	579	2,216	1	98	533	1,072	512	0.53	4.9
Reduced fertilizer + high rate sugar kelp meal	800	300	688	2,411	0	115	591	1,148	557	0.52	5.6
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Treatment			0.7528	0.5986	0.3732	0.3756	0.0936	0.6332	0.8599	0.4160	0.4161

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Early marketable yields from the first harvest on 8/26 and included all fruit size distribution classes.

[4] Total marketable yields included all fruit sizes and were from fruit harvested on 8/26, 9/2 and 9/9.

[5] Box equals 25 lbs.

[6] Soluble solids; average from all 3 harvests

Table 2. Treatment effects on soil properties of 'BHN 589' tomato grown in Riverhead, NY- 2021

			Soil Nutrients[3]															
	10-10-10[1]	Kelp[2]	Aluminum	Boron	Calcium	Copper	Iron	Magnesium	Manganese	Potassium	Sodium	Sulfur	Zinc	Phosphorus		% Moisture	Nitrate	Nitrite	Total N
Treatment	lbs/A	lbs/A	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	pH	(%)	(mg/kg)	(mg/kg)	(mg/kg)
Low rate sugar kelp meal	1000	75	12950	2.58	847.00	35.23	11750	1460	92.7	665	257.75	86.80	25.93	1194	5	13.90	2.2	1.175	63.4
High rate sugar kelp meal	1000	150	13825	2.78	879.50	36.55	12725	1560	101.8	704	273.5	97.45	26.38	1216.25	5.1	14.75	1.725	1.2	51.0
Low rate sugar kelp meal +20% std. reduction	800	75	13750	2.75	924.50	36.78	12475	1557.5	94.8	707.75	274.75	96.05	26.70	1257.5	5.2	13.45	2	1.125	56.1
High rate sugar kelp meal +20% std. reduction	800	150	14025	2.45	956.25	34.20	12575	1617.5	108.7	735.25	242.25	85.90	26.30	1172	5.2	14.48	1.675	1.2	47.9
Fertrell commercial kelp meal	1000	150	13750	2.80	1095.75	34.75	12625	1732.5	94.5	670.25	279	93.03	27.13	1257.5	5.1	14.93	1.825	1.15	34.6
Neptune's commercial kelp meal	1000	435	13550	2.85	948.25	32.28	12700	1652.5	103.0	727.5	284	96.30	26.80	1174.75	5.1	14.03	1.9	1.175	52.8
Sugar kelp extract	1000	Foliar	13875	2.73	833.00	36.23	12625	1590	100.8	676.5	272.25	86.43	27.73	1271	5.2	13.98	1.875	1.175	33.5
Fertrell commercial kelp extract	1000	Foliar	13525	2.93	875.25	32.55	12250	1560	97.5	722	292	85.68	25.88	1135	5.2	13.95	1.325	1.175	65.8
Neptune commercial kelp extract	1000	Foliar	13850	2.65	997.75	35.33	12575	1610	91.5	699.25	264.75	95.83	26.85	1240.25	5.1	13.68	2.575	1.175	38.9
Standard fertilizer + high rate sugar kelp meal	1000	300	12425	2.65	806.75	29.90	11450	1435	96.3	645.25	263.75	80.35	24.43	1090.75	5.1	13.88	1.725	1.2	49.2
Reduced fertilizer + high rate sugar kelp meal	800	300	13175	2.80	824.00	28.70	12152.5	1602.5	99.0	677.75	280.25	86.85	26.78	1181.25	5.1	14.35	1.65	1.175	67.4
Standard fertilizer	1000		13800	2.85	899.25	32.10	12490	1657.5	101.2	685.5	286.5	104.20	26.03	1165.25	5.3	13.88	1.875	1.175	39.2
Fisher's Protected LSD (0.05)			*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Treatment			0.9642	0.7228	0.2813	0.904	0.9596	0.9955	0.9883	0.9291	0.6669	0.7099	0.9859	0.9999	0.1745	0.8771	0.402	0.5193	0.833

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflect treatment specifications

[3] Soil samples taken on September 14th and sent to PACE

Table 3. Effects of kelp and fertilizer applications on tissue nitrogen of 'BHN 589' tomato grown in Riverhead, NY- 2021

Treatment	10-10-10[1] lbs/A	Kelp[2] lbs/A	Nitrogen[3] (%)
Low rate sugar kelp meal	1000	75	2.49
High rate sugar kelp meal	1000	150	2.39
Low rate sugar kelp meal +20% standard reduction	800	75	2.39
High rate sugar kelp meal +20% standard reduction	800	150	2.26
Fertrell commercial kelp meal	1000	150	2.67
Neptune's commercial kelp meal	1000	435	2.12
Sugar kelp extract	1000	Foliar	2.64
Fertrell commercial kelp extract	1000	Foliar	2.20
Neptune commercial kelp extract	1000	Foliar	2.36
Standard fertilizer	1000		2.20
Standard fertilizer + high rate sugar kelp meal	1000	300	2.42
Reduced fertilizer + high rate sugar kelp meal	800	300	2.37
Statistical Analysis (0.05)			p-value
Treatment			0.8312

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Total Nitrogen by Combustion Test, Brookside Laboratories Inc., Ohio taken on 9/11/21. Adequate range during harvest period (2.0-3.0).

Table 4. Effects of soil and foliar applied sugar kelp on fruit nutrient levels of 'BHN 589' tomato grown in Riverhead, NY- 2021

Treatment	10-10-10[1] lbs/A	Kelp[2] lbs/A	Ave wt (g)	Moisture (%)	Nitrogen (%)	Phosphorus (ppm)	Calcium (ppm)	Magnesium (ppm)	Potassium (ppm)	Boron (ppm)	Manganese (ppm)	Copper (ppm)	Zinc (ppm)	Iron (ppm)	Sulfur (ppm)
Low rate sugar kelp meal	1000	75	252.0	94.7	1004.9	281.6	49.2	99.7	2310.8	0.6	1.0	0.5	1.2	2.0	108.9
High rate sugar kelp meal	1000	150	259.9	94.8	843.4	252.3	41.4	91.5	2249.3	0.7	1.0	0.7	0.9	1.8	103.4
Low rate sugar kelp meal +20% standard reduction	800	75	270.2	94.6	995.5	271.2	40.8	102.5	2450.3	0.7	1.0	0.7	1.0	2.0	108.4
High rate sugar kelp meal +20% standard reduction	800	150	265.4	95.0	983.9	261.5	36.7	100.8	2419.5	0.7	1.0	0.8	0.9	1.7	104.3
Fertrell commercial kelp meal	1000	150	242.3	94.8	875.3	255.4	49.6	98.2	2337.8	0.6	1.0	1.0	0.9	1.6	99.0
Neptune's commercial kelp meal	1000	435	263.9	94.6	1007.2	251.9	36.2	94.2	2255.5	0.6	1.0	0.9	0.9	1.8	98.2
Sugar kelp extract	1000	Foliar	270.7	94.6	1041.5	269.0	36.2	99.8	2343.8	0.7	1.0	6.9	1.0	1.9	100.6
Fertrell commercial kelp extract	1000	Foliar	269.2	94.8	1012.4	265.2	40.2	99.5	2348.5	0.6	1.0	0.6	1.0	1.8	103.8
Neptune commercial kelp extract	1000	Foliar	255.4	94.6	852.4	263.2	54.0	103.4	2387.5	0.7	1.0	0.7	1.0	2.1	109.8
Standard fertilizer	1000		255.1	94.6	659.2	241.7	39.3	86.0	2160.5	0.7	1.0	0.7	0.8	1.5	93.7
Standard fertilizer + high rate sugar kelp meal	1000	300	260.9	94.3	897.7	252.2	47.5	99.9	2398.5	0.7	1.0	1.5	1.0	1.9	105.8
Reduced fertilizer + high rate sugar kelp meal	800	300	255.6	94.0	888.4	292.2	45.7	113.7	2699.5	0.9	1.0	1.7	1.1	2.0	109.6
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Treatment			0.9237	0.5222	0.3355	0.6666	0.3764	0.3257	0.2314	0.0729	0.0000	0.4632	0.3791	0.6221	0.7636

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

Evaluation of Application of Sugar Kelp Extract to Greenhouse-Grown Tomato Seedlings and Petunia and Tomato Transplants

Nora Catlin, Floriculture Specialist, Cornell Cooperative Extension – Suffolk County

This is the second year of a two-year trial which investigated whether the sugar kelp (*Saccharina latissima*) would result in similar benefits on plant growth as other commercially available seaweeds, in particular Norwegian kelp (*Ascophyllum nodosum*), or rockweed. Two trials were conducted on greenhouse plants to evaluate the possible effects of locally grown sugar kelp extract applied as an amendment. One trial studied the effects of sugar kelp extract on germination and seedling growth of tomato. The second trial studied the effects of kelp extract on two common greenhouse crops, tomato and petunia, grown using different fertilizer rates – a standard rate and a 50% rate.

Materials and Methods – Tomato Seedling Trial

Kelp Drying and Processing

On 3-June, locally harvested sugar kelp was delivered to the Long Island Horticulture Research and Extension Center (LIHREC) in Riverhead, NY. The kelp was rinsed thoroughly with fresh water and line dried in a greenhouse. The kelp was then cut off the growing lines, crushed into smaller pieces by hand into paper bags, and the paper bags were placed in a drying oven at 160°F for 48 hours. After drying the kelp was crushed and ground into a coarse meal using a standard kitchen food processor.

Kelp Extract Procedure

Kelp extract was prepared for each application by boiling 10g of finely ground, dried kelp, in 100 ml of distilled water for 30 minutes. The solution was then filtered first through cheesecloth then through #4 Whatman paper.

Trial Procedures

Tomato 'Celebrity' were seeded on 29-June using ProMix BX Mycorrhizae growing media. Seeds were seeded into individual cells of 105-plug trays. Trays were cut in half, creating 49 cells, and treatments were replicated over six 49-cell trays. Seedlings were irrigated with clear water until the appearance of first true leaves, after which seedlings were fertigated every other irrigation using 50 ppm N of 15-5-15 fertilizer.

Trays were treated weekly treatments (30-Jun, 8-Jul, 14-Jul, 21, Jul, 28-Jul) of two rates of kelp extract (1%, 10 mL/L, and 0.5%, and 5 mL/L) and a water control. Kelp treatments and the water control were applied weekly, using a watering can; each cell was estimated to receive 4-5 ml of solution.

Germination rates were recorded daily from seeding for 2 weeks. On 4-Aug, stem caliper diameter was measured at approximately 1 centimeter above the soil line, seedlings were harvested at the soil line for dry weight determination, and root heath and growth were rated on a scale of 1 to 5, with 5 being the best formed and healthiest root systems. After harvest, growing media was collected and a composite sample from each replicate tray was tested for pH and electrical conductivity (EC) using the 1:2 dilution method and Oakton pHTestr 30 and Oakton ECTestr 11 meters. Foliage was saved after recording dry weight to be sent for nutritional analysis (Brookside Laboratories, New Bremen, OH). Data were subject to Analysis of Variance (ANOVA; JMP) and, where applicable, means were separated using Tukey's HSD (p=0.05).

Results – Tomato Seedling Trial

There were no differences between treatments for germination rate or percent germination (Table 1). However, differences were observed in final plant size (Table 2). The 1% sugar kelp treatment, resulted in the largest stem caliper measurements, and the 0.5% sugar kelp treatment resulted in the smallest, with the untreated control in between (Table 2). Dry weight and root index ratings were significantly lower for the 0.5% sugar kelp treatment compared to both the 1.0% sugar kelp treatment and the untreated control (Table 2).

No difference in media pH was found between treatments. The 1.0% sugar kelp extract had a significantly higher EC compared to both the untreated control and the 0.5% sugar kelp treatment (Table 3). The EC measurements were all lower than the recommended range of 500-1500 µS/cm (Ball Horticulture, Vegetable and Plug Growing Chart). For most plant nutrients, there were no significant differences found in nutritional analyses between treatment (Table 4). Exceptions include P, B, and Cu where increased P and B, and decreased Cu, was found in the kelp treatments.

Materials and Methods – Tomato and Petunia Greenhouse Trials

Kelp Drying and Processing and Kelp Extract Procedure

The kelp drying and processing as well as the kelp extract procedure is as described above.

Trial Procedures

Tomato 'Celebrity' were seeded on 5-May into a 105 plug tray using Pro Mix BX Mycorrhizae growing media. Plants were maintained in a greenhouse and irrigated as needed. Seedlings were fertilized at every other irrigation with 50 ppm N of 20-10-20 fertilizer starting on 21-June.

Petunia 'Pretty Grand Mellow Yellow' plugs were received in 512-plug tray from a commercial grower on 2-June, maintained in a greenhouse, irrigated as needed, and fertigated 3 times per week with 50 ppm of 20-10-20 fertilizer until transplant. Tomato 'Celebrity' and Petunia 'Pretty Grand Mellow Yellow' were transplanted on 28-June using Pro Mix BX Mycorrhizae growing media, into 4.5-inch square containers.

Two rates of sugar kelp extract, 0.5% (5ml/L) and 1% (10ml/L) were evaluated under both low (75 ppm N) and standard (150 ppm N) rates of fertilizer. Additionally, untreated controls were evaluated under both fertilization rates and the commercially available kelp extract product Stimplex (made from extract of *Ascophyllum nodosum*; 0.5%, 5ml/L) was evaluated under standard fertilization rate. Fertilizer (15-5-15) was applied as constant liquid feed via subirrigation using ebb and flow benches.

Treatments were applied weekly, starting the week of transplant, as a drench using a watering can. Each pot received approximately 30 ml of solution. Treatments were applied on 30-Jun, 8-Jul, 14-Jul, 21-Jul, 28-Jul, and 5-Aug (petunia only). Treatments were replicated across 15 single plant replicates. Media pH and electrical conductivity (EC) were measured on three of the replicates on 7-Jul, 22-Jul and 2-Aug using the pour-thru method using Oakton pHTestr 30 and Oakton ECTestr 11 meters.

Six replicates per treatment were randomly chosen for plant growth data collection. Data collection occurred after 2-Aug for tomato and 9-Aug for petunia. Plant growth data collected included leaf chlorophyll index (as measured with Minolta SPAD-502 meter) taken from 3 recently matured leaves, a root index evaluation where roots were rated on a scale of 1 to 5 (5= best/healthiest), and plants were harvested at the soil line for dry weight determination. For tomato, stem caliper (diameter) was also recorded at approximately 1 centimeter above the soil line. Foliage was saved after recording dry weight to be sent for nutritional analysis (Brookside Laboratories, New Bremen, OH).

The remaining six replicates were subjected to a drought stress test. Plants were watered until saturation and the growing media was covered with foil to reduce water loss through the growing media. Plants were not further irrigated and were evaluated daily for wilt using a 0 to 5 scale (where 1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt). In addition to evaluation, plants were weighed daily as a measure of water loss until the weight difference from the prior day was less than 5 g. The tomato drought stress evaluation was initiated on 3-Aug and ended on 9-Aug, and the petunia drought stress evaluation was initiated on 9-Aug and ended on 18-Aug.

Results – Tomato and Petunia Greenhouse Trials

Tomato

For tomato, any difference observed in dry weight was related to fertilizer treatment and not kelp treatments, and there were no meaningful differences in stem caliper measurements (Table 5). No differences were found between treatments for root index ratings (Table 5).

Differences were found in the pH and EC between treatments, but the differences were predominantly related to the different fertilizer rates and not kelp treatments (Table 6). There were no significant increases of leaf chlorophyll index values of the kelp treatments compared to the untreated control treatments (Table 7). There were some significant differences between treatments in nutritional analyses, however differences from the control and were predominantly related to fertilizer rate (Table 8).

In the drought stress test, some differences were observed in both the wilt evaluation and the percent weight loss data, however, these differences were related to fertilizer and not kelp treatments (Tables 9 and 10 and Figures 1 and 2).

Petunia

Kelp application did not result in any significant differences in dry weight; significant differences were found but were related to fertilizer treatment (Table 11). No significant differences between treatments in root index ratings were found on treated petunia plants (Table 11). While there were differences in pH and EC between treatments, kelp treatments did not have an effect on media pH and EC and the differences were a result of fertilizer rate (Table 12). Kelp treatments did not result in a difference in leaf chlorophyll index values compared to control plants for plants grown at the 150 ppm N rate, however the 0.5% and 1.0% sugar kelp treatments resulted in significantly higher leaf chlorophyll index values that the untreated control at 75 ppm N (Table 13). Some differences were observed in nutritional analyses between treatments (Table 14), though generally differences were a result of fertilizer rate.

In the drought tolerance evaluation, some differences drought symptoms were observed between treatments. Generally, the lower fertilizer rate had improved wilt evaluation ratings as well as well less percent weight loss. While some kelp treatments had a delay in drought symptoms and a reduction in weight loss compared to the controls, these differences were not significant (Tables 15 and 16 and Figures 3 and 4).

Final Comments

In 2020, both tomato seedlings and petunia showed an improvement in growth with the application of sugar kelp extract. However, in 2021 sugar kelp extract application did not result in gains

of plant size, stem diameter, or other growth characteristics when compared to control treatments. The commercially available seaweed extract, Stimplex (*Ascophyllum nodosum*) also did not result in any significant differences in plant growth compared to controls.

In 2020, and exploratory drought stress test was conducted and results merited further investigation. In 2022, a more thorough study on drought tolerance was conducted. There was a clear improvement in drought tolerance for treatments at the low fertility level, however, while there were some improvements in drought tolerance observed with kelp treatment, no differences were significant.

The differences between results in 2020 and 2021 may be due to a difference in properties of the kelp harvested, a difference in the weather and growing conditions, or a combination of factors. It may be that the effects of the application of sugar kelp extract are inconsistent and too variable to be meaningful. Additional trials may help confirm whether or not sugar kelp extract has a measurable effect on plant growth.

Tables and Figures

Table 1. Effect of applications of sugar kelp extract on germination rate and percent germination of tomato.

Treatment	Days to Germination	% Germination
0.5% sugar kelp extract	5.3 a	95.6 a
1.0% sugar kelp extract	5.4 a	97.3 a
Untreated Control	5.4 a	96.6 a

Means within a column with similar letters are not significantly different according to ANOVA (p=0.05)

Table 2. Effect of applications of sugar kelp extract on the growth of tomato seedlings after ~5 weeks growth.

Treatment	Stem Caliper (mm)	Dry Weight (g)	Root Index (0-5 scale)
0.5% sugar kelp extract	1.92 c	0.05 b	4.16 b
1.0% sugar kelp extract	2.08 a	0.06 a	4.72 a
Untreated Control	1.99 b	0.06 a	4.69 a

Root index was evaluated on a scale of 1-5, where 5=best/healthiest

Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Table 3. Effect of applications of sugar kelp extract on tomato plug tray media pH and electrical conductivity (EC) after 5 weeks.

Treatment	pH	EC (µS/cm)
0.5% sugar kelp extract	6.10 a	303 b
1.0% sugar kelp extract	6.06 a	358 a
Untreated Control	6.10 a	296 b

Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Table 4. Effect of applications of sugar kelp extract on final foliar nutritional analyses of tomato seedlings.

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Iron (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract	1.41 a	0.516 a	0.483 a	3.61 a	2.47 a	0.727 a	26.7 ab	54.7 a	250 a	16.3 b	63.3 a	23.9 a	1437 a
1.0% sugar kelp extract	1.24 a	0.486 ab	0.462 a	3.52 a	2.50 a	0.681 a	29.9 a	56.7 a	253 a	16 b	59.4 a	24.8 a	1313 a
Untreated Control	1.16 a	0.430 b	0.435 a	3.44 a	2.46 a	0.750 a	25.5 b	55.3 a	238 a	19.5 a	62.4 a	29.7 a	1153 a

Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Table 5. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on growth of tomato transplants.

Treatment	Dry Weight (g)	Stem Caliper (mm)	Root Index (1-5 scale)
0.5% sugar kelp extract, 150 ppm N	9.27 a	7.78 ab	4.7 a
1.0% sugar kelp extract, 150 ppm N	8.22 a	7.94 ab	4.5 a
0.5% sugar kelp extract, 75 ppm N	6.20 b	7.52 ab	4.8 a
1.0% sugar kelp extract, 75 ppm N	5.55 b	7.01 b	4.8 a
0.5% Stimplex, 150 ppm N	8.59 a	7.45 ab	4.8 a
Untreated control, 75 ppm N	6.07 b	7.43 ab	4.8 a
Untreated control, 150 ppm N	8.41 a	8.45 a	4.5 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 6. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on tomato media pH and electrical conductivity (EC) as measured with the pour-thru procedure.

Treatment	pH			EC		
	7-Jul	22-Jul	2-Aug	7-Jul	22-Jul	2-Aug
0.5% sugar kelp extract, 150 ppm N	5.86 a	5.31 b	5.32 b	1.11 a	0.72 a	0.48 ab
1.0% sugar kelp extract, 150 ppm N	5.80 a	5.28 b	5.35 b	1.11 a	0.84 a	0.55 ab
0.5% sugar kelp extract, 75 ppm N	5.98 a	5.81 a	5.87 a	0.73 c	0.33 b	0.27 b
1.0% sugar kelp extract, 75 ppm N	5.86 a	5.84 a	5.97 a	0.85 bc	0.31 b	0.24 b
0.5% Stimplex, 150 ppm N	5.85 a	5.30 b	5.35 b	1.13 a	0.79 a	0.68 a
Untreated control, 75 ppm N	5.96 a	5.69 a	5.89 a	0.75 c	0.37 b	0.25 b
Untreated control, 150 ppm N	5.91 a	5.14 b	5.41 b	1.10 ab	1.00 a	0.47 ab

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 7. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on leaf chlorophyll index of tomato plants.

Treatment	Leaf Chlorophyll Index
0.5% sugar kelp extract, 150 ppm N	52.2 ab
1.0% sugar kelp extract, 150 ppm N	50.6 b
0.5% sugar kelp extract, 75 ppm N	54.2 ab
1.0% sugar kelp extract, 75 ppm N	52.6 ab
0.5% Stimplex, 150 ppm N	55.3 a
Untreated control, 75 ppm N	53.9 ab
Untreated control, 150 ppm N	52.3 ab

Leaf chlorophyll index measured using a chlorophyll meter (Minolta SPAD-502).
Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 8. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on final foliar nutritional analyses of tomato.

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract, 150 ppm N	5.02 a	0.799 ab	0.77 b	4.52 a	3.16 a	0.606 d	56.7 ab	94.6 a	67 ab	14.8 ab	52.9 ab	21.5 a	1633 a
1.0% sugar kelp extract, 150 ppm N	5.1 a	0.818 ab	0.765 b	4.61 a	3.3 a	0.642 cd	59.2 ab	97.1 a	71.5 ab	15 ab	48.4 abc	24.5 a	1560 a
0.5% sugar kelp extract, 75 ppm N	3.78 b	0.624 c	0.818 ab	4.14 a	3.17 a	0.834 ab	51.6 b	76.8 a	65.0 ab	10.2 c	37.8 c	20.4 a	1313 a
1.0% sugar kelp extract, 75 ppm N	3.86 b	0.705 bc	0.879 a	4.43 a	3.45 a	0.931 a	57.8 ab	96.1 a	73.4 ab	11 bc	40.3 bc	23.5 a	1365 a
0.5% Stimplex, 150 ppm N	5.13 a	0.849 a	0.832 ab	4.92 a	3.61 a	0.701 bcd	65.1 a	92.8 a	77.9 a	16.9 a	58.1 a	21.2 a	1570 a
Untreated control, 75 ppm N	3.77 b	0.661 c	0.841 ab	4.35 a	3.18 a	0.797 abc	51.2 b	72.4 a	61.2 b	10.1 c	46.6 abc	19.3 a	1368 a
Untreated control, 150 ppm N	5.18 a	0.802 ab	0.778 b	4.37 a	3.40 a	0.647 cd	61.7 ab	91.0 a	68 ab	15.9 a	50.1 abc	25.6 a	1470 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 9. Drought stress evaluation of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 3-August with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt.

Treatment	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
0.5% sugar kelp extract, 150 ppm N	1.0	2.7 a	4.5 a	5.0 a	5.0	5.0	5.0
1.0% sugar kelp extract, 150 ppm N	1.0	2.0 abc	5.0 a	5.0 a	5.0	5.0	5.0
0.5% sugar kelp extract, 75 ppm N	1.0	1.0 c	2.3 b	5.0 a	5.0	5.0	5.0
1.0% sugar kelp extract, 75 ppm N	1.0	1.0 c	1.5 b	4.8 a	5.0	5.0	5.0
0.5% Stimplex, 150 ppm N	1.0	2.5 ab	4.5 a	5.0 a	5.0	5.0	5.0
Untreated control, 75 ppm N	1.0	1.5 bc	2.0 b	4.8 a	5.0	5.0	5.0
Untreated control, 150 ppm N	1.0	2.8 a	4.5 a	5.0 a	5.0	5.0	5.0

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Figure 1. Drought stress evaluation of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 3-August with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt).

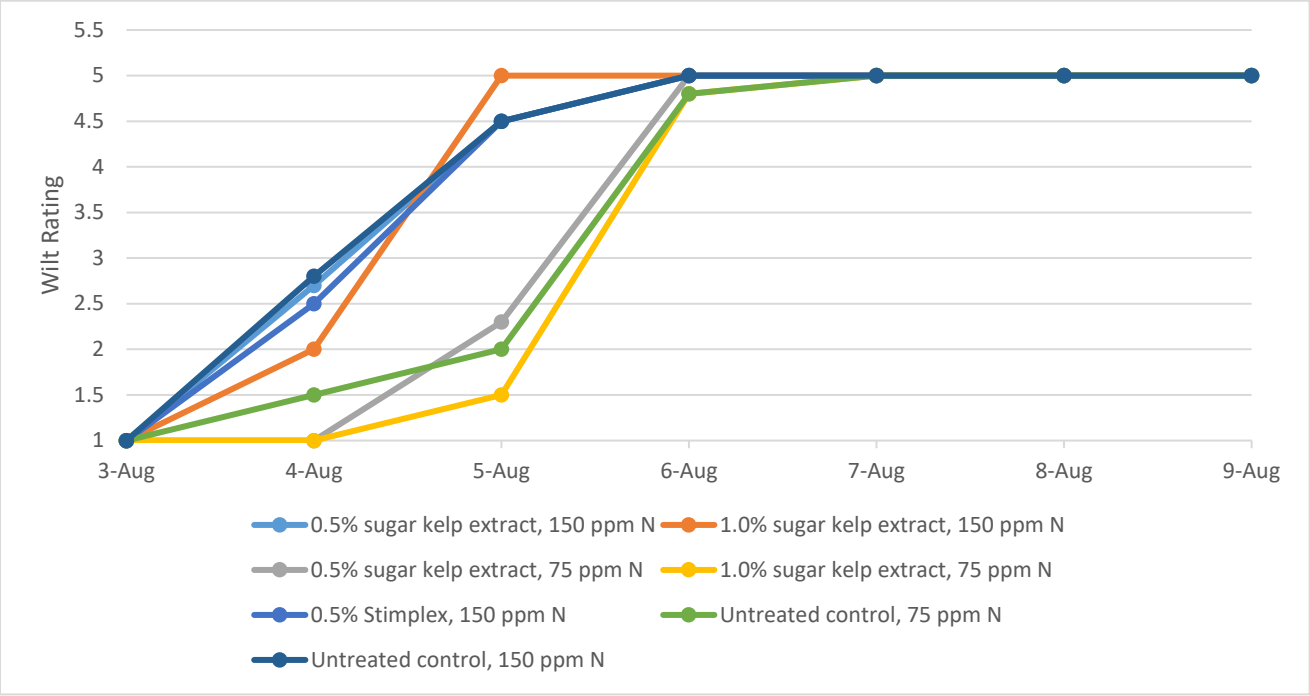


Table 10. Percent weight loss of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) during a drought tolerance evaluation. On 3-Aug plants were irrigated to saturation and the growing media was covered with foil to eliminate water loss from the media. Pots were weighed daily as a measure of water loss.

Treatment	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
0.5% sugar kelp extract, 150 ppm N	47.91 b	42.94 a	38.45 ab	36.19 a	33.78 a	33.36 a
1.0% sugar kelp extract, 150 ppm N	49.26 b	42.28 a	38.33 ab	36.13 a	33.79 a	33.36 a
0.5% sugar kelp extract, 75 ppm N	61.15 a	41.13 a	35.49 c	33.40 b	31.32 b	30.93 b
1.0% sugar kelp extract, 75 ppm N	65.49 a	42.85 a	35.75 c	33.39 b	31.30 b	30.88 b
0.5% Stimplex, 150 ppm N	49.48 b	43.82 a	38.80 a	36.21 a	33.77 a	33.34 a
Untreated control, 75 ppm N	62.04 a	42.74 a	36.40 bc	34.08 b	32.06 b	31.66 b
Untreated control, 150 ppm N	48.37 b	43.25 a	38.61 a	36.35 a	34.00 a	33.62 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Figure 2. Percent weight loss of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) during a drought tolerance evaluation. On 3-Aug plants were irrigated to saturation and the growing media was covered with foil to eliminate water loss from the media. Pots were weighed daily as a measure of water loss.

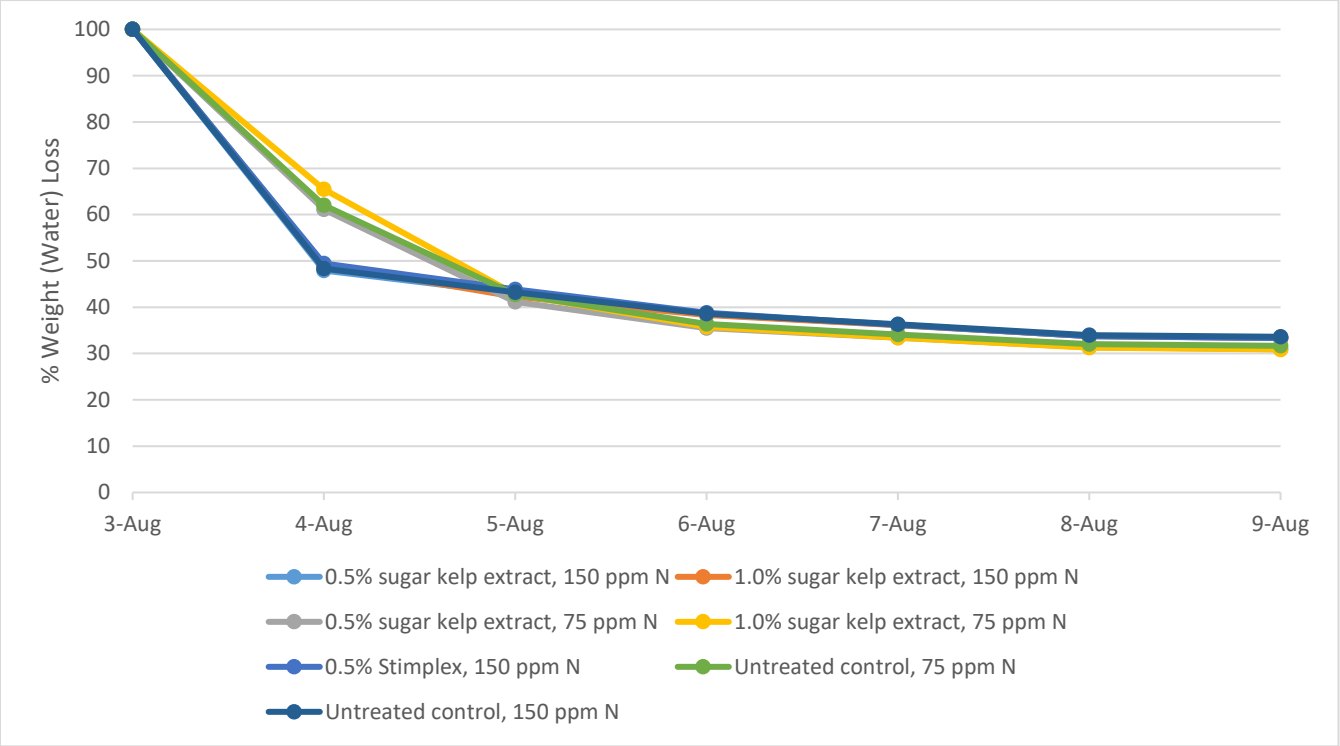


Table 11. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on growth of petunia.

Treatment	Dry Weight (g)	Root Index (1-5 scale)
0.5% sugar kelp extract, 150 ppm N	4.62 ab	4.7 a
1.0% sugar kelp extract, 150 ppm N	5.15 a	4.8 a
0.5% sugar kelp extract, 75 ppm N	3.12 b	4.5 a
1.0% sugar kelp extract, 75 ppm N	4.21 ab	4.8 a
0.5% Stimplex, 150 ppm N	4.97 a	4.5 a
Untreated control, 75 ppm N	4.18 ab	4.8 a
Untreated control, 150 ppm N	5.83 a	4.8 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 12. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on petunia media pH and electrical conductivity (EC) as measured with the pour-thru procedure.

	pH			EC		
Treatment	7-Jul	22-Jul	2-Aug	7-Jul	22-Jul	2-Aug
0.5% sugar kelp extract, 150 ppm N	5.95 a	5.63 c	5.49 b	1.04 a	0.82 a	0.59 ab
1.0% sugar kelp extract, 150 ppm N	5.92 a	5.79 bc	5.65 b	1.07 a	0.76 a	0.59 ab
0.5% sugar kelp extract, 75 ppm N	6.02 a	6.37 a	6.47 a	0.74 b	0.44 b	0.34 b
1.0% sugar kelp extract, 75 ppm N	6.00 a	6.20 ab	6.32 a	0.73 b	0.51 b	0.35 b
0.5% Stimplex, 150 ppm N	5.98 a	5.76 bc	5.55 b	1.03 a	0.86 a	0.73 a
Untreated control, 75 ppm N	6.01 a	6.20 ab	6.22 a	0.73 b	0.46 b	0.34 b
Untreated control, 150 ppm N	5.89 a	5.69 bc	5.35 b	1.10 a	0.82 a	0.78 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 13. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on leaf chlorophyll index of petunia.

Treatment	Leaf Chlorophyll Index
0.5% sugar kelp extract, 150 ppm N	26.1 ab
1.0% sugar kelp extract, 150 ppm N	25.0 ab
0.5% sugar kelp extract, 75 ppm N	28.6 a
1.0% sugar kelp extract, 75 ppm N	28.9 a
0.5% Stimplex, 150 ppm N	26.1 ab
Untreated control, 75 ppm N	23.8 b
Untreated control, 150 ppm N	25.1 ab

Leaf chlorophyll index measured using a chlorophyll meter (Minolta SPAD-502).
Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 14. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on final foliar nutritional analyses of petunia.

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract, 150 ppm N	5.06 a	0.767 a	0.541 ab	6.63 ab	2.080 a	0.350 ab	22.7 a	87.6 ab	111.5 ab	11.0 ab	62.07 c	40.7 a	4690 bc
1.0% sugar kelp extract, 150 ppm N	4.96 a	0.709 ab	0.520 ab	6.77 ab	1.99 a	0.344 ab	23.3 a	83.7 ab	123.0 a	10.2 abc	70.05 bc	37.5 a	4395 bc
0.5% sugar kelp extract, 75 ppm N	3.53 b	0.617 b	0.384 c	6.2 ab	1.89 a	0.292 c	19.2 a	68.0 b	139.3 a	8.4 c	69.87 bc	40.3 a	3907 c
1.0% sugar kelp extract, 75 ppm N	3.42 b	0.656 ab	0.434 bc	6.01 b	1.85 a	0.309 bc	20.7 a	65.4 b	64.0 c	8.5 bc	85.97 ab	35.4 a	5812 ab
0.5% Stimplex, 150 ppm N	4.95 a	0.688 ab	0.496 ab	7.22 a	1.84 a	0.358 a	21.3 a	92.3 ab	68.7 c	10.4 abc	93.80 a	57.8 a	3812 c
Untreated control, 75 ppm N	3.36 b	0.653 ab	0.475 bc	6.40 ab	1.89 a	0.319 abc	21.5 a	77.8 b	69.6 c	8.5 bc	91.80 a	44.4 a	6297 a
Untreated control, 150 ppm N	4.95 a	0.699 ab	0.585 a	6.59 ab	1.96 a	0.356 ab	23.9 a	113.5 a	87.8 bc	11.4 a	69.25 bc	73.9 a	4762 abc

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 15. Drought stress evaluation of petunia plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 9-August with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt.

Treatment	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug
0.5% sugar kelp extract, 150 ppm N	1.0	2.2 ab	3.7 a	4.8 a	5.0 a	5.0 a	5.0	5.0	5.0	5.0
1.0% sugar kelp extract, 150 ppm N	1.0	2.3 ab	3.7 a	4.7 a	4.8 a	5.0 a	5.0	5.0	5.0	5.0
0.5% sugar kelp extract, 75 ppm N	1.0	1.2 b	1.7 c	2.8 b	4.0 b	4.7 a	5.0	5.0	5.0	5.0
1.0% sugar kelp extract, 75 ppm N	1.0	1.7 b	2.2 bc	3.3 b	4.0 b	4.7 a	5.0	5.0	5.0	5.0
0.5% Stimplex, 150 ppm N	1.0	1.8 b	3.2 ab	4.5 a	5.0 a	5.0 a	5.0	5.0	5.0	5.0
Untreated control, 75 ppm N	1.0	1.7 b	1.8 c	3.3 b	4.2 b	4.8 a	5.0	5.0	5.0	5.0
Untreated control, 150 ppm N	1.0	3.2 a	3.8 a	4.7 a	5.0 a	5.0 a	5.0	5.0	5.0	5.0

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Figure 3. Drought stress evaluation of petunia plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 9-August with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt).

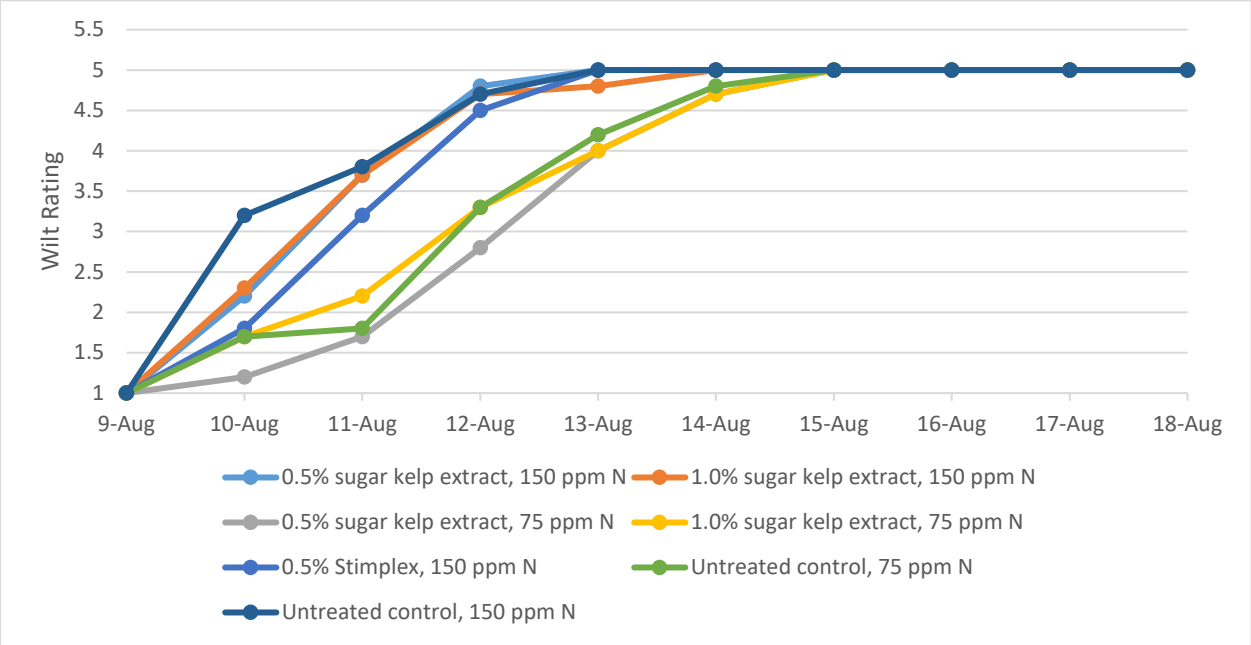
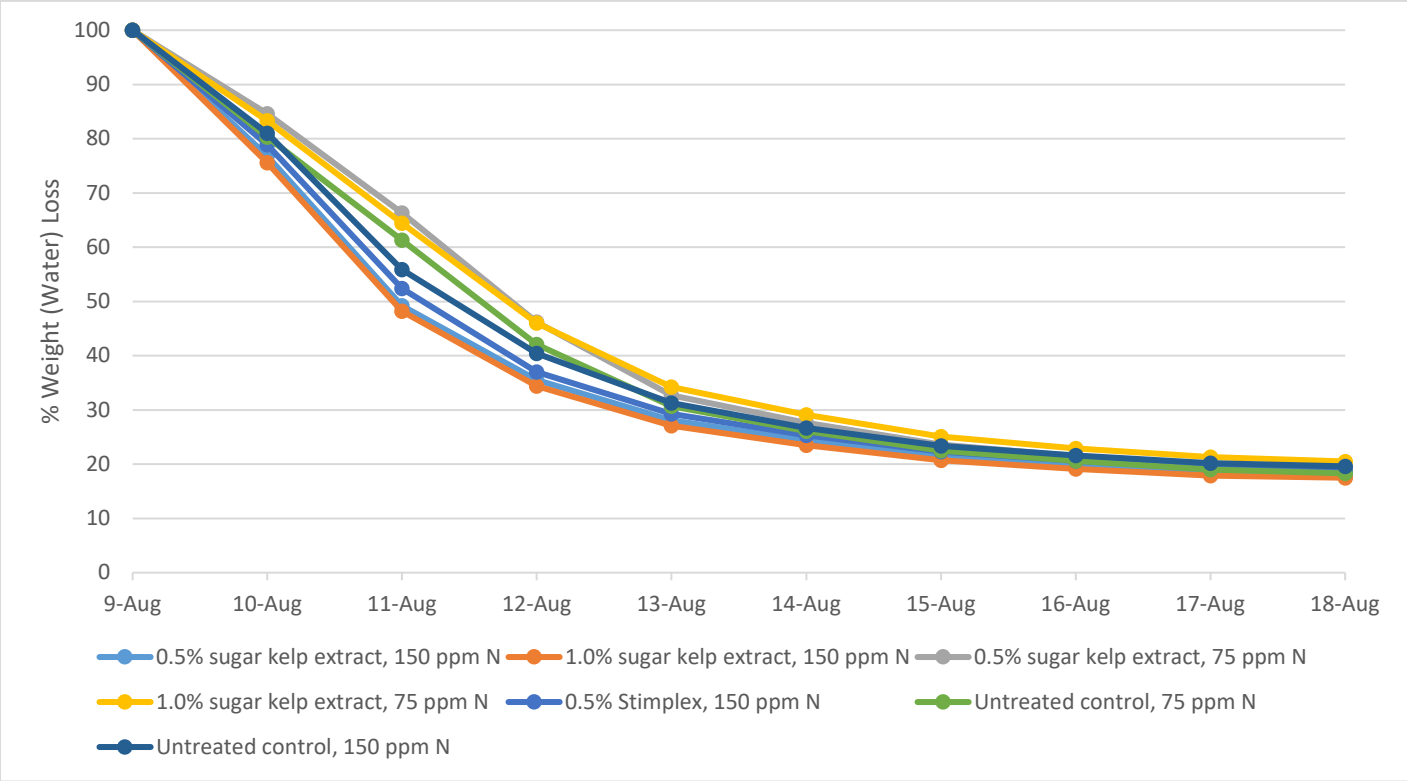


Table 16. Percent weight loss of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) during a drought tolerance evaluation. On 9-Aug plants were irrigated to saturation and the growing media was covered with foil to eliminate water loss from the media. Pots were weighed daily as a measure of water loss.

Treatment	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug
0.5% sugar kelp extract, 150 ppm N	76.8 bc	49.2 c	35.5 bc	28.1 ab	24.4 ab	21.5 b	19.7 b	18.3 bc	17.8 bc
1.0% sugar kelp extract, 150 ppm N	75.6 c	48.2 c	34.4 c	27.1 b	23.5 b	20.7 b	19.1 b	17.9 c	17.5 c
0.5% sugar kelp extract, 75 ppm N	84.6 a	66.3 a	46.2 a	32.7 ab	27.6 ab	23.6 ab	21.5 ab	19.9 abc	19.2 abc
1.0% sugar kelp extract, 75 ppm N	83.3 ab	64.4 a	46.0 ab	34.2 a	29.1 a	25.1 a	22.9 a	21.3 a	20.5 a
0.5% Stimplex, 150 ppm N	78.9 abc	52.4 bc	37.0 abc	29.3 ab	25.3 ab	22.3 ab	20.6 ab	19.3 abc	18.7 abc
Untreated control, 75 ppm N	80.3 abc	61.3 ab	42.1 abc	30.7 ab	26.1 ab	22.5 ab	20.6 ab	19.0 abc	18.3 bc
Untreated control, 150 ppm N	81.0 abc	55.9 abc	40.4 abc	31.3 ab	26.7 ab	23.4 ab	21.6 ab	20.2 ab	19.6 ab

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Figure 4. Percent weight loss of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) during a drought tolerance evaluation. On 9-Aug plants were irrigated to saturation and the growing media was covered with foil to eliminate water loss from the media. Pots were weighed daily as a measure of water loss.


100
90
80
70
60
50
40
30
20
10
0
% Weight (Water) Loss
9-Aug
10-Aug
11-Aug
12-Aug
13-Aug
14-Aug
15-Aug
16-Aug
17-Aug
18-Aug
0.5% sugar kelp extract, 150 ppm N
1.0% sugar kelp extract, 150 ppm N
0.5% sugar kelp extract, 75 ppm N
1.0% sugar kelp extract, 75 ppm N
0.5% Stimplex, 150 ppm N
Untreated control, 75 ppm N
Untreated control, 150 ppm N

Outreach Materials

DEC DELIVERS
KEEPING YOU CONNECTED AND INFORMED
NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Share or view as a web page || Update preferences or unsubscribe

Long Island Nitrogen Action Plan (LINAP) - Monthly Newsletter
Long Island Sound Study (LISS) Update

In this month's issue of the LINAP newsletter, we highlight the ongoing nitrogen reduction related initiatives led by our LINAP partners at the Long Island Sound Study.

- LISS Management Committee Finalizes 2021 Work Plan
- Report Highlights 15 Years of Long Island Sound Futures Fund Accomplishments
- Hypoxic Area Continues to Decline in the Sound
- Returning the Urban Sea to Abundance
- Environmental Justice Workgroup
- Solute Transport Model
- Sugar Kelp Pilot Projects
- Interactive Web-based Viewer to Illustrate the Potential Future of Marsh Systems

---

Long Island Sound Study
A Partnership to Restore and Protect the Sound

Sugar Kelp Pilot Projects

This year the NYSDEC, with funding from LISS, conducted a pilot project at three sites to assess the potential for using sugar kelp, a seaweed that grows in the winter and is harvested in the spring, to naturally remove nitrogen in near-shore waters. Over the winter, mooring lines were seeded with sugar kelp at three locations including Milton Harbor, the East River in the Throggs Neck section of the Bronx, and Northport Harbor, working with Save the Sound, SUNY Maritime College, Cornell Cooperative Extension, and the Village of Northport. After the growing season ended, tissue samples were analyzed to estimate how much nitrogen was removed from the water. The Bronx site was also tested for heavy metals, pesticides, and other contaminants.

NYSDEC is working with Cornell Cooperative Extension on a multi-year study to see if a fertilizer amendment made from the kelp enhances plant growth. Fertilizer made from the kelp harvest as part of the pilot study described above is being applied to tomato and petunia plants in greenhouse and field trials at the Long Island Horticultural Research and Extension Center in Riverhead, NY, Cornell Cooperative Extension of Suffolk County will conduct an analysis of the soils, leaves, and fruit to assess its effectiveness.

Image credit: Save the Sound

New England Interstate Water Pollution Control Commission (NEIWPCC)
August 25 ·

Can seaweed help improve water quality in the Long Island Sound?
For #NationalWaterQualityMonth we're looking at how sugar kelp, a type of seaweed, is being tested to determine if it can remove nutrients like nitrogen from the waters of Long Island Sound, a process known as bioextraction. Sugar Kelp was grown at 3 sites in the Sound, harvested, dried and processed for a fertilizer pilot study to explore its potential for commercial uses, which is ongoing now.
Learn more about the study: https://bit.ly/3ycf4i8
Shout out to study partners NYS Department of Environmental Conservation, Long Island Sound Study, SUNY Maritime College, Save the Sound, Cornell Cooperative Extension of Suffolk County, and the Village of Northport.

Photos

Milton Harbor site photos

Kelp line in the water at Milton Harbor site in January 2021 (photo credit: Peter Linderoth, Save the Sound)

Group photo with kelp spool in Milton Harbor (photo credit: Peter Linderoth, Save the Sound)

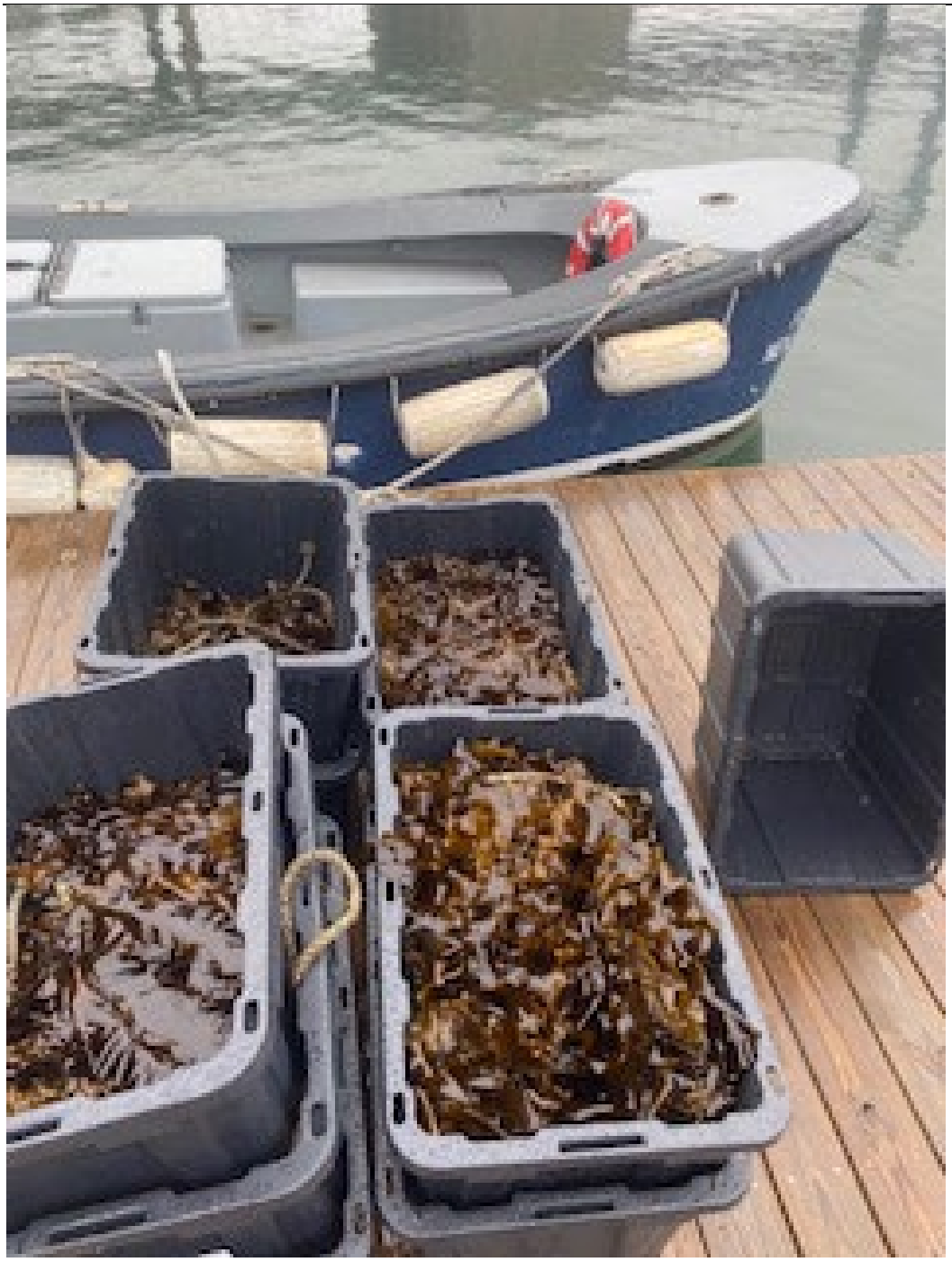
Spooling out kelp line in January 2021 in Milton Harbor (photo credit: Peter Linderoth, Save the Sound)

Milton Harbor kelp line at harvest in April 2021 (photo credit: Kristin Kraseski)

East River Bronx Site Photos

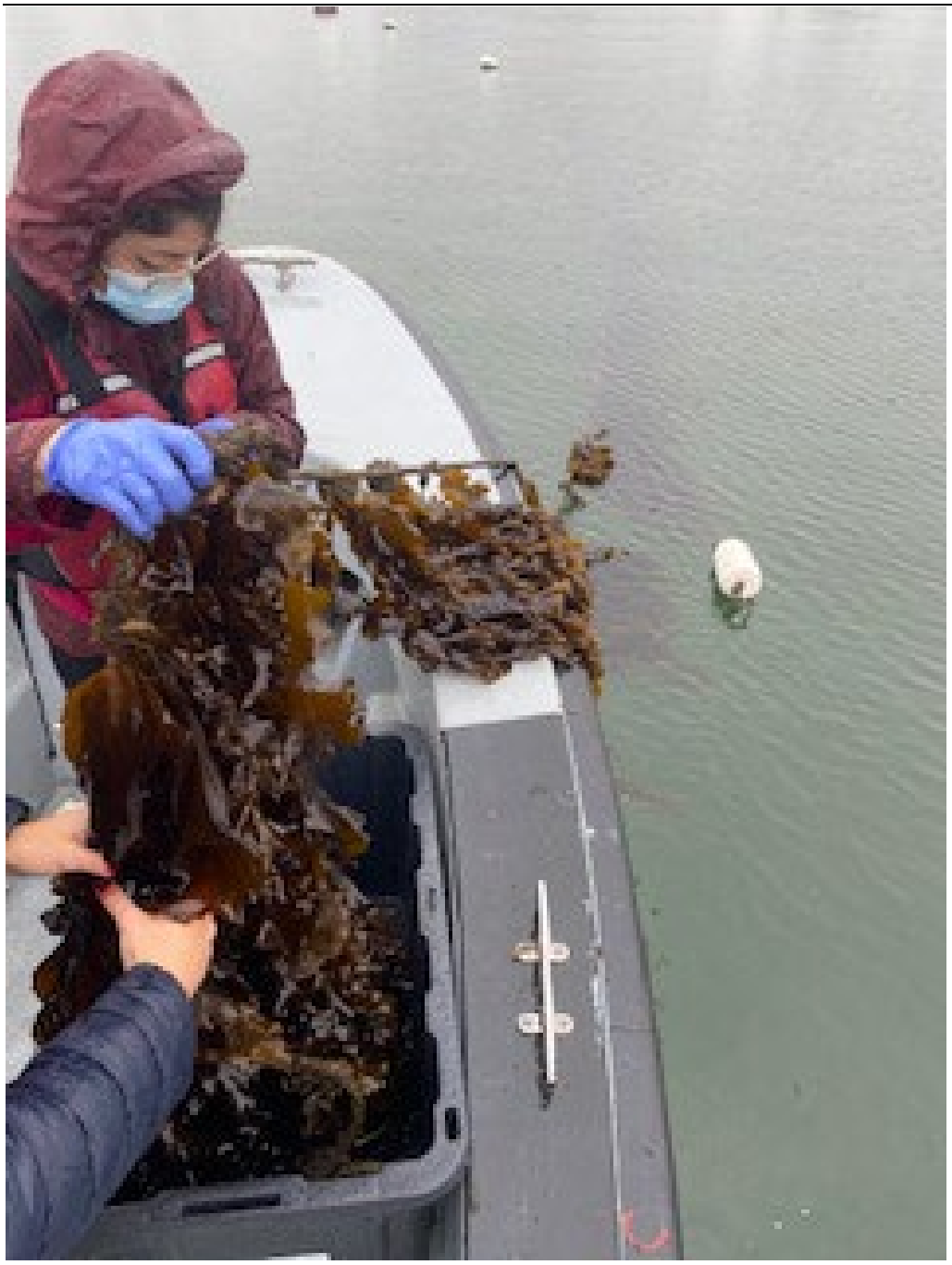
East River site location and line (photo credit: Dr. Caterina Panzeca, SUNY Maritime College)

Spooling out kelp onto lines, January 2021 in East River, Bronx (photo credit: Dr.Caterina Panzeca, SUNY Maritime College)



Kelp harvest at East River, Bronx site in June 2021 (photo credit: Dr. Caterina Panzeca, SUNY Maritime College)

Kelp harvest at East River, Bronx site in June 2021 (photo credit: Dr. Caterina Panzeca, SUNY Maritime College)



Kelp harvest at East River, Bronx site in June 2021 (photo credit: Dr. Caterina Panzeca, SUNY Maritime College)

Northport Harbor site photos:

Kelp line in Northport Harbor (photo credit: Kristin Kraseski)

Kelp lines at Northport Harbor site at harvest in April 2021 (photo credit: Barry Udelson, Cornell Cooperative Extension of Suffolk County)