LI Sound Futures Fund 2013 - Clean Water, Habitat Restoration, and Species Conservation - Submit Final Programatic Report (New Metrics)
Grantee Organization: University of Connecticut
Project Title: Using Seaweed (Kelp) to Bioextract Pollution (CT)

Project Period 10/01/2013 - 9/30/2015

Project Location Description (from Proposal) Thimble Islands, Branford, CT.

Project Summary (from Proposal) Determine pollutant removal capacity of seaweed (kelp) using an expandable off-shore installation, and provide information for potential kelp farmers and coastal managers about bioextraction technology.

Summary of Accomplishments The project goals were to demonstrate economic opportunities and environmental impacts of scalable seaweed farm systems in LIS for nutrient bioextraction and water quality improvement. To achieve these goals, we developed a scalable kelp farm design and outplanted the sugar kelp on 7 × 50 m longlines at the Thimble Island Oyster Co. farm (Branford, CT). The sugar kelp was cultured at two different spacing conditions between longlines, 6 vs. 13 m. While the spacing between longlines did not affect the tissue nitrogen and carbon, productivity, nitrogen and carbon removal appeared to be higher at the internal lines than that from the external lines. Inorganic nitrogen and phosphorus concentrations at different locations of the farm system (internal and external) showed no difference. These results suggest that the external lines received higher physical stresses than the internal lines, causing a reduction of primary productivity. However, there is a limitation of the datasets due to the severe loss of biomass caused by historically severe weather during the project period. We have worked on a re-designed scalable kelp farm that will take in consideration of severe winter weather conditions, currents and winds in LIS that will enable workboats to safely operate during sampling and harvest. We also have developed a teaching curriculum on nutrient bioextraction. It will be available to other schools, educational and related programs around LIS and the US. We have made 32 presentations including 20 invited presentations in relevant and appropriate events during the project period. Our work has received a great deal of media attention including the national wide media, Washington Post, CNN, The New Yorker, etc.

Lessons Learned

1. In a scalable sugar kelp farm, the productivity, tissue nitrogen and carbon contents were similar through the farm system regardless spacing between longlines.
2. Inorganic nitrogen and phosphorus concentrations at different locations of the farm system (internal and external) showed no difference.
3. Productivity, nitrogen and carbon removal appeared to be higher at the internal lines than that from the external lines because the external lines received higher physical stresses than the internal lines, caused the reduction of productivity.
4. Historically severe winter weather created unusually cold sea temperatures that resulted in sea ice covering all kelp culture locations. Kelp longlines were even moved over 1.0 km away from the farm by the ice, resulting in a complete loss of biomass. The scalable kelp farm (one hectare) design developed in this project is believed to help growers to be prepared for similar weather events in the future, especially in Long Island Sound because, this new design considers severe winter weather conditions, currents and winds in LIS, and the necessity for safe boat operations during sampling and harvest.
5. The estimates of nutrients extracted by the sugar kelp farm in a scalable 1 ha farm are 38 (N), 7.2 (P) and 870 kg ha-1 (C), respectively. However, these values are underestimated due to the biomass reduction by the severe winter weather conditions (ice shearing) during the project period. The values will be higher if the farm is prepared for the severe winter conditions using the farm re-design developed in this project.
6. The kelp aquaculture may also be a useful tool for phytoremediation.

Activities and Outcomes

Funding Strategy	**Capacity, Outreach, Incentives**
Activity / Outcome	LISFF - Outreach/ Education/ Technical Assistance - # of schools participating
Required	Recommended
Description	Enter the number of elementary, middle, and high schools participating in the project

# of schools participating - Current	2.00
# of schools participating - Grant Completion	2.00

Notes	UConn and BRASTEC

Funding Strategy	**Capacity, Outreach, Incentives**
Activity / Outcome	LISFF - Volunteer participation - # volunteers participating
Required	Recommended
Description	Enter the number of volunteers participating in projects

# volunteers participating - Current	2.00
# volunteers participating - Grant Completion	9.00

Notes	UConn

Funding Strategy	**Habitat Management**
Activity / Outcome	LISFF - BMP implementation for nutrient or sediment reduction - Lbs nutrients avoided (annually)
Required	Recommended
Description	Enter the amount of nutrients prevented from entering system annually

Lbs nutrients avoided (annual) - Current	0.00
Lbs nutrients avoided (annual) - Grant Completion	116.00

Notes	Nutrient reduction per site (quarter ha kelp farm with six 50 m longlines) Nitrogen: 4 lb Phosphorus: 1 lb Carbon: 111 lb

Show Map Below

The following pages contain the uploaded documents, in the order shown below, as provided by the grantee:

Upload Type	File Name	Uploaded By	Uploaded Date
Final Report Narrative - Standard	1 UCONN Final Report (11-24-2015).pdf	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide1.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide2.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide3.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide4.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide5.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide6.jpg	Yarish, Charles	11/29/2015
Photos - Jpeg	Slide7.jpg	Yarish, Charles	11/29/2015
Other Documents	2 Appendix 1 Kelp Farm Design for Long Island Sound.pdf	Yarish, Charles	11/29/2015
Other Documents	3 Appendix 2 seaweed curriculum (11-24-2015).pdf	Yarish, Charles	11/29/2015
Other Documents	4 Appendix 3 Presentations (11-24-2015).pdf	Yarish, Charles	11/29/2015
Other Documents	5 Appendix 4 Media Appearance.pdf	Yarish, Charles	11/29/2015
Other Documents	6 Wrack Line (Bioextraction).pdf	Yarish, Charles	11/29/2015

The following uploads do not have the same headers and footers as the previous sections of this document in order to preserve the integrity of the actual files uploaded.

Final Programmatic Report Narrative

Instructions: Save this document on your computer and complete the narrative in the format provided. The final narrative should not exceed ten (10) pages; do not delete the text provided below. Once complete, upload this document into the on-line final programmatic report task as instructed.

1. Summary of Accomplishments

In four to five sentences, provide a brief summary of the project's key accomplishments and outcomes that were observed or measured.

The project goals were to demonstrate economic opportunities and environmental impacts of *scalable* seaweed farm systems in LIS for nutrient bioextraction and water quality improvement. To achieve these goals, we developed a scalable kelp farm design and outplanted the sugar kelp on 7 × 50 m longlines at the Thimble Island Oyster Co. farm (Branford, CT). The sugar kelp was cultured at two different spacing conditions between longlines, 6 vs. 13 m. While the spacing between longlines did not affect the tissue nitrogen and carbon, productivity, nitrogen and carbon removal appeared to be higher at the internal lines than that from the external lines. Inorganic nitrogen and phosphorus concentrations at different locations of the farm system (internal and external) showed no difference. These results suggest that the external lines received higher physical stresses than the internal lines, causing a reduction of primary productivity. However, there is a limitation of the datasets due to the severe loss of biomass caused by historically severe weather during the project period. We have worked on a re-designed scalable kelp farm that will take in consideration of severe winter weather conditions, currents and winds in LIS that will enable workboats to safely operate during sampling and harvest. We also have developed a teaching curriculum on nutrient bioextraction. It will be available to other schools, educational and related programs around LIS and the US. We have made 32 presentations including 20 invited presentations in relevant and appropriate events during the project period. Our work has received a great deal of media attention including the national wide media, Washington Post, CNN, The New Yorker, etc.

2. Project Activities & Outcomes

Activities

- Describe and quantify (using the approved metrics referenced in your grant agreement) the primary activities conducted during this grant.
- Briefly explain discrepancies between the activities conducted during the grant and the activities agreed upon in your grant agreement.

Outcomes

- Describe and quantify progress towards achieving the project outcomes described in your grant agreement. (Quantify using the approved metrics referenced in your grant agreement or by using more relevant metrics not included in the application.)
- Briefly explain discrepancies between what actually happened compared to what was anticipated to happen.
- Provide any further information (such as unexpected outcomes) important for understanding project activities and outcome results.

Objective/task 1. Develop QAPP

QAPPs for the field sampling and analyses were developed. The original draft was submitted on January 10, 2014, the second draft was submitted on Feb. 7, 2014 and followed by the final draft submitted on Feb. 12, 2014. The final draft was approved by the US EPA, New England Interstate Water Pollution Control and the Long Island Sound Study on Mar. 10, 2014 (QA Tacking #: RFA – 14041). All the sampling and analyses were conducted based on these approved QAPPs.

Outcomes

- QAPP: 1 (proposed) → 1 (to date)

Objective/task 2. Design and develop an appropriate scalable farm system in each location.

A scalable kelp farm with 7 × 50 m longlines was designed and developed at the Thimble Island Oyster Co. farm site (Branford CT). Throughout the project period, a larger scalable kelp farm (one hectare) was designed and developed by our ocean engineer, Dr. Clifford A. Goudey, which is appropriate to kelp farm sites in Long Island Sound (e.g. Greenwich, Fairfield, Milford, and Branford, CT), as well as other nearshore sites in the US. This novel design takes in consideration of winter weather conditions (including winter storms, the severe ice rafting and cold temperature, etc.) and the necessary spacing for boats to safely operate during sampling and harvest (See Appendix 1 for details).

Outcomes

- A scalable kelp farm design for the current and potential kelp farm sites in Long Island Sound: 1 (proposed) → 1 (to date)

Objective/task 3. Collect kelp meiospores and inoculate of *seedstring* for grow-out in LIS:

Native *Saccharina latissima* seedstring was produced using the nursery rearing technology developed at UCONN's Yarish Seaweed Marine Biotechnology laboratory with the assistance of grants from the CT Sea Grant College Program, NOAA SBIR Phase I & II (with Ocean Approved, LLC.) and NFWF grants. To develop seedstring of native *Saccharina latissima*, meiospores of wild-harvested specimens were collected in October and November in 2013 and 2014 from off Pine Island and Black Ledge (Groton, CT), Fishers Island (NY) and Ft. Wetherill (Jamestown, RI). Over 1,000m of seedstring was produced at the sugar kelp nursery systems at UCONN and Bridgeport Regional Aquaculture Science and Technology Education Center (BRASTEC) in 2013-2014 growing season; and over 3,000 m in 2014-2015 growing season (Fig. 1). When plants reached 1mm in size, the *seedstring* was outplanted on longlines at the Thimble Island farm and D.J. King Lobsters' farm sites.

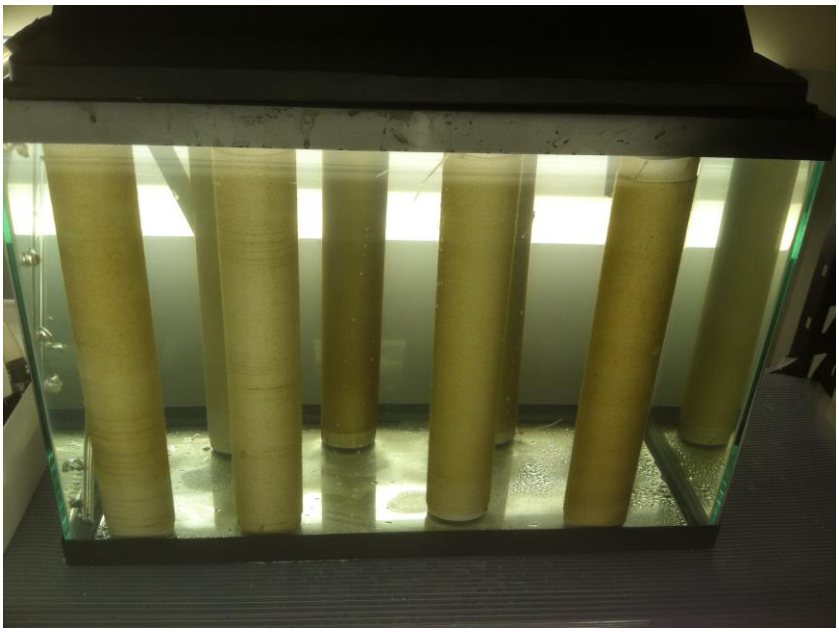

Fig. 1. Sugar kelp seedstring, ~ 3 weeks old, grown at UCONN nursery.

Outcomes

- Length of kelp seedstring produced: > 3000 m (to date)

Objective/task 4. Cultivate *Saccharina latissima* on longlines in one quarter ha kelp farm in LIS:

2013-2014 growing season

The outplanting of kelp at the kelp farm site off Thimble Island Oyster Co. (Branford, CT) was delayed until December 3, 2013, because of delays in the final approval of grant by NFWF (Nov. 22 2013). On December 3, 2013, kelp seedstring

was outplanted on 7 × 50 m longlines with two different spacing between longlines (6.5 m vs. 13.0 m) at 1 m depth at the Thimble Island Oyster Co. kelp farm site (41.25749° N / 72.767890° W) (Fig. 2). Additionally, kelp seedstring was outplanted on 2 × 100 longlines at another permitted farm off Branford, D.J. King Lobsters (41.144720° N, 72.475240° W) on Dec. 21, 2013. The rapid January decline in water temperature down to -1 ℃ caused a significant reduction of growth of the sugar kelp. The water temperature stayed at low (-1 ~ 2 ℃) over a two-month of period (Jan. - Mar., 2014; Fig. 2). The study site was not even accessible due to ice formation for over one month. Although the kelp was harvested in early June, 4-5 weeks later than previous years, kelp grew only to ~1 m in length (Fig. 3), which is smaller than previous years (~3 m in 2011-2012 growing season and ~2m in 2012-2013 growing season). This slow growth significantly affected the kelp productivity, and therefore, nutrient bioextraction capacity.

Fig. 2. Kelp seedstring outplanting at Thimble Island Oyster Co. farm.

Fig. 3. UCONN research assistant, Jennifer Savicky collecting the kelp at harvest, 2014 at D.J. King Lobsters kelp farm.

2014-2015 growing season

Kelp seedstring deployments were made on Oct. 28th at both Thimble Island Oyster Co. and D.J. King Lobsters. However, February and March severe weather conditions created unusually cold sea temperatures that resulted in sea ice covering all kelp culture locations. The water temperature remained below zero from Jan 31 – Mar. 10, with the lowest -1.4℃ from Feb.

16 to 21 (Fig. 4. At the Thimble Island Oyster Co.'s farm site, ice rafts hit the farm very hard. Some lines were moved over 1.0 km away from the farm by the ice. Only two kelp lines remained with sparse growth of kelp. Ice sheered most of the plants off the longlines. At the D.J. King Lobsters' farm site, all lines were moved by the ice. Two lines were found more than 1.0 km east from the site. All kelp was removed from these lines too. Ice sheered all plants off these lines. Additional outplanting (2 × 100 m longline) at the D.J. King Lobsters' site was attempted on Mar 17th, 2015 with the seedstring that UCONN maintained at its nursery, but no growth was observed until June.

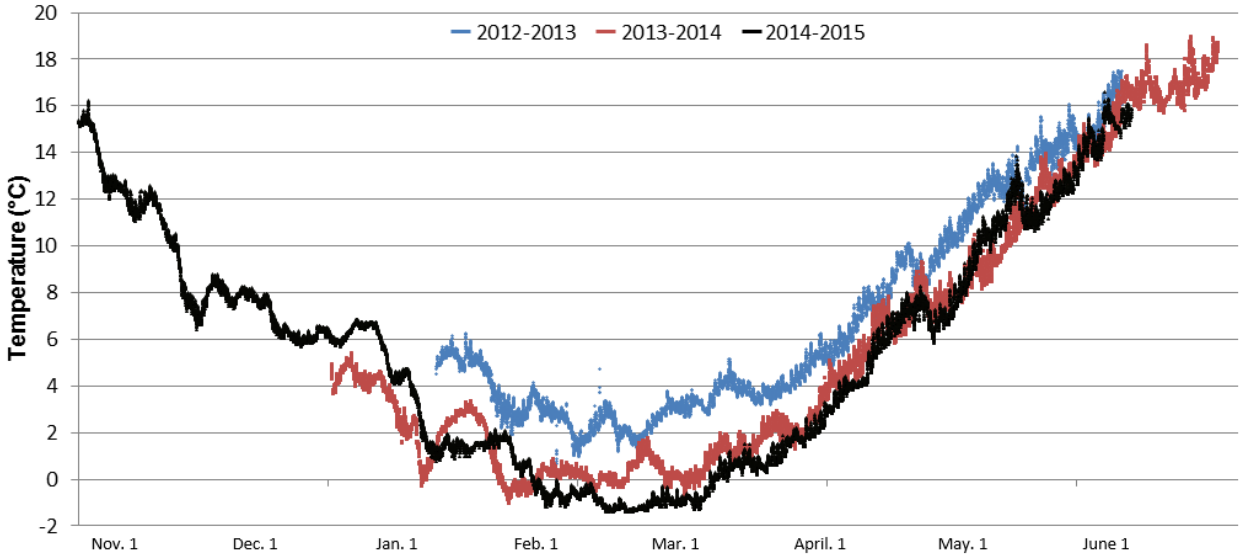

Fig. 4 Temperature profile comparison between 2012-2013, 2013-2014 and 2014-2015 growing seasons

Outcomes

- # of kelp farms: 2 (proposed) → 5 (to date)

Objective/task 5: Determination of growth, productivity, and nutrient removal capacity of *S. latissima*:

Productivity

- During the 2013-2014 growing season, productivity from the internal lines appeared to be higher than that from the external lines (Fig. 5 6). It may be because the external lines have received higher physical stresses than the internal lines. However, the productivity was from 0.91 kg m^{-1} (13 m spacing and external line) to 2.5 kg m^{-1} (6.5 m spacing and internal line). The productivity at the D.J. King Lobsters farm site was also similar, 2.7 kg m^{-1}. These values were less than half of the productivity of the previous years (10-17 kg m^{-1}). It was due to the extremely low cold temperature period (~ 2 months) during 2013-2014 growing season. Spacing between longlines (6.5 vs. 13 m) did not appear to be a factor affecting the productivity. During the 2014-2015 growing season, the productivity was measured on the remaining longlines at Thimble Islands Oyster Co., 3.7 kg FW per meter. This is also way less than the productivity in previous years. It was impossible to determine spacing or position effects in terms of productivity and other parameters during 2014-2015 growing season due to the severe loss of biomass (caused by the shearing of the kelp from the longlines by the ice).

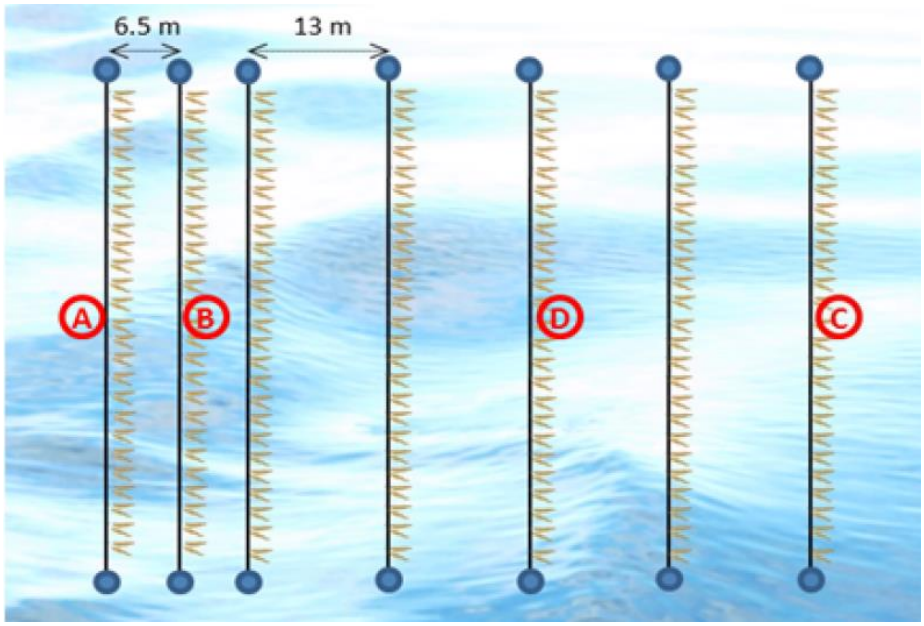

Fig. 5. Top view of the kelp farm design at the Thimble Island Oyster Co., and tissue and water sampling locations (A-D).

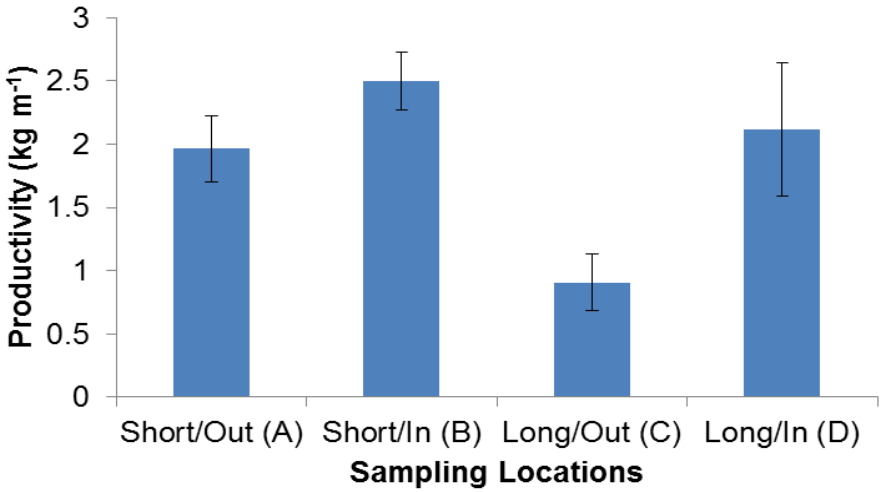

Fig. 6. Productivity at different sampling locations at the Thimble Island Oyster Co. kelp farm during the 2013-2014 growing season. Short: 6.5m spacing; long: 13 m spacing, Out: external longline; In: internal longline.

Tissue nitrogen (N) and carbon (C) contents

Spacing between longlines did not affect the tissue C and N contents in 2013-2014 growing season (data not shown). However, the tissue N contents appeared to be higher at harvest in June (0.80±0.10%) than those in March (0.64±0.04%) or in April (0.60±0.06%), while the tissue C contents did not show any seasonal variations. The C:N ratio was high, 50.2 (March), 54.4 (April) and 39.1 (June), indicating nitrogen limitation at the Thimble Island Oyster Co.'s farm site. At the D.J. King Lobsters' farm site, the tissue N content was higher (1.27%) than that at the Thimble Island Oyster Co.'s farm site, while tissue C (27.34%) and C:N ratio (21.9) were lower than those at the Thimble Island Oyster Co.'s farm site. It may be because the D.J. King Lobsters' farm site is closer to a wastewater treatment plant at Branford than the Thimble Island Oyster Co.'s farm site. During the 2014-2015 growing season, limited tissue samples were collected only at harvest at the Thimble Island Oyster Co.'s farm site due to the severe winter weather conditions and complete loss of biomass at the D.J. King Lobsters' farm site. Tissue nitrogen and carbon contents were 1.55 ±0.12% and 35.40±3.03%, respectively.

Nutrient bioextraction

Integrating average total production (harvested biomass) and average tissue nutrient content at harvest provided overall estimates of nutrient bioextraction per meter of longline. Because tissue nitrogen and carbon contents were not different at different sampling locations, nitrogen and carbon removal patterns at different sampling locations were dependent on productivity. Like productivity, nitrogen and carbon removal appeared to be higher at the internal lines than that from the external lines. Spacing between longlines (6.5 vs. 13 m) did not appear to be a factor affecting the nitrogen and carbon removal. The values of nitrogen removal were 1.62 (location A), 1.83 (location B), 0.83 (location C) and 1.58 g m^{-1} (location D), respectively. The carbon removal was 64.3 (location A), 78.1 (location B), 26.3 (location C) and 65.5 g m^{-1} (location D), respectively. We also estimated nitrogen, carbon and phosphorus removal in our *hypothetical* nutrient bioextraction 1 hectare sugar kelp farm systems (Table 1).

Table 1. Nutrient bioextraction for hypothetical *Saccharina latissima* farms with longline separation distances of 1.5 and 6.0 m.

Year	Site	1.5 m longline spacing			6.0 m longline spacing		
		N removal (kg ha^{-1})	P removal (kg ha^{-1})	C removal (kg ha^{-1})	N removal (kg ha^{-1})	P removal (kg ha^{-1})	C removal (kg ha^{-1})
2014	Thimble Island Oyster Co.	10.6	7.2	439.1	2.5	1.6	99.5
	D.J. King Lobsters	23.1		500.0	2.7		111.4
2015	Thimble Island Oyster Co.	38.3		877.7	9.7		222.7

The N stable isotope

As we did in a previous NFWF supported projects, the source of dissolved inorganic N was evaluated using stable isotopes (^{15}N, ^{14}N). A sewage treatment plant is located > 6 km (D.J. King Lobsters' farm) and > 7 km (Thimble Island Oyster Co.'s farm) west of each farm. The N stable isotope ratios in samples were analyzed at the University of California - Davis' Stable Isotope Facility (Davis, CA). The $\delta^{15}N$ values in kelp were above values typical of marine dissolved inorganic N (4–6‰; Owens, 1987; Peterson and Fry, 1987) from Feb to June in tissues grown at the Thimble Island Oyster Co.'s farm and at harvest in the D.J. King Lobsters' farm in 2014, as well as at harvest at the Thimble Island Oyster Co.'s farm in 2015, suggesting the primary N source at both sites was sewage derived inorganic nitrogen (Fig. 7).

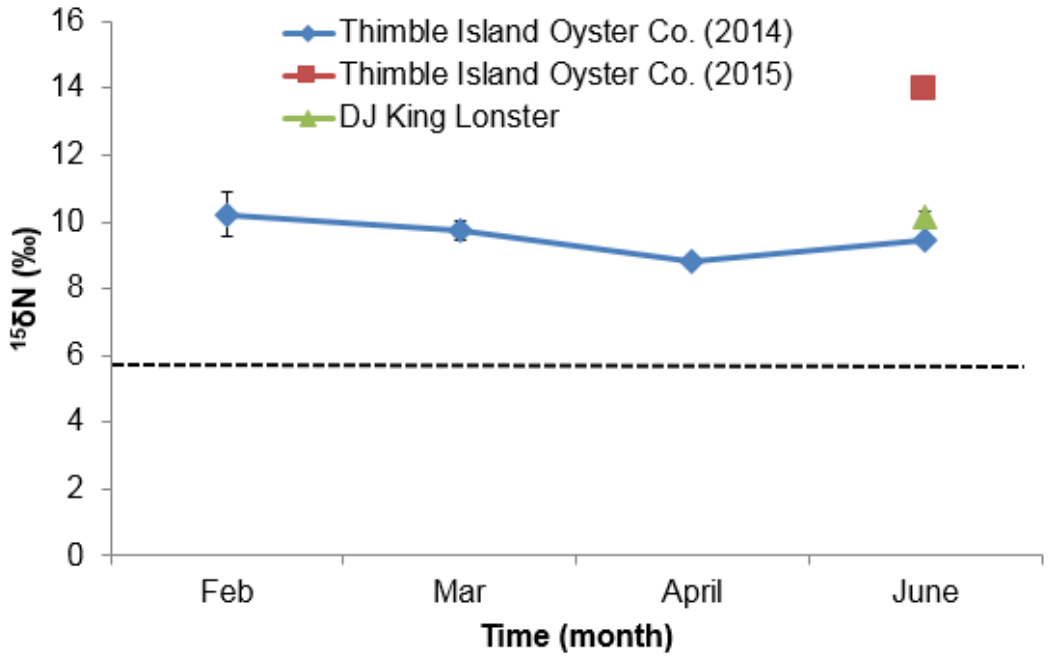

Figure 7. $\delta^{15}N$ signature in kelp tissues grown at the Thimble Island Oyster Co.'s farm and D.J. King Lobsters' farm. Dotted line represents the highest δ15N value in the marine dissolved inorganic N.

Phytoremediation

Heavy metal contents were also evaluated with sugar kelp samples at harvest from the Thimble Island Oyster Co.'s farm site in 2014 (Table 2). We also estimated heavy metal removal rates in our *hypothetical* nutrient bioextraction 1 hectare sugar kelp farm systems (Table 3).

Table 2. Total heavy metal and phosphorus contents (μg g^{-1}) in sugar kelp tissue from the Thimble Island Oyster Co.'s farm site at harvest (mean ± SD).

	Cr	As[1]	Cd	Pb	Hg[2]	P
2014	2.01 (±0.89)	27.02 (±2.33)	0.17 (±0.04)	1.16 (±0.60)	0.068 (±0.011)	5057.4 (±516.3)

Table 3. Potential heavy metal removal (g ha^{-1}) in our *hypothetical* nutrient bioextraction 1 hectare sugar kelp farm system (1.5 m or 6.0 spacing).

	Cr	As	Cd	Pb	Hg
1.5 m spacing	3.7	49.4	0.32	2.1	0.13
6.0 m spacing	0.9	12.5	0.08	0.54	0.03

Outcomes

- Productivity: > 1,650 lb FW (Thimble Island Oyster) and 1,200 lb FW (D.J. King Lobsters) in 2013-2014 growing season, and 407 lb FW (Thimble Island Oyster) in 2014-2015 growing season.
- Nitrogen removal: 24 lb (proposed) → 1.3 lbs. (to date) at Thimble Island Oyster farm and 2.1 lb (to date) at D.J. King Lobsters in 2013-2014 growing season. In 2014-2015 growing season, 0.6 lb (to date) at Thimble Island Oyster
- Carbon removal: 400 lb (proposed) → 51 (to date) at Thimble Island Oyster farm and 45 lb (to date) at D.J. King Lobsters in 2013-2014 growing season. In 2014-2015 growing season, 15 lb (to date) at Thimble Island Oyster
- Phosphorus removal: 6 lb (proposed) → 0.83 (to date) at Thimble Island Oyster farm in 2013-2014 growing season.

Objective/task 6. Evaluation of impacts on nitrogen and phosphorus concentration

No clear patterns were observed in terms of the concentrations of dissolved inorganic nutrients at within and around the farm systems of the Thimble Island Oyster Co.'s farm during 2013-2014 growing season (Fig. 8). No clear seasonal pattern was observed either. However, interestingly, the total inorganic nitrogen concentration was remained similar from Feb. to May and was even increased in June. In the previous years at the same location, the total inorganic nitrogen decreased as water temperature increased. Ice melt from the severe winter might have caused a continuous discharge of nutrients into the Sound. The inorganic nutrient concentrations were higher at the D.J. King Lobsters' farm site throughout the growing season (Fig. 9). It may be because this site is closer to the wastewater treatment plant at Branford than the Thimble Island Oyster Co.'s farm site.

During the 2014-2015 growing season, total nitrogen concentrations at the Thimble Island Oyster Co. farm were 10.16 μM in May and 8.24 μM in June, respectively, while those at the D.J. King Lobsters' farm site were 19.11 μM in March, 23.70 μM in April and 10.61 μM in May, respectively. Phosphorus was not detected at both sites during this sampling period (data not shown).

[1] EPA Standard for drinking water is10 ppb, FDA standard for animals treated with veterinary drugs is 0.5-2 ppb. These standards are for Inorganic Arsenic. "Shellfish (especially bivalve mollusks and crustaceans) concentrate arsenic in seawater, but it exists in the organic forms, which have not been shown to produce adverse effects in humans consuming these seafoods. This type of organic arsenic is also rapidly excreted" (http://www.epa.gov/ttn/atw/hlthef/arsenic.html)

[2] FDA Standard: 1 μg g^{-1} dry weight base. This standard is for fish, shellfish, crustaceans and other aquatic animals (fresh, frozen or processed).

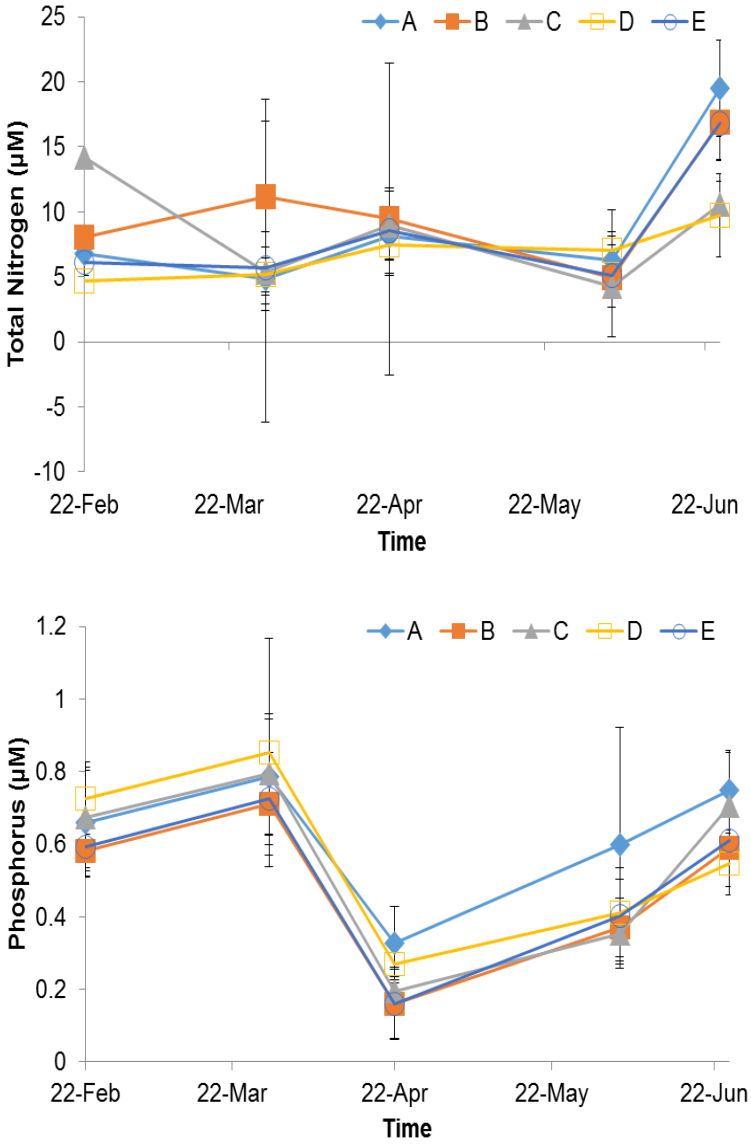

Fig. 8. Dissolved inorganic nutrient concentrations over the course of the study at the Thimble Island Oyster Co.'s farm site in 2013-2014 growing season. Top panel: total dissolved inorganic nitrogen. Bottom panel: dissolved phosphorus.

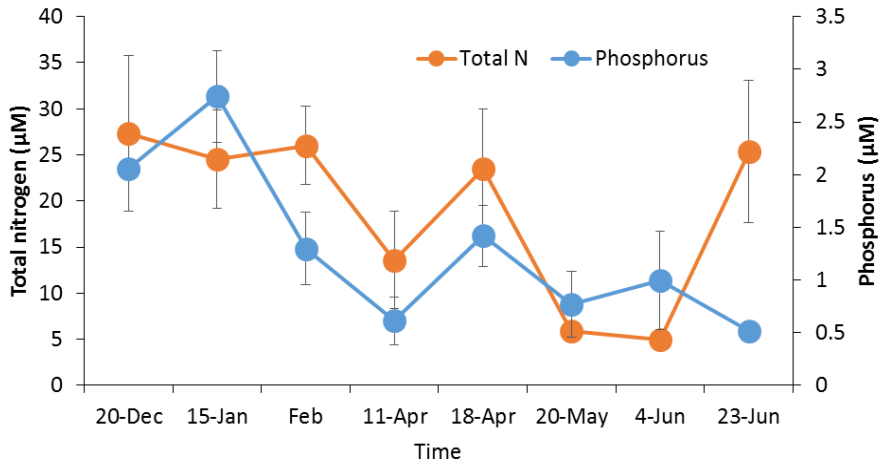

Fig. 9. Dissolved inorganic nitrogen and phosphorus concentrations over the course of the study at the D.J. King Lobsters' farm site in 2013-2014 growing season.

Objective/task 7. Development of teaching curriculum on nutrient bioextraction and phytoremediation.

Teaching curriculum
With the PIs assistance, BRASTEC's Bridgeport Aquaculture College Alliance (BACA) Program faculty, staff and students developed a teaching curriculum on nutrient bioextraction (see Appendix 2 for details). This teaching curriculum will be available to other schools, educational and related programs around LIS and the US. The BRASTEC staff along with the PIs have also presented their novel teaching curriculum at regional and national educators and scientific conferences.

Presentations
We have made 32 presentations including 20 invited presentations in relevant and appropriate events during the project period (see Appendix 3 for details).

Publications
Kim J.K., G.P. Kraemer and C. Yarish. 2015. Use of sugar kelp aquaculture in Long Island Sound and the Bronx River Estuary for nutrient extraction. Marine Ecology Progress Series. 531: 155-166; &
Kraemer, G.P., J.K. Kim and C. Yarish. 2014. Seaweed aquaculture: bioextraction of nutrients to reduce eutrophication. Association of Massachusetts Wetland Scientists Newsletter. April 2014 No. 89, 16-17.

Outcomes:
- # of schools participating: 2 (proposed) → 2 (to date)
- # of volunteers: 5 (proposed) → 9 (to date)
- # of teaching curriculum on nutrient bioextraction: 1 (proposed) → 1 (to date)
- # of publications: 0 (proposed) → 2 (to date)
- # of presentations: 0 (proposed) → 32 (to date)
- # of media appearance: 0 (proposed) → 14 (to date)

3. Lessons Learned
Describe the key lessons learned from this project, such as the least and most effective conservation practices or notable aspects of the project's methods, monitoring, or results. How could other conservation organizations adapt their projects to build upon some of these key lessons about what worked best and what did not?

1. In a scalable sugar kelp farm, the productivity, tissue nitrogen and carbon contents were similar through the farm system regardless spacing between longlines.
2. Inorganic nitrogen and phosphorus concentrations at different locations of the farm system (internal and external) showed no difference.
3. Productivity, nitrogen and carbon removal appeared to be higher at the internal lines than that from the external lines because the external lines received higher physical stresses than the internal lines, caused the reduction of productivity.
4. Historically severe winter weather created unusually cold sea temperatures that resulted in sea ice covering all kelp culture locations. Kelp longlines were even moved over 1.0 km away from the farm by the ice, resulting in a complete loss of biomass. The scalable kelp farm (one hectare) design developed in this project is believed to help growers to be prepared for similar weather events in the future, especially in Long Island Sound because, this new design considers severe winter weather conditions, currents and winds in LIS, and the necessity for safe boat operations during sampling and harvest.
5. The estimates of nutrients extracted by the sugar kelp farm in a scalable 1 ha farm are 38 (N), 7.2 (P) and 870 kg ha^{-1} (C), respectively. However, these values are underestimated due to the biomass reduction by the severe winter weather conditions (ice shearing) during the project period. The values will be higher if the farm is prepared for the severe winter conditions using the farm re-design developed in this project.
6. The kelp aquaculture may also be a useful tool for phytoremediation.

4. Dissemination
Briefly identify any dissemination of lessons learned or other project results to external audiences, such as the public or other conservation organizations.

- We have made 20 invited presentation, including institutions in four foreign countries (Korea, China, Israel and Mexico), Long Island Sound Citizens Summit, The CT DEEP Nitrogen Trading Board, Long Island Sound Assembly, Maine Sea Grant, Scripps Institution of Oceanography, Wesleyan University Men's Club of Newtown, Cornell Cooperative Extension of Suffolk County, Three Rivers Community College, First Sunday Science at the Seaside Center, Bruce Museum (Greenwich, CT), Sherwood Island State Park, Oceanic Institute of Hawaii Pacific University, etc. Additional 12 presentations were made in relevant scientific conferences and events.
- Our work has received a great deal of media attention, including Washington Post, The New Yorker, CNN, Riverhead News-Review, Scientific American, lohud.com, www.27east.com, nationswell.com, wildfoodgirl.com, futurefood2050.com, gastropod.com, Wild Food Girl, inkct.com, etc. (Appendix 4)
- One of our farmers has won the prestigious $100,000 2015 Fuller Challenge Prize from the Buckminster Fuller Institute.

5. Project Documents
Include in your final programmatic report, via the Uploads section of this task, the following:

- 2-10 representative photos from the project. Photos need to have a minimum resolution of 300 dpi and must be accompanied with a legend or caption describing the file name and content of the photos;
- report publications, GIS data, brochures, videos, outreach tools, press releases, media coverage;
- any project deliverables per the terms of your grant agreement.

POSTING OF FINAL REPORT: *This report and attached project documents may be shared by the Foundation and any Funding Source for the Project via their respective websites. In the event that the Recipient intends to claim that its final report or project documents contains material that does not have to be posted on such websites because it is protected from disclosure by statutory or regulatory provisions, the Recipient shall clearly mark all such potentially protected materials as "PROTECTED" and provide an explanation and complete citation to the statutory or regulatory source for such protection.*

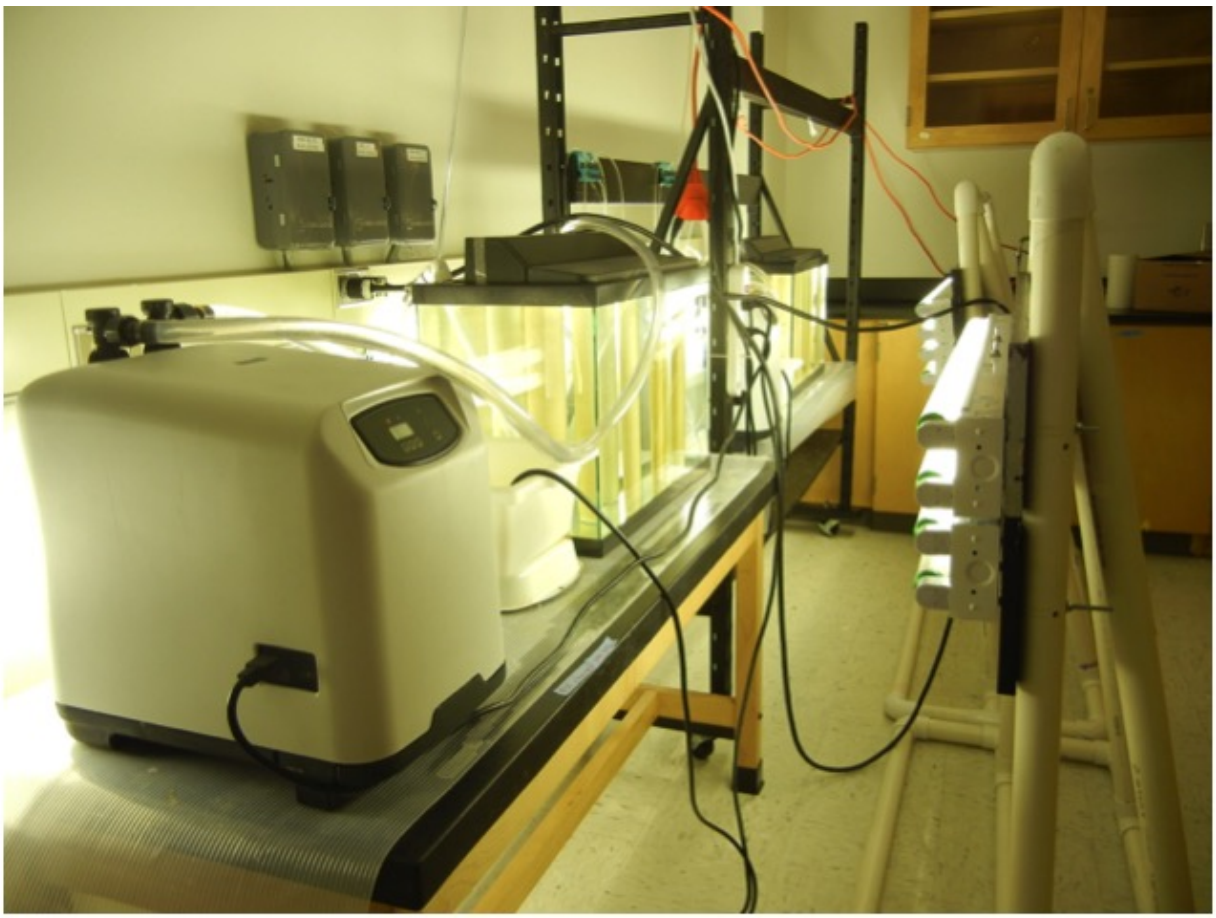

Fig. 1. The sugar kelp nursery system at the University of Connecticut (UCONN) at Stamford. UCONN has over 3,500m seedstring production capacity at its kelp nursery.

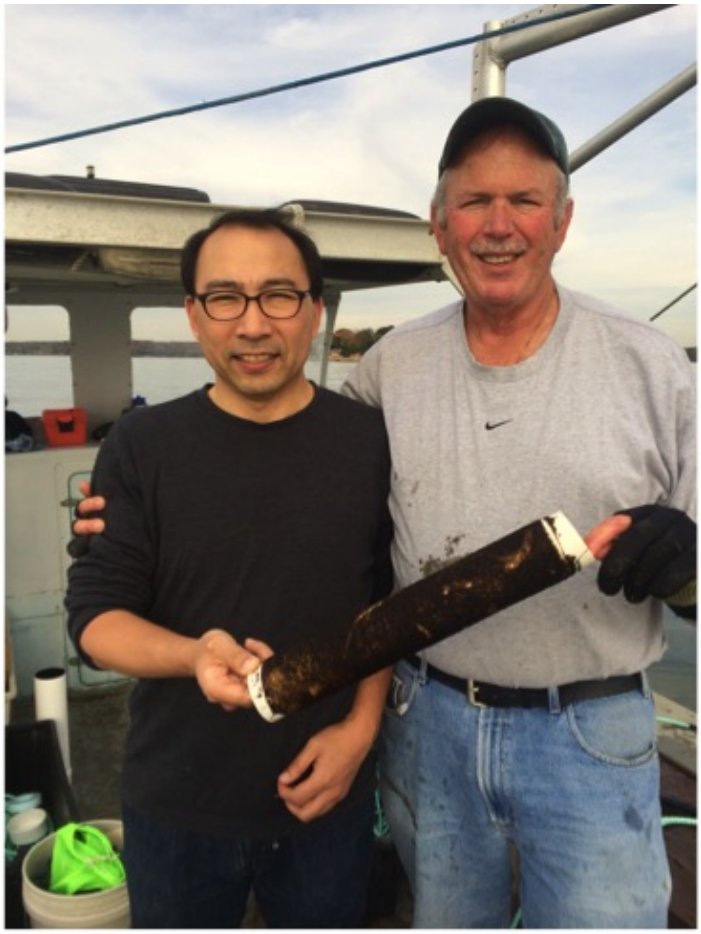

Fig. 2. Drs . Charles Yarish and Jang K. Kim holding seed spool. kelp farm at the Thimble Island Oyster Co. kelp farm at Branford, CT.

Fig. 3. Bren Smith, the owner of Thimble Island Oyster Co., holding the sugar kelp line at his kelp farm in the Thimble Islands, Branford, CT

Fig. 4. D.J. King, the owner of D.J. King Lobsters, holding the sugar kelp line with Dr. Jang K. Kim at his kelp farm at the mouth of the Branford River Estuary, Branford, CT

Fig. 5. Bren Smith, the owner of Thimble Island Oyster Co. holding the kelp line in May, 2015. The productivity was very low due to severe weather conditions during the 2014-2015 growing season.

Fig. 6. Frozen sea at Stoney Creek harbor, Branford, CT. The study sites at Branford were not accessible due to ice formation for over one month (2013-2014 growing season) and for over two months (2014-2015 growing season).

Fig. 7. The ice formed due to severe weather in 2015 moved the seaweed lines and Ice sheered most of the plants off the longlines.

Appendix 1. Kelp Farm Designs for Long Island Sound

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General considerations

Kelp farming in Long Island Sound (LIS) is a nascent industry evolving largely out of the shellfish-farming sector. Because of this prior experience, the states bordering LIS have a mature permitting process from other sea farming activities. LIS offers a nutrient-rich environment that sees only modest currents and is protected from large ocean waves. However, is has a heavily populated shoreline, many user conflicts, and little protection from wind waves.

The present industry is typified by small vessels that are suitable for the scale of operations generally permitted by the states and are adequate for the environmental conditions in the sound. Pictured in Figure 1, we see a small boat typical of what is used in suspended shellfish culture.

Figure 1. Typical boat for tending aquaculture leases.

An important difference between shellfish farming and macroalgae culture is the weight of the product being grown. Shellfish are heavy and require significant amounts of flotation as they grow, unless they are being grown on the seabed in cages. Because of the requirement for sunlight and dissolved nutrients, seaweed culture needs to be closer to the sea surface. Being close to neutrally buoyant, the addition of large numbers of floats to compensate for shell growth is not needed. However, to avoid interference with vessel navigation the lines that make up the farm structure want to be kept below a depth required by permitting agencies.

Experiments in Long Island Sound with sugar kelp (*Saccharina latissima*) have shown growth rates of 17.5 kg/m, among the highest reported in the world. In order to facilitate the growth of the macroalgae sector, reliable culture system designs are needed that can be serviced by existing infrastructure. System reliability is an important issue in the site permitting process and well-engineered standard designs should speed approval.

A common practice is some coastal shellfish farms is the use of longlines to suspend the cultured product in a linear array with each line suspended between opposing anchors as seen in Figure 2.

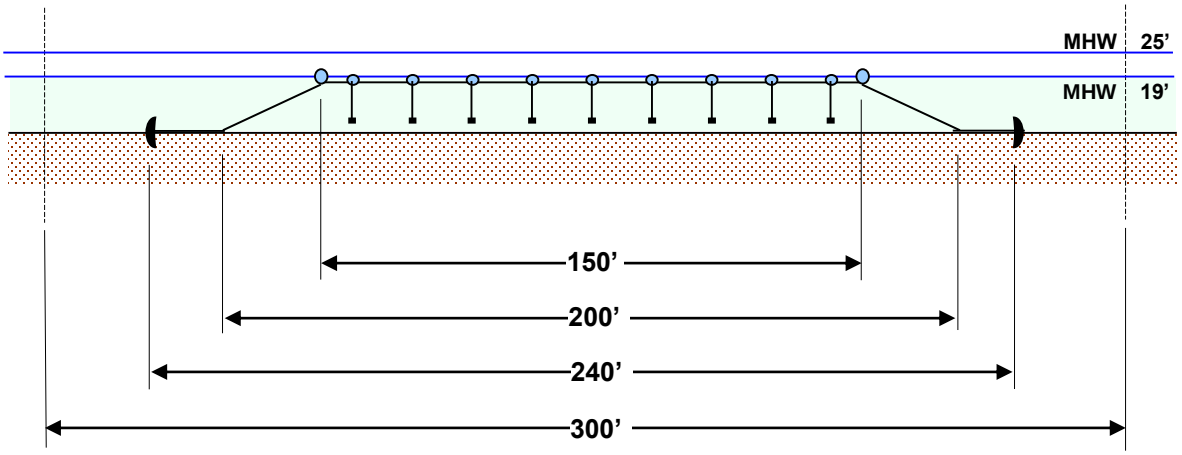

Figure 2. A typical long line system for supporting shellfish of macroalgae culture.

However, this approach does not scale well since in order to usefully exploit lease sites, multiple longlines would be needed and the required number of anchors and mooring lines can become prohibitive as shown in Figure 3. A better design is needed that involves fewer anchors and does not required precise anchor placement.

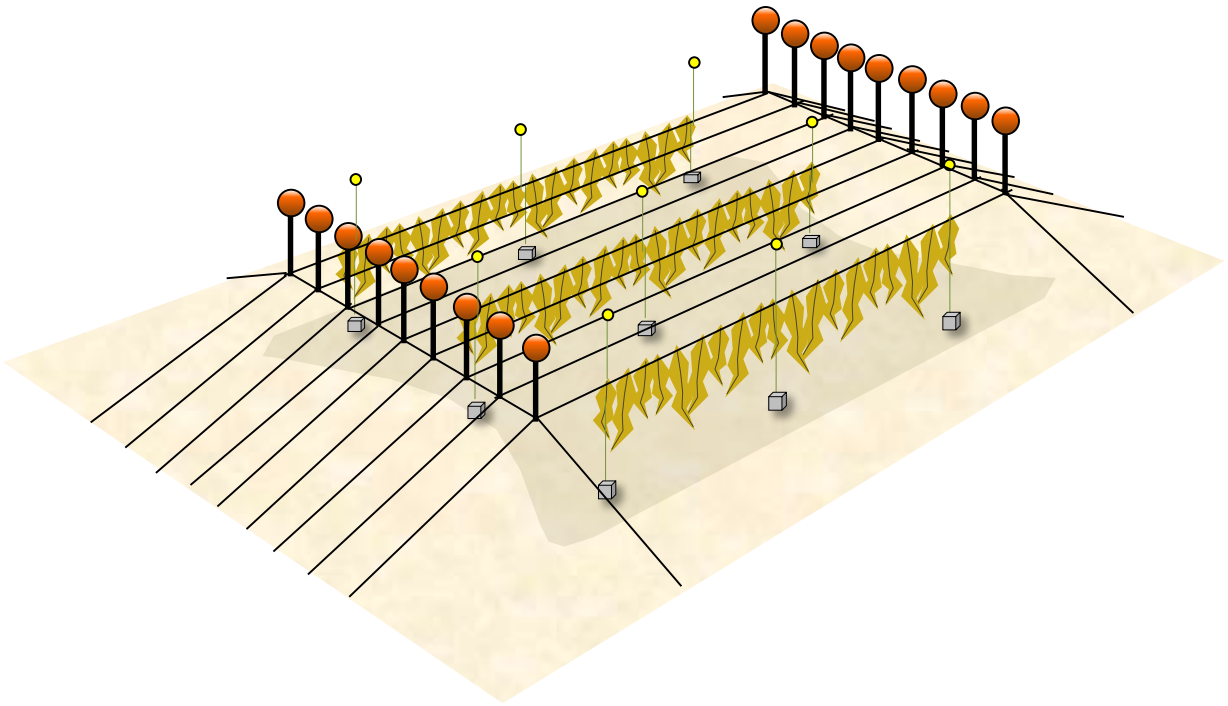

Figure 3. A hypothetical kelp farm array where each longline is kept taut by opposing anchors.

Candidate farm locations

Based on tidal current studies and available leasing areas, five farm sites have been proposed as being suitable for kelp farm development and they are shown in Figure 4. Figure 5 shows the current ellipses based on circulation model simulations.

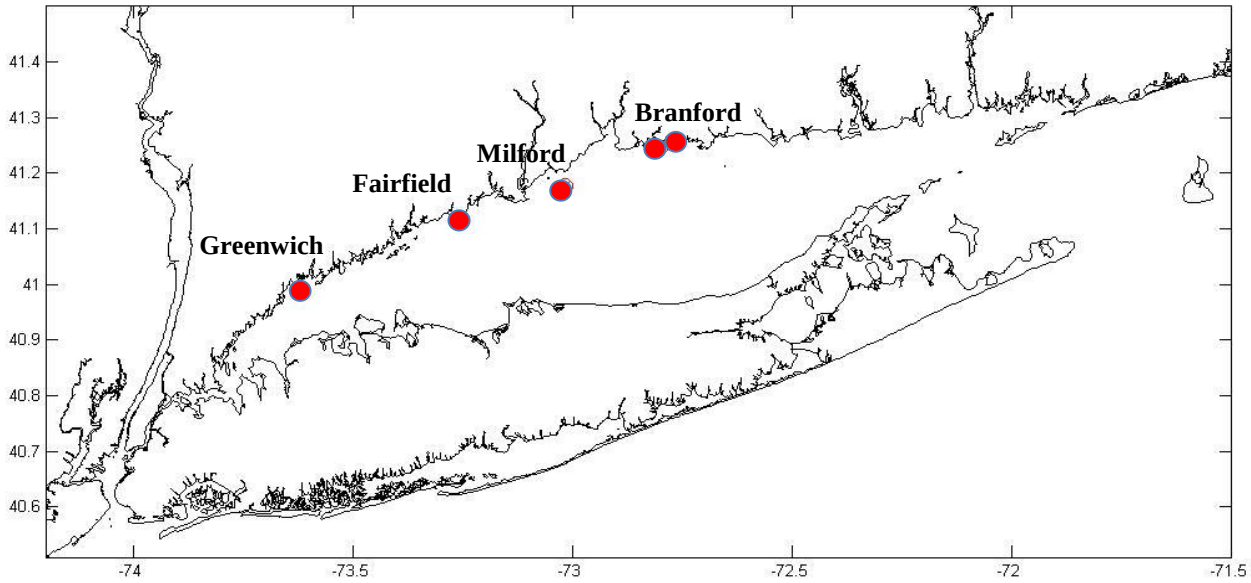

Figure 4. Hypothetical LIS kelp farm sites.

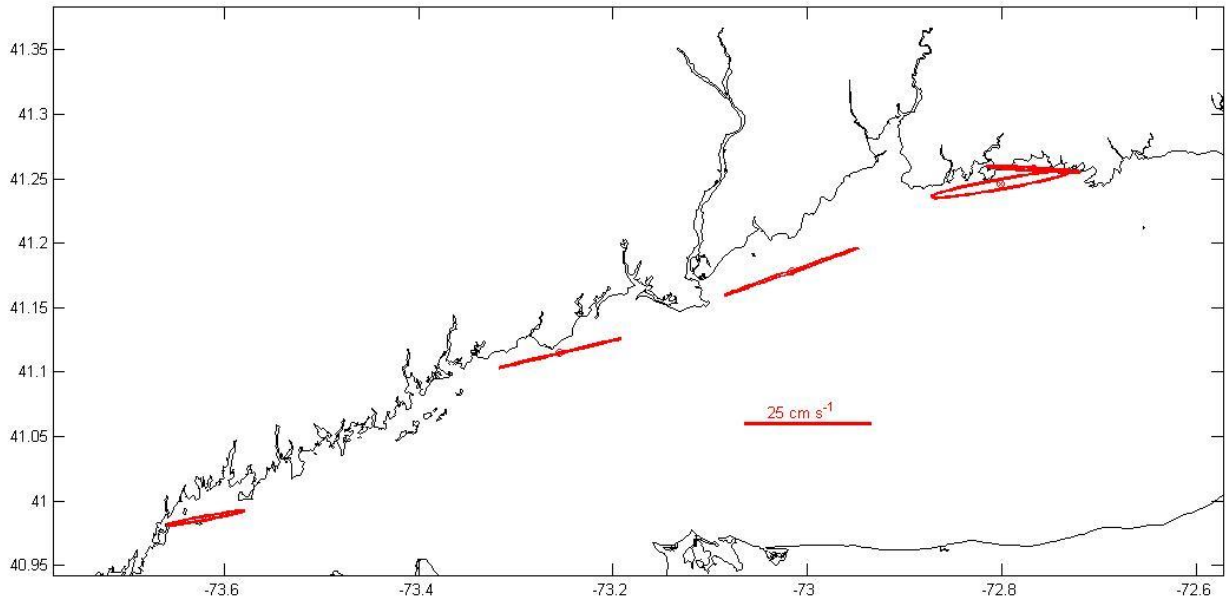

Figure 5. Tidal current ellipses at the five candidate sites.

The depths, currents, and wave exposure were factored into the requirements for a kelp farm design. It is necessary to provide a stable array geometry and maintain control of the kelp depth, yet allow sufficient flexibility for the servicing of the long lines.

In order to provide uniform support to the kelp longlines the use of a catenary structure is proposed (see Figure 6). This will reduce the need for many anchors and eliminate the requirement for their precise placement.

Figure 6. The inspiration for the catenary kelp farm.

The catenary offers a means of providing uniform tension across a series of longlines in the same way that it provides uniform support to a bridge roadway. Figure 7 showed these principals applied to the framing line of a catenary array. The lengths and angles of this geometry are shown in Table.1

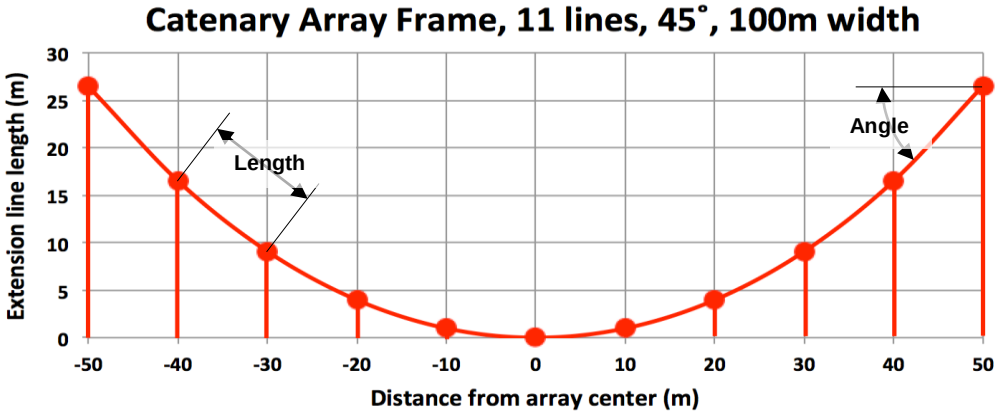

Figure 7. The general configuration of a 100m wide, eleven-longline array.

Width (m)	Line (m)	Angle (˚)	Length (m)
-50	26.5	-45.1	14.2
-40	16.5	-36.6	12.5
-30	9.1	-27.1	11.2
-20	4.0	-16.6	10.4
-10	1.0	-5.6	10.0
0	0.0	0.0	
10	1.0	5.6	10.0
20	4.0	16.6	10.4
30	9.1	27.1	11.2
40	16.5	36.6	12.5
50	26.5	45.1	14.2
Total catenary length			116.7

Table 1. The line lengths and angles of the catenary shown in above.

These specifications can be scaled to other gross dimensions while arrays of different line count can be calculated using catenary formulas. Applied to a kelp farm, the arrangement is shown in Figure 8.

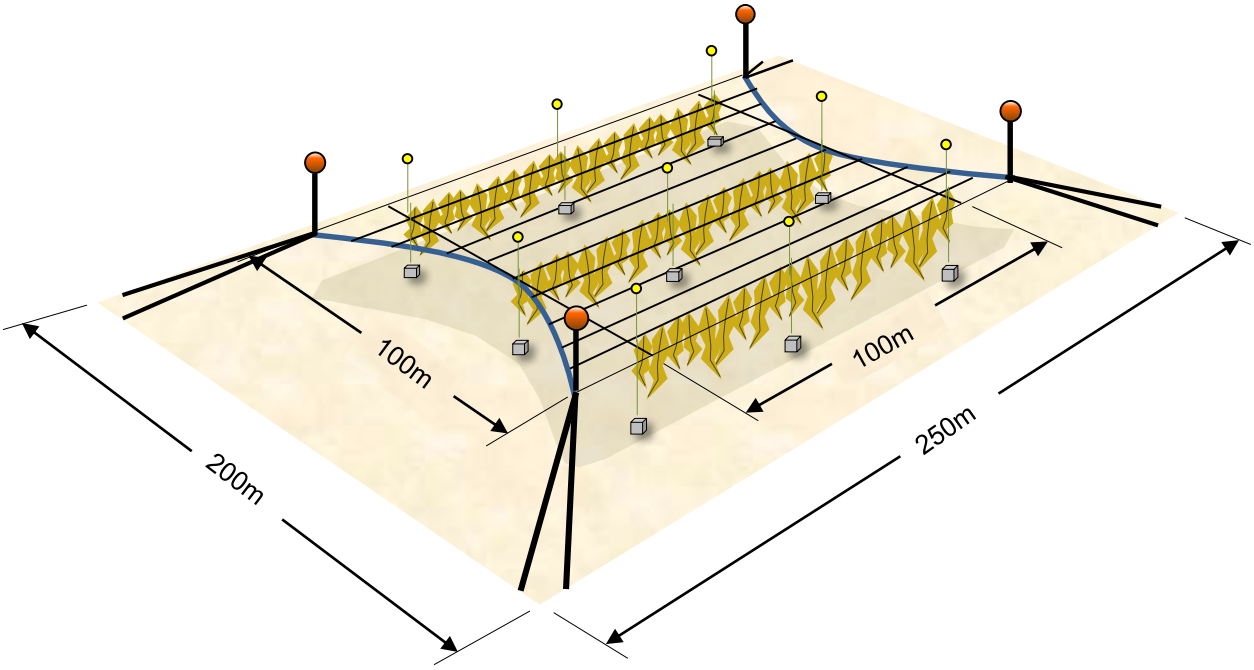

Figure 8. A pictorial of a catenary kelp farm.

For an eleven-longline array, the resulting design has reduced the mooring requirements from 26 anchors only a pair of anchors at each corner and without the need for precise placement. However, the required holding power of each of these eight anchors is 3.9 times the individual longline anchors. The management of these anchors from small boats may require a fresh examination of anchoring.

Anchor Technologies

There are numerous types of anchors that can be considered, including drag embedment, penetrating, deadweight, and combination. The first category includes such designs as Danforth, Bruce, and Vryhof as seen in Figure 9.

Figure 9. A Danforth anchor.

Penetrating anchors include helical screw-in anchors, driven anchors such as Manta Ray and Stingray designs (Figure 10), and drilled and grouted types.

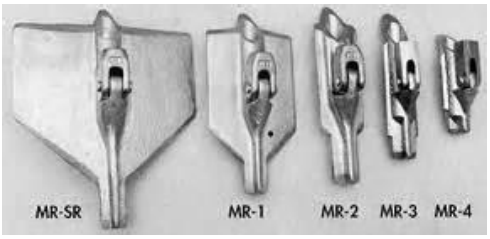

Figure 10. Manta Ray anchors are driven into the seabed and toggle to prevent extraction.

Deadweight anchors depend on their weight and their friction on the seabed to provide holding power. They are made of iron, steel, concrete, or rock with the density of the material relative to that of seawater determining the resultant underwater weight. Figure 11 shows a popular concrete design while Figure 12 shows the adaptation of steel railroad wheels.

Figure 11. Deadweight anchors of poured concrete.

Figure 12. A steel anchor adapted from a salvaged railroad wheel.

Combination anchors combine deadweight and shape and include mushroom anchors, Dormor anchors, and other shapes designed to dig into the seabed if its bottom friction is exceeded and typified in Figure 13.

Figure 13. A cast iron Dormor anchor.

Shaped concrete offers some unique cost advantages. For example, Figure 14 shows a large truncated pyramid shape used for an offshore fish cage single-point mooring. Both the underwater weight of the block and the angled shape of the sides of the block contribute to its effectiveness. If it begins to slide due to its frictional forces being exceeded, the front edge will begin to dig into the bottom. It is advantageous to have a rough and slightly concave underside of the block to increase these behaviors.

volume	212	cu. m.
diameter	8.1	m.
max. current	1	m/s
1" mesh drag	2,566	lbs
1/2" mesh multiplier	1.75	
1/2" mesh design drag	4,491	
2x fouling margin	8,981	lbs
concrete	150	lbs/cu ft
S.W. weight	64	lbs/cu ft
coef. of friction	0.7	
Submerged buoy	770	lbs
cage buoy	100	lbs
Req. UW weight	13,700	lbs
Desigh dry weight	23,895	lbs
Concrete volume	159.3	cu ft
	5.9	cu yds
	4.513	cu m
Anchor height	0.5	m
	1.64	ft
Base dimension	4.00	m
	13.13	ft
Top dimension	2.00	m
	6.57	ft

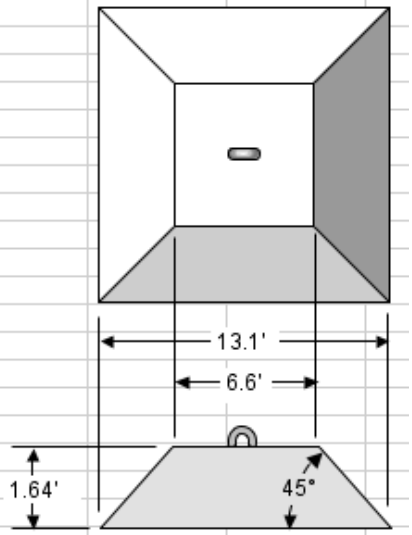

Figure 14. A shaped concrete anchor used for a fish cage in the Gulf of Mexico.

This anchor would be too large for a kelp farm application and is not of optimal shape since it was designed to resist pull in any direction. The anchors needed for the catenary array have a single direction of pull and therefore their shape can be simpler. An attractive option to the use of a wheelbarrow tray of the type shown in Figures 15a and 15 b as a form.

Figure 15a. A 4 cu ft. wheelbarrow
Poly tray cost - $34.97

Figure 15b. 10 cu ft. wheelbarrow
Cost - $169.00, Poly tray only - $128.58

Figure 16 pictures an anchor block poured using such a form and it presents an excellent shape for a combination type anchor.

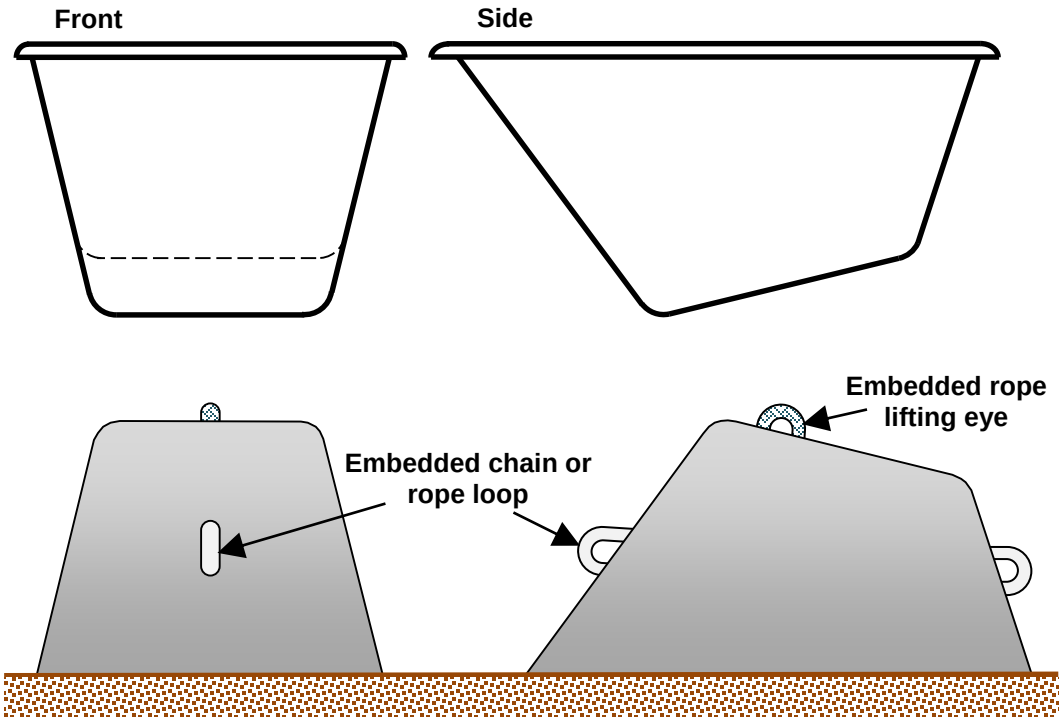

Figure 16. A shaped-deadweight anchor cast in a 10 cu. ft. wheelbarrow tray.

The specification of concrete anchors must take into consideration the displacement of the concrete when submerged, as this diminishes the resulting frictional forces. Table 2 offers the holding power of a concrete deadweight anchor based on a friction coefficient of 0.7.

Wheelbarrow tray						
Size	Anchor weight	UW weight	Mooring line angle	Holding Power (lbs)		
cu ft	lbs	lbs	degrees	single	double	triple
4	600	344	10	237	478	719
	600	344	20	226	467	708
	600	344	40	184	425	666
6	900	516	10	356	717	1,078
	900	516	20	339	701	1,062
	900	516	40	277	638	999
8	1200	688	10	474	956	1,437
	1200	688	20	453	934	1,416
	1200	688	40	369	851	1,332
10	1500	860	10	593	1,195	1,797
	1500	860	20	566	1,168	1,770
	1500	860	40	461	1,063	1,665

Table 2. The holding power of single, double, and triple concrete anchors.

In Table 2 results are provided for these anchors singly and connected in series where the holding power is cumulative. Only the front anchor's friction is diminished by the upward angle of the mooring line. By including a line between each anchor that is at least as long as the water depth, the setting of these multiple anchors is possible from a modest-sized boat. See Figure 17.

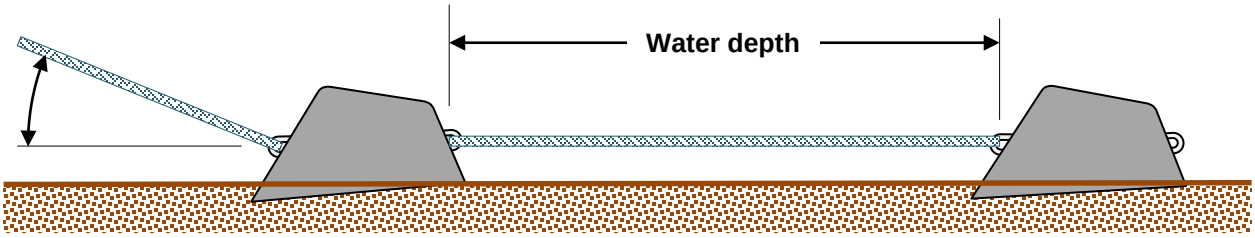

Figure 17. Multiple anchors with the "mooring line angle of Table 2 indicated.

Array buoys

The catenary array requires flotation at the corners where the mooring lines intersect with the end of the catenary. The amount of flotation needed is determined largely by the pretension of the system established during installation, the drag of the array components due to tidal currents, and the vertical angle of the mooring lines.

Generally a surface buoy is utilized as it can also serve as an obvious marker to boaters for the existence of the array. However, these surface buoys can present problems in the winter when portions of LIS can freeze over or when there are flows of ice passing over the farm. Conventional buoy shapes present the opportunity for ice to entrap the buoy resulting in forces on the mooring array and the anchors in excess of their designed loads.

On the left of Figure 18 we see a typical buoy with a shape that encouraged entrapment in the ice. On the right we see a tapered buoy that resists entrapment by pulling down and out of the ice flow.

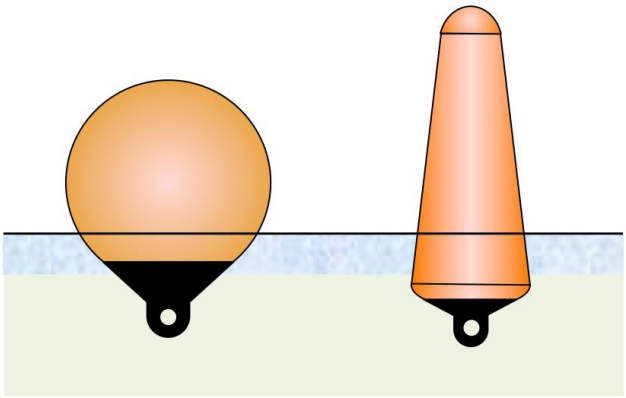

Figure 18. A conventional buoy and one designed to resist ice entrapment.

Appendix 2. Teaching curriculum on nutrient bioextraction

How sweet it is?
Nutrient Bioextraction using The Sugar Kelp *Saccharina latissima*
Lesson Plans
Bridgeport Aquaculture Science and Technology Education Center
Holly Turner-Moore
Kirk Shadle

Essential Questions:

What are the natural and anthropogenic sources of nitrogen into Long Island Sound?

How can sugar kelp be used to remove extract nitrogen from Long Island Sound?

What are the impacts to Long Island Sound as a result of nitrogen loading? What are the sources of nitrogen in Long Island Sound?

Standards

- **Next Generation Science**
  - *To Be Completed*
- **Connecticut Common Core**
  - *To Be Completed*
- **Agriculture Food and Natural Resource**
  - *To Be Completed*

ACTIVITY 1: Nitrogen and Long Island Sound

Focus:
Students will complete a web quest to learn about anthropogenic sources of nitrogen and then develop a nitrogen cycle diagram highlighting the sources found in their research. Describe the process of nutrient bioextraction and discuss how it can be used to mitigate nitrogen pollution.

Focus questions:
What are the sources of nitrogen in Long Island Sound natural and anthropogenic?
How does nitrogen impact the Long Island Sound ecosystem?
What is nutrient bioextraction and how can sugar kelp be used to extract nitrogen?

Learning Objectives:
The students will:
- Diagram the nitrogen cycle
- Identify 3 major anthropogenic sources of nitrogen into Long Island Sound
- Outline the process of eutrophication

- Describe how eutrophication leads to hypoxic and anoxic conditions in Long Island Sound
- Define nutrient bioextraction
- Compare and contrast the major groupings of benthic marine macroalgae
- Describe how kelp can be used to extract nitrogen from Long Island Sound and then be used as a commercial product

Required resources:

Nitrogen Cycle Diagram
Nitrogen web quest worksheet
Access to computers
Nutrient Bioextraction-PowerPoint (UCONN-Kim & Yarish)

Websites:

Nitrogen Control Program Long Island Sound-DEEP
http://www.ct.gov/deep/cwp/view.asp?a=2719&q=325572&deepNav_GID=1635%20
Long Island Sound Study
http://longislandsoundstudy.net/indicator/lis-point-source-nitrogen-trade-equalized-loads/

ACTIVITY 2: Theoretical Farm Site

Focus:

Students will compare data from two theoretical farm sites, analyze data from each, and calculate the amount of nitrogen uptake by sugar kelp grown and harvested at each site.

Focus Questions:

Which farm site removed the most nitrogen?
What factors impact the growth of kelp?

Learning Objectives:

The students will:

- Compare data from two theoretical farm sites and determine the factors that impact the growth of the kelp at each site.
- Calculate the total nitrogen extracted at each site
- Graph growth data at each site and compare the impact of temperature, salinity and nitrogen availability at each site

Required resources

Farm site data
Access to a graphing program

How sweet it is?

The sugar kelp, *Saccharina latissima,* is a fast growing Phaeophyte (brown seaweed) that can be used for a variety of commodities. These include: as a food for humans and animals, fertilizer, cosmetics or for nutrient bioextraction of nitrogen, phosphorus and carbon. In Activity 1, you had earned how nitrogen cycles through an ecosystem and the natural and anthropogenic sources of nitrogen. With your new understanding of the impacts of excess nitrogen on an ecosystem, use the data to calculate the amount of nitrogen removed from two farm sites. Then, use that data to support your argument to implement a nitrogen trading program in Activity 3.

University of Connecticut professors, Drs. Charles Yarish and Jang K. Kim, teachers, and students at B.R.A.S.T.E.C (Bridgeport Regional Aquaculture Science and Technology Education Center) have been growing and harvesting sugar kelp *Saccharina latissima* for the past 4 years on a farm site off of Fairfield, CT, in Long Island Sound (**SITE A**). In addition, Drs. Yarish and Kim operate an experimental site in the mouth of the Bronx River Estuary (**SITE B**). Through a variety of experiments and observations, Drs. Yarish and Kim, have determined that sugar kelp has the ability to contain between 2% and 4% tissue nitrogen based on dry weight (DW). The ration of fresh weight to dry weight is ~10 to 1. These percentages are based on a variety of factors including light availability, water temperature, and the amount of nitrogen (principally nitrate and ammonia) in the vicinity of the farm. **Use the data below to calculate the total nitrogen removed by the sugar kelp at each farm site and respond to the questions based on the experiment.**

Table 1. Data collected for sugar kelp grown at each site

	Site A-B.R.A.S.T.E.C	**Site B-Bronx River Estuary**
Kelp farm size	1 hectare	1 hectare
Long line length	10 meter spacing between long lines	5 meter spacing between long lines
Total number of long lines	10 × 100 m long lines	20 ×100 m long lines
Tissue Nitrogen-Dry weight (Remember 10:1 FW to DW)	2%	4%
Calculate the total length of line		
An average of 15kg of kelp is harvested per meter. **Calculate the total kelp harvest per site:**		
Calculate the total amount of Nitrogen removed by the kelp at each site:		

1. What are some variables that were be controlled during this experiment? List at least three:
    a.
    b.
    c.

2. If we wanted to maximize the amount of kelp grown at each site what factors should be taken into account?

3. Write a conclusion using the data above.

4. What factors may impede the growth of the kelp on the farm site (s)?

5. How many hectares of sugar kelp grown at 5 meter spacing would be required to remove 50 kg of nitrogen at site A?

Required resources
Farm site data
Access to a graphing program

ACTIVITY 3

Focus:
Students will develop a government action plan to mitigate nitrogen in Long Island Sound and determine the value of nutrient bioextraction.

Focus Questions:

- What are the impacts to Long Island Sound as a result of nitrogen loading? What are the sources of nitrogen in Long Island Sound?
- What government agencies regulate nitrogen loading of Long Island Sound?
- How are these government agencies currently regulating nitrogen loading of Long Island Sound? Are there any non-government agencies involved in the studies of nitrogen in Long Island Sound?
- What is the state of public opinion concerning the issue of nitrogen loading in Long Island Sound?

Learning Objectives

- Students will analyze and evaluate the current data of nitrogen loading in Long Island Sound
- Students will develop a comprehensive outline of government process to address the loading issue
- Students will describe how human activities can influence the nitrogen loading issue

- Students will evaluate data sets of nitrogen loading and debate the issue through role play as invested members of the public
- Students will develop a comprehensive action plan to facilitate government action addressing the nitrogen loading issue

Activity 4: Government Action Plan

1. Develop a comprehensive concept map of background knowledge regarding nitrogen loading in Long Island Sound.
2. Prioritize the issues of nitrogen loading in Long Island Sound based on the data sets analyzed.
3. Correlate the issues of nitrogen loading in Long Island Sound with the local community organizations' action platforms.
4. Establish a series of contacts to develop a "common point" platform of support between the local community organizations.

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Appendix 3. Presentations

Invited

Kim, J.K., C. Yarish and G.P Kraemer. Scripps Institution of Oceanography, UCSD. 2015. Nutrient bioextraction by seaweed aquaculture in urbanized estuaries in Northeast America. Nov. 3, 2015, San Diego, CA;

Kim, J.K., C. Yarish and G.P Kraemer. Korean Society of Environmental Risk Assessment and Health Science. 2015. 8th International Conference on Environmental Health Science: Advanced Technology in Marine Ecosystem, Environmental Diseases, and Health. Oct. 27-29. (Keynote), Incheon, Korea;

Kim, J.K., C. Yarish and G.P Kraemer. Korean Society of Phycology. 2015. Algae: organisms of ultimate possibilities. Oct. 22-23. (Keynote), Iksan, Korea;

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Yarish, C. "Taking Action for the Future: Alternative Technologies and Innovative Solutions: Alternative Technologies", 24rd Annual Long Island Sound Citizens Summit: Coming Back from the Brink, April 10, 2015 (panel member);

Kim, J.K., C. Yarish and G.P Kraemer. Cornell Cooperative Extension of Suffolk County. 2015. Cultivation of native seaweeds including kelp and the red alga, *Gracilaria*, in Northeast America for Food, Feeds and Fertilizer. April 8, 2015, Riverhead, NY;

Yarish, C., J.K. Kim, and G.P. Kraemer. "Cultivation of Seaweeds in Northeast America for Food, Feeds and Fertilizer", Three Rivers Community College 2015 Environmental Issues Seminar Series, April 1, 2015, Norwich, CT;

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Kraemer, G.P., T. Hidu, J.K. Kim and C. Yarish. "Seaweed for food, feed and fertilizer – now and in the future", CT NOFA 33rd Annual Winter Conference, March 7, 2015, Danbury, CT;

Kim J.K., C. Yarish and S. Redmond. 2015. Introduction to the Kelp Nursery Technologies: Wild-sourced Seeding and Hybridization. Northeast Aquaculture Conference and Exposition & the 35th Milford Aquaculture Seminar, Jan. 14-16, 2015, Portland, Maine (http://www.northeastaquaculture.org/wp-content/uploads/2015/01/NACE-Program.pdf);

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Redmond S., J.K. Kim and C. Yarish. 2015, Introduction to the Kelp Farming Technologies: Open Water Farming. Northeast Aquaculture Conference and Exposition & the 35th Milford Aquaculture Seminar, Jan. 14-16, 2015, Portland, Maine (http://www.northeastaquaculture.org/wp-content/uploads/2015/01/NACE-Program.pdf ;

Kim J.K., G.P. Kraemer and C. Yarish, 2014. Kelp farming in Long Island Sound and the New York Estuaries for Nutrient Bioextraction. Joint Aquatic Sciences Meeting, May 18-23, 2014. Portland, Oregon; (http://www.sgmeet.com/jasm2014/static/files/jasm2014-program.pdf);

Kim J.K., G.P. Kraemer and C. Yarish. 2014. Sugar Kelp Aquaculture: a Coastal Management Tool and New Business Opportunities in Long Island Sound and New York Coastal Waters. Northeast Algal Society Annual Meeting, Newport, RI;

Koval D.J., J.K. Kim, G.P. Kraemer and Charles Yarish. 2014. GIS Modeling of Potential Aquaculture Sites in Long Island Sound for Nutrient Bio-extraction. Northeast Algal Society Annual Meeting, Newport, RI;

Yarish, C., J.K. Kim and G.P. Kraemer. 2014. Seaweed aquaculture for nutrient bioextraction and other ecosystem services in Long Island Sound and other urbanized estuaries in northeast America. 2014 Ocean Sciences Meeting, New Orleans, Louisiana; &

Kraemer G.P., J.K. Kim, C. Yarish and T. Hidu. 2014. Cultivation of seaweed in Long Island Sound for food, feed and fertilizer. CT NOFA 33rd Annual Winter Conference, Danbury, CT.

Appendix 4. Media appearance

http://www.lohud.com/story/money/2013/10/16/seaweed-farming-proves-sound/2997751/

Seaweed farming proves Sound

Written by **KEN VALENTI**
OCTOBER 16, 2013.

If you're munching on a trendy salad that has a certain marine quality to it, or if your cocktail has a twist of kelp, your dining excursion may help to save Long Island Sound.

Seaweed has become the latest tool in the long battle to breathe new life into the estuary, just as it is becoming more popular on dinner plates at upscale restaurants.

At three spots in the central and western Sound, scientists from the University of Connecticut and an aquatic farmer, working with other schools, have been testing the idea by growing sweet kelp in the winter and gracilaria, another type of seaweed, in the summer.

As the marine foliage sprouts rapidly along lines 50 or 100 meters long, it uses up nitrogen, a nutrient so overabundant in the Sound that it topples the balance of life, creating oxygen-depleted dead zones in warm weather where fish and other creatures struggle to survive.

"Every line you pull out that grows, you're removing nutrients," said Charles Yarish, professor of ecology, evolutionary biology and marine sciences at the University of Connecticut.

Two years ago, he and others from the University of Connecticut, Purchase College and other entities started the program, stringing lines at the mouth of the Bronx River and off Fairfield, Conn. They started with funding from groups including Connecticut Sea Grant and the Long Island Sound Study, a partnership of federal, state and local governments as well as private entities.

A year ago, aquafarmer Bren Smith of Branford, Conn., got in on the project, after his shellfish beds among the Thimble Islands had been battered by major storms.

"I got wiped out by Irene and Sandy," he said. "I lost 80 percent of my crop two years in a row. ... I came to the conclusion that I had to adapt."

Last year, he strung two 50-meter lines studded with sea kelp over the beds in December. Five months later, he had two tons of seaweed.

Unlike the other sites, Smith's had approvals for the seaweed grown there to be sold as food. So he sold half and gave half away to cultivate a market. It was gone in six weeks to chefs and others who would toss it into salads or slice into "noodles." One entrepreneur was experimenting with kelp in mixed drinks, Smith said.

The foliage that is not eaten by humans can be used as fertilizer or biofuel. Extracts are used as emulsifiers in other foods or in cosmetics.

Yarish offered a workshop on the growing process and its benefits last week in Mamaroneck.

While the seaweed improves the health of the water, it can do the same for diners. It is loaded with nutrients such as iron, calcium and iodine, said Paul Dobbins, president of Ocean Approved, a Maine-based producer of kelp as food products.

And it's finding its way onto more menus.

"The popularity of Japanese food has really propelled seafood into the forefront of dining," said Louise Kramer, spokeswoman for the Specialty Food Association. "People are getting more experimental with it."

"There's a lot of interest in sustainability and the environment," Kramer said. "People want to be good. There's this great interest in where your food comes from and locally sourced products."

Nisa Lee, a Westchester-based caterer, uses Ocean Approved kelp many ways, sometimes simply tossed in a salad with olive oil and lemon.

"It has great texture," she said. "It is incredibly refreshing."

No one has the illusion that seaweed farmers alone soon will restore the balance of nitrogen just by growing their crops. The researchers estimate that a 2.5-acre farm of marine foliage could remove 600 pounds of nitrogen over the five-month winter growing period. During the summer, the amounts vary. The same 2.5 acres, strung with gracilaria, could remove 73 pounds of nitrogen in July and about 20 pounds in October, they estimate.

Excess nitrogen that enters the Sound in sewage, animal waste and from other sources is measured not in hundreds of pounds, but in thousands of tons. Sources in Connecticut alone added 57,000 tons of nitrogen to the Sound in 2005, the latest year cited in a 2012 annual report from the Long Island Sound Study.

But the foliage is one of many tools in the effort to boost the Sound's health. And it's a cinch to grow, with seedlings cultivated by Yarish and assistant research professor Jang Kim in a UConn lab in Stamford. It's as easy as stringing the lines in the Sound's waters and letting them dangle.

"It takes zero inputs," Smith said. "There's no fresh water, no fertilizer, no land use." Also, it goes in after hurricane season, in December, and its rapid growth reduces the risk of trouble with harsh weather, he said.

"(In five months) they go from practically invisible or a fuzz to about 10 feet," said George Kraemer, professor of environmental studies at Purchase College, SUNY, who was involved in the project. "And these lines get so heavy, it takes a couple to three people to pull the line out of the water."

Mark Tedesco, director of the Environmental Protection Agency's Long Island Sound office, said the seaweed brings other benefits, such as providing shelter for marine creatures.

"There's no negative environmental impact from having these plants growing," said Tedesco, whose office heads the Long Island Sound Study. The partnership gave about $250,000 in grants to start the program.

The gracilaria grows quickly, too, Yarish said.

"I put out a fistful, about 20 grams, and then we come back in two weeks, it's the size of a soccer ball and we give it a haircut," he said.

The effort is expanding. Smith will string seven lines in December.

Mamaroneck Supervisor Nancy Seligson, an advocate of Long Island Sound improvement, sees promise in its growth.

"They're on a small scale right now," she said. "But the hope is that experiments like this could be expanded to a very large scale that can make a real difference."

http://www.27east.com/news/article.cfm/Sag-Harbor/42759/Seaweed-Could-Be-The-Next-South-Fork-Crop

Seaweed Could Be The Next South Fork Crop

Publication: The Southampton Press
By Virginia Garrison
Dec 19, 2013

They call kelp "the virtuous vegetable" up in Maine. Seaweed is good for you, what with its potassium and calcium and iodine and Omega-3.

Off the Connecticut shore of Long Island Sound, the Thimble Island Oyster Company now farms seaweed, and kelp accompanies oysters, clams and mussels in community-supported fishery shares just like the vegetables rewarding shareholders in CSAs. "Eating like a fish"—that is, eating seaweed—can ease pressure on fish stocks, according to Thimble Island's website, which also notes that Manhattan restaurants are serving kelp linguine, kelp ice cream, even kelp cocktails, all using its harvest.

Not only is seaweed a sustainable food source, without the need for irrigation, land or pesticides, but it can remove nutrients such as nitrogen that promote excessive algae growth, improving the health of water bodies while removing carbon from the atmosphere.
Imagine South Fork farm stands and restaurants selling homegrown kelp harvested by local baymen, or by oyster growers who want to make use of the water above their shellfish beds. Is the farming of sea vegetables the next logical step beyond the cultivation of shellfish?

The answer depends on who's giving it, considering a number of hurdles ranging from official certification to protecting the environment to finding a spot where seaweed farming could turn a profit without interfering with other activities.

"You've got some good opportunities there as long as the growers are able to get the proper permits from the Department of Environmental Conservation and also the Army Corps of Engineers. ... You've got some excellent areas," said Charles Yarish at the University of Connecticut in Stamford, who mentioned Montauk, the Peconic bays, Shelter Island and Long Island Sound as possibilities. A professor of ecology and evolutionary biology and an expert in aquaculture-cultivated seaweed, Dr. Yarish helped get kelp farms off the ground at both the Thimble Island Oyster

Company and Ocean Approved in Portland, Maine, a former mussel farm that last year harvested more than 100,000 pounds of three native seaweeds germinated onshore and then set out on lines descending into the water.

“Once the kelp gets to about 1/2 to 2 millimeters long, then we move it into the open ocean,” explained Paul Dobbins, an owner of Ocean Approved. In 90 to 110 days the seaweed will grow to be anywhere from 9 to 12 feet long, with a harvest of about 33,000 pounds per acre. Ocean Approved sells most of its fresh-frozen product, which comes in cuts like “slaw,” “noodle” and “salad,” to restaurants and food service organizations. The Maine company—whose nutritionist, Stefanie Sacks, lives in Montauk—says its product is much more vibrant-looking and tasty than dried seaweed imported from Asia.
“Business is booming,” Mr. Dobbins said, adding that the company’s tillers of the ocean were “right in the middle of our seeding season” for next spring’s harvest.

“The rest of the world has done it, and now the U.S. is starting to catch up ... globally, we are really behind the curve,” Mr. Dobbins said. “I believe aquaculture is how we’re going to feed the world’s population.”

Mr. Dobbins and Dr. Yarish led three workshops in New England on kelp farming this fall. Together, they drew 154 participants, including Joe Tremblay, who’s been involved in raising oysters in Sag Harbor and nearby through an “oyster club” of private individuals, the Cornell Cooperative Extension’s Southold Project on Aquaculture Training (SPAT) program and the Southampton Town Trustees.

“There was a lot of interest from people on Long Island,” said Mr. Tremblay, who attended a workshop at Roger Williams College in Rhode Island. “There’s a lot of potential.”

“I’m interested in growing seaweed because of so many of the problems we’re facing in our local estuaries,” he said, adding that he would like to find varieties that can be grown in smaller water bodies like Sag Harbor Cove where “you can make a difference” by using them to pull nitrogen out. Kelp requires colder water like that off Montauk, he said, also noting that a current impediment to farming sea vegetables locally is the lack of a mechanism for securing approvals from the DEC.

“The product is clean and it’s loaded with nutrients,” Mr. Tremblay said. “So the health food market for it is strong ... a combination of Asian and health food markets.” One might combine farming shellfish or even harvesting sea salt with farming seaweed, he said. “I can definitely see someone selling this at farmers markets and everyone eating it right up.”

An owner of Bay Burger in Sag Harbor, Mr. Tremblay said he wasn’t sure that raising seaweed is “what I want to do with my life,” but pointed out that he already has an ice cream business—Joe and Liza’s Ice Cream—“so I’m already in the frozen food market.” If he doesn’t get involved, he said, he hopes that someone else will.

“Somebody’s going to do it, no doubt about it,” said Gregg Rivara, an aquaculture specialist with Cornell Cooperative Extension’s marine program. Mr. Rivara ticked off several hurdles to growing seaweed locally, however. Kelp grows relatively high in the water column because it needs sunlight, which means boats could run afoul of the lines on which the plants are cultivated, There would also need to be a way to guarantee that the water is pure enough to make the seaweed safe to eat, perhaps by making sure it comes from places already certified for shellfish. Also, seaweed growers would need permission to use bodies of water, which generally are owned by the public: shellfish farmers who have leases for bottomland couldn’t just tack seaweed-growing onto their approval, Mr. Rivara said: “It’s like saying I’m leasing the house from this guy and I want to start a tire store.”

On the other hand, he said the idea held small-scale promise for perhaps “10 percent of the existing 40 or 50 people involved in shellfish aquaculture” on the East End, potentially providing an opportunity to diversify for fishermen who already have boats and gear and others simply thinking about a startup business.

“I’m all for what you call water-dependent uses of the shoreline,” said Mr. Rivara, who used to gather seaweed in Montauk and hang it on his clothesline before mixing it into soups and other dishes. He pointed out, too, that seaweed has also been seen as a potential source of fuel and for pharmaceutical use for years.

There's a long history to eating sea vegetables, but Americans really only started giving them a sniff in recent years, Mr. Rivara said. "You can get seaweed salad at most restaurants now. ... I think it's more of a niche market—there's a cachet to it—just like local wine and beer," he said. "I could see farmers carrying it at farm stands."

Larry Liddle, a professor emeritus of marine science at Stony Brook Southampton, who has long studied seaweed, said the use of sea plants as "scrubbers" is already in place both in the Harlem River—in that case with the DEC's permission to proceed experimentally—and in China, where Dr. Liddle has been working over the last three years with people who grow a red alga called gracilaria to remove nutrients and for use as food and as a gelling agent. He stressed that seaweed must be harvested if it is to remove nitrates; otherwise they will simply return to the water when the plants break down.

The kelp seen at Montauk Point is what the Japanese call kombu, an edible plant, although it's at the southernmost point of its range and thus not as plentiful as it is to the north.

"I think the issue, the overall issue, is the problem of introducing any nonnative species to any area," Dr. Liddle said of farming seaweed locally. "It might take over or something like that."

Diane McNally, clerk of the East Hampton Town Trustees, expressed a similar concern, adding that the prospect of using Trustee-owned waters had not so far been raised. At one point they discussed "seeding" a community shellfish garden, she said, adding that growing seaweed might somehow be worked into that program if it comes to pass. The private use of a public resource like Trustee waters has traditionally been tricky, she said, adding that the county has been leasing bottomland in Gardiners Bay and wondering whether growing seaweed might "fit in more easily ... in a scenario like that."

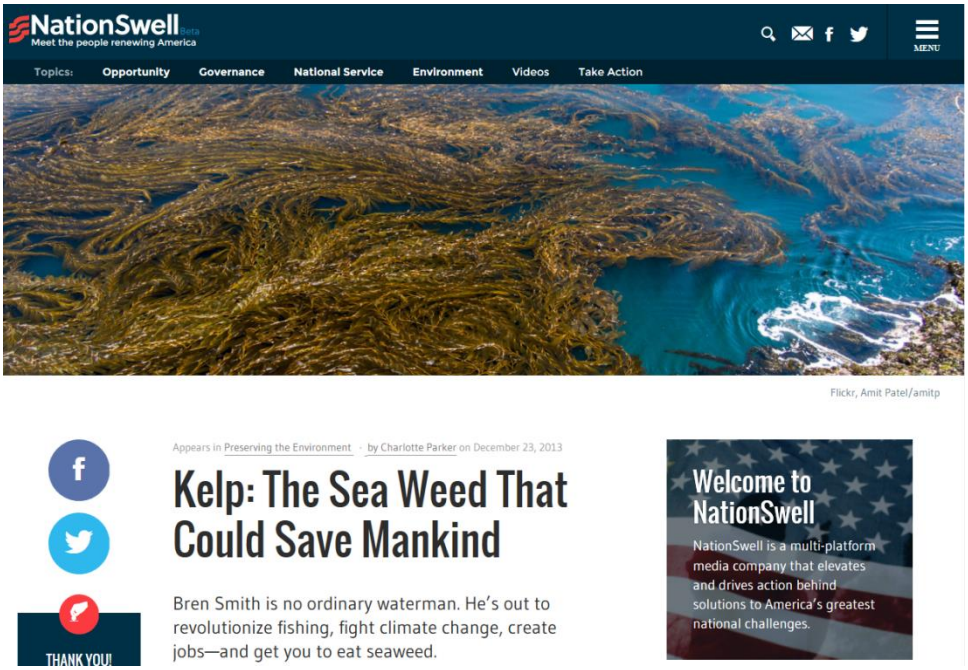
Southampton Town Trustee Bill Pell, who works out of Shinnecock Bay, said he had explored the idea of farming seaweed years ago after seeing it done on the West Coast. "You need deeper water, colder water," he said. "Our bays are warmer."

Another Southampton Trustee, Ed Warner, said he sees very little kelp where he fishes, including in western Peconic Bay, essentially from Gardiners Island west to Flanders. "I do see codium, basically the spaghetti grass," he said, adding that the native plants are likely to involve shellfish beds that had best not be disturbed.

But Dr. Yarish described the concept as "3D farming" where both the water column—with, say, oysters on the bottom and seaweed above—and the seasons can be exploited with greater efficiency. "Here's another crop for the shellfish farmer," he said. "And you're doing valuable ecosystem services."

He said a winter crop of sugar kelp would work particularly well in this area, growing from December through late April or early May, when recreational boats are out of the water and biological activity has slowed down. Fishermen or shellfish growers who own boats could grow kelp during their slow period, Dr. Yarish said, with the added advantage that the nutrients the seaweed removes are at their highest levels in January and February.

"So we're doing very important ecosystem services, and just by growing a commodity that has potential as a sea vegetable we're providing livelihoods," Dr. Yarish said. "It's good for the environment and it's good for business, you're giving people a good healthy commodity—and if you have a gluten allergy you can make a pasta that's gluten-free."



http://nationswell.com/sea-weed-save-mankind/

Kelp: The Sea Weed That Could Save Mankind

Preserving the Environment
by Charlotte Parker
December 23, 2013

Bren Smith is no ordinary waterman. He's out to revolutionize fishing, fight climate change, create jobs—and get you to eat seaweed.

Bren Smith blends into the New England seascape, a waterman decked out in waders tooling around on his boat in the Long Island Sound. On this hazy July morning, he's motored out aboard the Mookie III from a Stony Creek, Conn., dock to check on his oyster beds scattered between the Thimble Islands. Another boat putters by, and Smith raises his arm to point, his hands cloaked in rubber gloves to protect against the barnacles. "That guy," Smith says, "is only catching about five pounds of lobsters a day. He doesn't even pay for half his fuel with that." And with this observation, Smith shatters the illusion that he's just another fisherman chasing his catch.

Smith, in fact, is a genuine revolutionary, a man who sees powerful currents of change in the choppy waters off the Atlantic seaboard. And his neighbor, chugging past with his nearly empty hold, is proof that the end of a way of life is looming—and the beginning of a new one is at hand.

Climate change has affected the fishing beds. Ocean acidification, a product of rising atmospheric CO2 levels, kills off coral reefs, causes toxic algae blooms and dissolves the shells of oysters and other mollusks, researchers say.

And then there's what Smith calls the "rape and pillage" of the world's oceans—the overfishing that has dried up once-fertile sources of food, and sent unemployment in once-thriving seaside communities through the roof. Smith assigns himself a share of the blame. He fished for McDonald's in the Bering Sea some years back, and pushed the cod stocks to the brink. But grousing about it, and hoping government regulation will solve the problem, won't do the trick. What fishermen catch needs to be rethought. What fishermen should be doing, in Smith's view, is harvesting kelp.

Yes, you read that right: the slimy brown sea vegetation that has grossed out generations of New England beachgoers. You might think of it as an annoyance of no particular significance to mankind. Smith sees it as a jobs program, an amazing source of nutrition, a strategic adaptation to the havoc being wrought by global warming—and, quite possibly, the next big thing in trendy New York City restaurants.

He calls it his "path of ecological redemption," and he's calling on fishermen, businessmen and consumers to follow it with him.

A short, bald man blessed with the ability to sound businesslike and salty at the same time, Smith dropped out of high school at age 14 to become a fisherman, intending to spend his life at sea (even though, as a product of Newfoundland's icy waters, he never learned to swim). He stuck with it, while finding time to graduate from the University of Vermont

and take a law degree from Cornell. In 2002, he leased a plot of shellfish ground, and began growing oysters, mussels, scallops and clams. He started a community-supported fishery program, the first of its kind in the Northeast, supplying subscribers with a package of sustainably grown shellfish once a month during the summer months. Business was rolling along—until back-to-back hurricanes in 2011 and 2012 stuck him with cages full of oysters suffocated by mud. He began looking into species that could both renew their ecosystem and better resist storm surges.

His search was fueled by changes in the waters beneath his boat. The combination of overharvesting and ocean acidification had begun taking a dramatic toll. "There are thousands of boats beached, houses foreclosed, up and down the East Coast, in the gulf, everywhere," Smith says. "The idea that climate change is an environmental issue has sort of been misbranded. It's an economic issue."

Today, he runs what he calls a 3-D sea farm, covering some 20 acres. He harvests seaweed, mussels and scallops near the ocean surface, with oysters and clams in cages further below. He speaks of renewing, rather than depleting, the ecosystem on his watch. But his eyes really light up when he starts talking about kelp. It's a food source with "more iron than red meat, more calcium than milk and more protein than soybeans," he intones, on a video accompanying a Kickstarter campaign to raise money in support of his efforts. It's fuel, for machines—with the potential to one day relieve America's dependence on oil. And it's a source of jobs, for a region that desperately needs them. "It's an industry that doesn't exist, an industry we can scale up," Smith tells me.

He's making headway with his sales pitch. This year alone, he's been featured in *The New Yorker*, NPR, *The Wall Street Journal*, *McSweeney's Lucky Peach*, and *National Geographic*. He's visited with venture capital investors. He's teamed up with the Yale Farm, which has helped him spread the word—extending his reach into media and food circles. And lately, he's been making the 90-mile drive from his patch of ocean to New York City, the bed of his orange pickup packed with kelp in solar-powered coolers, delivering it to a handful of forward-thinking chefs to play around with in their kitchens.

David Santos is a believer. A veteran of the foodie landmark Per Se on Manhattan's Upper West Side, Santos took to Kickstarter himself to launch his own place, Louro, in the West Village. He's lined the walls with glass jars of creative combinations of ingredients he steeps for days on end, giving the place the aura of a genial mad scientist's lab. Sure, seaweed has long been part of a Japanese diet. But Americans need to be led a little. So Santos is sneaking dishes onto VIP and tasting menus—pureeing ribbons of kelp into house-made butter, frying them into tempura, sprinkling them into lemon soup and sautéeing them into a tomato sauce and crab mixture to make an "al diavolo" dish. Not your standard menu, but it's delicious, at least in Santos's hands. "Kelp is a better product than kale," he says. "It's cheaper, it tastes better, there are more nutrients, and more stuff you can do with it."

The trick, Santos says, is getting people to try it—maybe even before you fully acquaint them with what it is they're putting in their mouths. "It's seaweed. It's its own worst enemy in a way. We have to get people to understand this is not just stuff that was laying around—this is stuff that was grown with care, treated properly and produced appropriately," he says.

The toughest sell may be among Smith's fellow watermen. Persuading them to switch from cod to "sea vegetables" could be tricky, Smith knows. "The kelp is more like farming arugula than chasing things," he says. "And people think that's crazy: growing sea vegetables? Fishermen don't grow veggies! It seems kind of wimpy."

"Mother Nature created these technologies hundreds of millions of years ago, and they actually mitigate the harm we do to the sea. Our job now is to grow them."

Bren Smith

The fishermen may take some persuading. But Smith has scientists on his side.

Dr. Charles Yarish, a professor of ecology and evolutionary biology at the University of Connecticut at Stamford, has been researching the ecosystem benefits of kelp for 35 years. In bubbling, white fluorescent-lit tanks in his Stamford lab, two varieties of North Atlantic seaweed—sugar kelp or Saccharina latissima—grow from seed to thread on giant plastic beads. His team uses a system of anchored longlines strung with these beads and planted at three open-water farms—at the mouth of the Bronx River, off the coast of Fairfield, Conn., and on Smith's Thimble Island farm—to grow plants to maturity and test their potential to clean coastal waters.

Sugar kelp, like oysters, soak up nitrogen, carbon and other excess nutrients through a process called nutrient bioextraction. Using Yarish's technology and funded by a series of federal grants, Smith and Yarish have been testing a 3-D sea farm model, using the entire water column to produce food for human consumption, rebuild marine ecosystems and clean, nutrient-heavy waters.

A 20-acre oyster farm could compensate for the aquatic nitrogen pollution caused by 350 shoreline residents, and a 20-acre farm of kelp could remove 134 tons of the carbon that causes ocean acidification. Those same 20 acres could also

grow 24 tons of kelp in five months. “Mother Nature created these technologies hundreds of millions of years ago, and they actually mitigate the harm we do to the sea,” Smith says. “Our job now is to grow them.”

Jeremy Oldfield, field academic coordinator at the Yale Farm, a sustainable food project affiliated with the New Haven, Conn., university, worked with Smith this summer on developing a kelp-based fertilizer for his tomato crop. Oldfield calls kelp “a preloaded multivitamin for farm soil.” Students at the University of Connecticut School of Business are developing a first-round fuel product, based on a U.S. Department of Energy study that found kelp a rich source of sugar for biofuel.

Smith and Yarish have been working with lawmakers and regulators to suss out how to make the farming process easier. Yarish, his U Conn team, and Maine-based Oceans Approved, LLC, have recently started a training program for new kelp farmers in Maine, Rhode Island, and Connecticut.

In exploring seaweed’s potential, Smith shows an almost missionary zeal. “I’m just thinking about how Bren communicates,” says Oldfield. “He has a great sense of ‘food justice.’…It’s sort of like a manifesto.”

And it’s catching on—in this country and beyond. The Kickstarter campaign Smith launched this summer exceeded expectations. He had hoped to raise enough money to cover the cost of hurricane-resistant anchors, marker buoys, lines, installation and marine licensing fees for seven new longlines wrapped in kelp and mussel seeds. By the time the campaign closed in late July, he’d received donations from 734 people, and raised more than $37,000. By the end of August, all the new longlines had been installed on Smith’s Thimble Island farm.

Cash arrived from all over the world: Myanmar, Ghana, Vietnam and Brazil. Donors wondered if kelp could be used as animal feed, whether his 3-D farm model could work for other species of sea vegetables. “I don’t want to think too big and I’m not the one to do this, but I really think it could be replicated globally if you did an ecosystem analysis based on what could be restorative in each place,” Smith says. In Micronesia, for example, it could be conch, or sponges. “The question is,” he asks, “are we going to be able to model this where we scale it up sustainably, locally, where people own their own farms?”

Closer to home, there are now four new sea farmers awaiting permits in the Long Island Sound. The Bridgeport Regional Vocational Aquaculture School, a high school in Bridgeport, Conn., focusing on marine science, has made progress in procuring a kelp noodle-processing machine. Smith’s fisherman’s co-op has voted to install a kelp seed hatchery, which he hopes will become the first in a series of incubators for investigating value-added products such as fertilizer, cosmetics and biofuel.

In September, on the heels of being named to a list of Social Capital Markets’ global entrepreneurs for 2013, Smith traveled to San Francisco to give a talk on restorative species to a roomful of venture capitalists. At the end of October, he brought down the house at the annual TEDx Bermuda conference, where he discussed how his methods could be exported to Caribbean waters.

And there may be even bigger breakthroughs ahead. Impressed by a sampling of kelp lemon soup, kelp butter and kelp fettuccine with shrimp cooked up by chef Santos, Whole Foods is now exploring ways to get Thimble Island’s products on their shelves by next spring. And sometime next year, if all goes according to plan, attendees at the closing dinner for the International Oceans Conference will dine on kelp—served on White House platters.

Smith clearly enjoys the success, but remains anxious about what comes next—like a parent wary of letting his kid wander too far out of reach.

“My job is to advocate now, and then hopefully there will be hundreds of me, out trying it, perfecting it, innovating, and then I can go back to farming by myself. If I’m the only one talking about this in 10 years I’m going to have failed,” Smith says.

Let’s fix this country together.

wildfoodgirl.com

Wild Edible Notebook—March 2014 Release!

Sunday, March 2nd, 2014 at 5:10 pm

Wild sea vegetables are hard to come by here in the Colorado high country, so for the March 2014 issue of the *Wild Edible Notebook* I decided to travel through space and time to coastal Connecticut via several jars of seaweed—Irish moss (*Chondrus crispus*), sea lettuce (*Ulva sp.*) and sugar kelp (*Saccharina latissima*)—that I collected last summer and dried in my parents' house.

While researching the story I was fortunate to tap into the expertise of Dr. Charles Yarish, professor of ecology and evolutionary biology at the University of Connecticut, who promotes the cultivation of sea vegetables as a means to clean coastal waters while also providing good food for the dinner plate. This edition also includes a lighthearted jaunt into wild jellies and things to make with them besides toast. The issue concludes with a handful of recipes using wild foraged seaweeds, including one by West Coast seaweed purveyor Louise Gaudet, as well as a recipe for serviceberry jelly pork glaze by the awesome cook that is my dad.

The Wild Edible Notebook is an ongoing project, started in 2011. It is now available for iPad and iPhone in the Apple Newsstand, or in various PDF formats including screen-reading and 8.5×14" print-and-fold versions at www.wildfoodgirl.com/wild-edible-notebook for $1.99/month. Your support makes the continued development of this publication possible, both on the content and technical sides.

http://wildfoodgirl.com/2014/wild-edible-notebook-march-2014-release/

Wild Edible Notebook

March 2nd, 2014

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RIVERHEAD
NEWS-REVIEW

Agriculture

Kelp, a slippery seaweed, could be major moneymaker

by Carrie Miller | 07/11/2014 8:00 AM

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Kelp, a slippery seaweed, could be major moneymaker

by Carrie Miller
07/11/2014

It's a delicacy Asian cultures have enjoyed for centuries but is more commonly thought of as the slippery — and sometimes slimy — brown stuff that grows naturally in area waters and then washes up on beaches.
And one day, it could be a major moneymaker for the North Fork.
Though regional cash crops are typically cultivated on land, aquaculturists are pushing state and county lawmakers to permit the growing and selling of sugar kelp, or seaweed. They say the salty yet sweet leafy sea vegetable could benefit the economy, the environment, and even put baymen back to work at a time when making a living on the water is becoming increasingly difficult.
Researchers have suggested that farming kelp in Long Island Sound waters has the potential to produce annual sales of $47 million, according to County Executive Steve Bellone's office. But in order for sugar kelp to be farmed in Peconic Bay and Sound waters — where many of the state's aquaculture farms are located — state and county lawmakers need to make regulatory changes to allow it.
Currently, state law allows only for shellfish cultivation in these areas.
Cornell Cooperative Extension of Suffolk County is exploring the idea of growing the kelp industry locally and hopes to partner with researchers from the University of Connecticut on a study in Orient Harbor — if it can find the funds to do so.

Uncharted waters

"It's exciting," Southold aquaculturist Karen Rivara said of the industry's potential while giving Mr. Bellone a tour of the Peconic Land Trust's Shellfisher Preserve on Southold Bay last month. Ms. Rivara, who owns Aeros Cultured Oyster Company, is also president of the Long Island Farm Bureau. She is the organization's first aquaculturist to hold that title.
"I think it's hard to find a reason not to do it."

Area waters already ideal for growing shellfish are also perfect for kelp cultivation, she said, and would allow aquatic farmers another crop to harvest when the shellfish industry slows down, since kelp grows in the winter. The two can be grown in the same underwater space.

Ms. Rivara said the ultimate benefit of kelp is that it thrives on nitrogen, sucking up the very culprit wreaking havoc on the same waters, feeding harmful algal blooms and depriving waters of oxygen.

Growing shellfish and kelp side by side, she explained, would help protect her shellfish from being polluted by harmful algal blooms — one particular variety can cause paralytic shellfish poisoning in humans — and allow her to make a few bucks in the process.

Environmental benefits to be had

"The darker the color, the more nitrogen [the kelp] is soaking up," said Bren Smith, a Connecticut kelp farmer who grows his product in Long Island Sound waters and is banking on the sugar kelp industry to take off. A vocal advocate of kelp's growth potential, Mr. Smith owns Thimble Island Oysters and — as Ms. Rivara hopes to do — grows his shellfish and kelp within a single ecosystem.

And it just so happens that the darker the kelp's color, the richer and sweeter its flavor, said University of Connecticut professor Charlie Yarish, who has been studying seaweed cultivation for several decades.

"It is really a way of restoring the environment while making a product we can eat," he said.

Sugar kelp is produced when reproductive cells, known as spores, are collected from kelp already occurring naturally in local waters, Mr. Yarish explained.

The cells are retrieved from the leafy greens in a lab and settled on a string where they continue to reproduce, essentially growing off the string. The string is then wrapped around a rope and submerged horizontally across bay waters, where the kelp continues to grow by feeding on nitrogen already abundant in Peconic Bay and Sound waters.

"The kelp starts to grow vertically, and it grows very quickly, as soon as the water drops below 50 degrees," said Mr. Smith, who uses this exact process.

In December, January and February, kelp grows rapidly, sucking up nitrogen before phytoplankton — which multiply in warmer waters, eventually causing algal blooms — can begin feeding on it, Mr. Yarish said.

He said he developed the cultivation process with financial support from the Connecticut Sea Grant College Program and has passed his knowledge on to growers like Mr. Smith.

He hopes to one day mentor New York cultivators as well.

A growing market

According to a 2010 United Nations State of the World Fisheries and Aquaculture report, "countries in East and Southeast Asia dominate seaweed culture production (99.8 percent by quantity and 99.5 percent by value, according to 2008 data)."

China, Indonesia and the Philippines lead the way, accounting for over 85 percent of kelp production.

The U.S., however, has lagged behind, as only a handful of growers currently cultivate it nationwide and are located mostly in New England. As a result, it's had to import nearly all of its kelp meant for human consumption.

"I know that seaweed farming in Asian countries has been prolific," said Assemblyman Anthony Palumbo (R-New Suffolk), whose district spans the North Fork. "To kind of expand on that here, I think, is a great idea."

Demand for a domestically grown product safe from contaminants is growing, Mr. Smith said. He added that his company's 18-ton-a-year kelp yield — for which he earns about 35 cents per pound, when wet — is nowhere near filling increasing domestic demand.

Companies including Whole Foods Market are working to incorporate kelp into other products, as a way of expanding the market, Mr. Yarish said. Because kelp has a very short shelf life when gathered fresh from the sea, freezing or incorporating it into other products is a way of preserving it.

The question is, "How do we take this weird thing and get it on the kitchen table?" Mr. Smith said. "How can we make kelp the new kale, which is now on every restaurant menu?"

Sugar kelp is rich in calcium, folic acid and vitamins A, B, D, E and K, according to multiple research studies. As a result, it's been touted by many health food outlets as the next "superfood."

Because of this, it has potential not only for the dinner table but also in pharmaceutical and cosmetic markets.

It's also high in iodine, which is commonly used in supplements given to people with thyroid problems, according to New York University hospital researchers.

Kelp extract is also added to skin care products, helping to give the appearance of firmer skin.

And because it sucks up all that nitrogen, it can also be used as a natural fertilizer, Mr. Yarish said.

Mr. Smith said he hopes land farmers will consider using the seaweed as fertilizer and stop using synthetic forms of nitrogen on land, which inevitably makes its way into area waters.

“We’re taking land- and sea-based farming and trying to close the nitrogen loop,” he said.

What’s being done now

Cultivating kelp in town or privately owned waters and creeks wouldn’t require a change in law, said Chris Pickerell, director of Cornell’s marine program. However, state-owned lands — where many local aquaculture farms exist — would need to amend current legislation to allow for seaweed cultivation.

Ms. Rivara is one of more than 40 growers taking advantage of state-owned land through Suffolk County’s Shellfish Aquaculture Lease Program, which gives area growers access to underwater lands for farming in the Peconic Bay.

Many other shellfish farmers operate on state-owned lands leased in the Long Island Sound, she said. Currently, she said, there’s no way to apply for a permit for seaweed cultivation on state-controlled lands.

“We don’t have the legal mechanism to do it,” she said.

Mr. Pickerell said that “In the simplest sense, it is a matter of adding the words ‘seaweed cultivation’ into the current law.”

He said he’s been working with County Legislator Al Krupski (D-Cutchogue) and state Assemblymen Fred Thiele (I-Sag Harbor) to create legislation to change the law. Ms. Rivara has spoken with Mr. Bellone in hopes of initiating the change.

Senator Ken LaValle (R-Port Jefferson) said a kelp industry would “both lead to job creation and stimulate our economy, while cleaning our waters.”

In a letter supporting Cornell’s pilot cultivation study, Mr. Bellone called the industry’s potential “an extremely interesting, and potentially lucrative, economic development opportunity.” He added that the program will help “develop policies that can help grow and support the industry.”

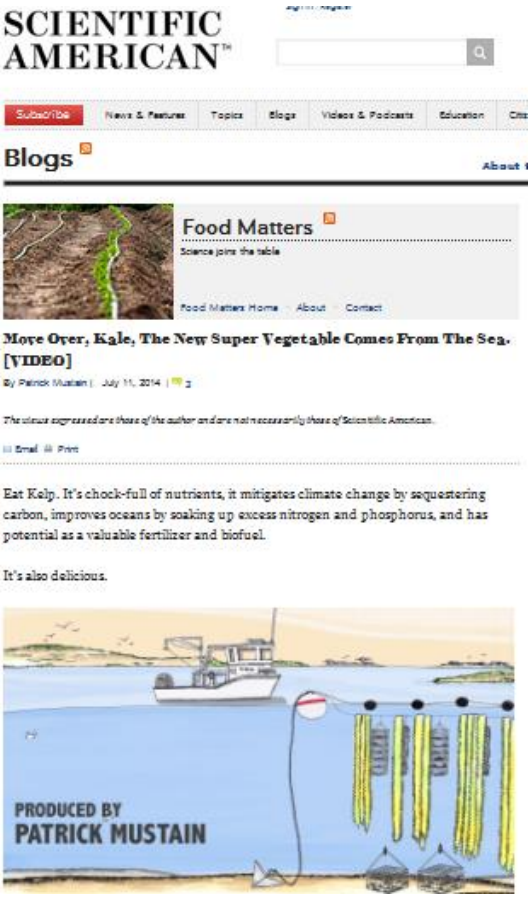
Cornell has applied for grant funding from both the National Oceanic and Atmospheric Administration and the New York State Energy Research and Development Authority’s Cleaner, Greener Communities grant program. It hopes to raise enough money to plan, design, construct and acquire the equipment necessary for a start-up kelp farm.

Mr. Palumbo said, “I would like to see the results of the program so we can see how to manage it [the industry] properly, to find that happy medium so that we can both reduce nitrogen and produce an additional product that can be sold,” adding that the right environmental groups are involved in the project.

From a community standpoint, Mr. LaValle said, the project “will help ensure the maritime industry of aquaculture remains viable, and create new opportunities for the next generation to work on the water.”

He said he has written a letter to the state, which runs NYSERDA, in hopes of receiving project funding from them.

“This is a win-win for everything,” Mr. Pickerell said. “We need to get all of our ducks in a row in terms of the regulatory approvals.”



http://blogs.scientificamerican.com/food-matters/2014/07/11/move-over-kale-the-new-super-vegetable-comes-from-the-sea-video/

Move Over, Kale, The New Super Vegetable Comes From The Sea.

By Patrick Mustain
July 11, 2014

Eat Kelp. It's chock-full of nutrients, it mitigates climate change by sequestering carbon, improves oceans by soaking up excess nitrogen and phosphorus, and has potential as a valuable fertilizer and biofuel.
It's also delicious.
Bren Smith, owner of Connecticut-based Thimble Island Oyster Company, and director of the organization Greenwave started growing kelp and shellfish as a reaction to several crises he faced in his own life: overfishing, climate change, and rampant unemployment in the fishing industry. He was working on the Bering Sea when the cod stocks crashed, and he lost oyster crops to both ocean acidification and two hurricanes.
Based in part on the research of Dr. Charles Yarish at the University of Connecticut, Smith's 3-D ocean farming model uses the entire ocean column to grow as many different foods as possible in as small an area as possible. "I'm growing more food in 20 acres of ocean now than I was in 100 acres a few years ago," he said. Oyster cages mark the sea floor, and curtains of kelp sprout along lines suspended by surface buoys. Mesh containers housing scallops, clams and mussels hang among the long kelp leaves. All of these species extract nutrients that leech into the water from land-based agricultural runoff (a significant contributor to ocean dead zones), and that's central to Smith's approach. His work with Greenwave is aimed at jump-starting a "blue-green" economy: identifying restorative species in any given ecosystem that make the oceans healthier, that are nutritious, delicious, and economically viable. This is an "elegant solution," to some of the problems inherent in our current food system, Smith said.
Indeed, solutions are needed. Menus of Change (MOC), a meeting hosted by the Culinary Institute of America and the Harvard School of Public Health, highlighted the need for reforming the way we produce food. The MOC annual report pointed to a "perfect storm" of problems associated with industrial food production, including challenges like depletion of arable land and fresh water, antibiotic resistance, drought and other extreme weather associated with climate change, food insecurity, and obesity. A 2011 report from the Food and Agriculture Organization of the United Nations identified

the global food production sector as one of the most significant drivers of climate change, consuming about 30 percent of the world's total energy consumption, and producing over one-fifth of its greenhouse gas emissions.

One session at MOC explored the potential of underutilized sea foods, and the promise of ocean-based food production: it requires no fresh water, no land, and if done properly can actually mitigate climate change, rather than contribute to it. But there are challenges: Panelist William Bradley described unsuccessful attempts at serving sea vegetables to visitors to the New England Aquarium, where he acts as Executive Chef. Another panelist, Chef Bun Lai has had some success in his restaurant Miya's Sushi, but he pointed out that many Americans are still simply unfamiliar or uncomfortable with the idea of eating plants from the sea.

Bren Smith hopes this will change, and has been working with Chef David Santos at Louro Restaurant in New York to develop innovative ways to prepare sea vegetables. The possibilities are endless. Kelp leaves cut into strips make a perfect al dente noodle; pickled kelp stems are crisp, flavorful and refreshing; kelp butter makes a unique but mild and rich spread; and a simple plate of kelp with a bit of sweet sesame dressing gives any fancy kale salad a run for its money. "It just make sense that this would be the next super-food," said Santos, pointing to kelp's healthfulness, environmental impact, and diversity of uses and flavors.

There are many reasons that sea farming like Smith's model may be a key component in the way we think about the future of food production, as described in a recent report by Business Insider. Menus of Change focused on solutions that support health, sustainability, and economics. But at the end of the day, these solutions also have to be delicious. Smith's 3-D farming fulfills all of those criteria, and shows that similar approaches can be viable.

"I think what's kind of exciting now, is because we've screwed things up so badly, because our backs are against the wall, we have to innovate. I mean all over the world we need to come up with answers in order to really change our relationships to the oceans, and reformat the economy, and that's where a lot of my hope comes from, and where a lot of the excitement comes from, because we have to do something, and I think that's going to cause a lot of creativity, resilience, and solutions," he said.

But those solutions will only work when we as consumers are ready to step up and embrace new foods and new ways of eating. So go get yourself some kelp, and bon appétite.

http://www.cnn.com/2014/09/20/opinion/sutter-climate-change-oysters/

'I'm on the front lines of this crisis'

By **John D. Sutter**, CNN
Mon September 22, 2014

On Long Island Sound (CNN) -- On Friday morning, I boarded a leaky oyster boat in Connecticut with a captain who can't swim. Our destination: Manhattan, 84 miles down the coast. Mission: get world leaders to act on climate change.

If anyone can accomplish that herculean task it should be Bren Smith, a 42-year-old oysterman off the coast of Branford, Connecticut, who has become a sort of reluctant poster boy for *doing* something about the crisis instead of just talking about it.

Bren's oyster beds were wiped out twice by hurricanes, once by Irene and then, a year later, by Sandy. Warming waters and ocean acidification aren't helping his business model, either. But instead of giving up, he's currently helping to pioneer new techniques for "ocean farming," growing, among other things, kelp seaweed for use in pasta, martinis and biofuel.

That he can't swim hasn't stopped him from spending his life on the ocean, which he loves. ("The world disappears; it doesn't exist when you're out here," he said, bouncing over 3- and 4-foot waves). And that he, single-handedly, can't stop climate change didn't stop him from driving his boat down the coast to attend the People's Climate March in New York on Sunday, which is being billed as the largest public demonstration for climate action to date.

"This isn't a shtick. I actually believe in this," he said of the reason he's boating from Connecticut to New York for the rally. "I love the ocean. I want to protect it."

Bren -- who described himself as being "on the front lines of the this crisis" -- will be one of the most important people to attend Sunday's People's Climate March, which is expected to draw more than 100,000 protestors ahead of United Nations climate summit on Tuesday. He's essential to the international climate conversation for two reasons. One, he's a witness to the reality of climate change today -- here and now and in America. Too often we think of this as an Arctic-only problem, or a 100-years-in-the-future problem. It's actually both urgent and local, as Bren and so many others can attest. And two: Instead of just griping about the changes, he's actually doing something to help.

"This isn't a story of giving up," he said. "This is a story of hope."

Preach, brother.

We all have a lot to learn from Bren.

Opinion: Why climate change is an 'everybody issue' now

I was lucky enough to get to join him and his co-conspirator, Ron Gautreau, 52, on the 7½-hour journey from the Thimble Island Oyster Co., near Branford, Connecticut, to Pier 59 in the Chelsea neighborhood of Manhattan. We took Bren's 1983 workboat, which he calls "Mookie II," named for the Mets' legendary Mookie Wilson. It chugged along, past the mansions of Greenwich, Connecticut, and the industrial decay of Bridgeport, at a steady and slightly sea-sickening pace of about 17 mph.

He told me he took the boat instead of a car because traffic on Interstate 95 headed into New York is "f---ing hell" and because it's a fun bit of "political theater," inspired in part by 1970s protests in which farmers drove their tractors across the country to Washington to demand better farm policy.

Between bouts of losing our footing and hollering over the wind, I got to learn some of Bren's inspirational story. He grew up in in Petty Harbour, Newfoundland, a fishing village with 14 houses, as he tells it, at "the edge of the world." His parents were from New York and Connecticut, but moved there during the Vietnam War to dodge the draft. Their son took to the tiny village well, and started fishing at a young age. Because it was so remote, he said, it was a place where people were "fascinated with everything new."

It was a place of doers and makers, not complainers.

Bren's parents later moved him to the Boston area. People sat around too much, and he missed being out on the ocean -- subject to its moods, humbled by its strength. So, at 14, he dropped out and went to work as a commercial fishermen -- first in Massachusetts, then on the Bering Sea, where he saw 60-foot waves. He dreamed about the work even when he wasn't doing it -- fell in love with a life lived out on the water. It was so cold, he said, he never bothered to learn to swim. That's not uncommon among fishermen, he told me. The prevailing view: Swimming prolongs drowning.

He's no stranger to ecological catastrophe. He witnessed the collapse of cod populations in the Atlantic, which he said put many of his friends out of work. And then, when he'd established himself as an oysterman on Long Island Sound, the hurricanes came. While scientists say it's impossible to attribute any single storm to human-induced climate change, the warming atmosphere is expected to make hurricanes larger and more dangerous. And just as Bren rebuilt from one storm, the second hit. He lost 80% of his oysters and about half of his equipment, he told me.

"That just blanketed the farm and killed everything," he said.

Three days after Sandy hit, he told me, he got online and started researching alternative methods of oyster cultivation -- and new crops to "farm" in the ocean. He came upon the work of Charles Yarish, a professor at the University of Connecticut who studies seaweed cultivation. Yarish helped Bren devise a system, Bren told me, to grow kelp underwater in vertical columns, attached to buoys on the surface.

He calls the result a "3-D ocean farm" -- almost invisible from the surface, but capable of producing 10 tons of seaweed per acre per year, along with oysters, clams and mussels, some of which attach themselves to the towers of kelp. This vertical farming method might help prevent his entire operation from being wiped out if another storm swept through, pushing mud across the floor of Long Island Sound.

As part of a nonprofit called GreenWave, he's trying to help spread this idea to other "ocean farmers" by open-sourcing the model and teaching what he knows.

It's a success story, at least for now. Bren now says the hurricanes were among the best things to happen to him -- because they forced him to innovate, to come up with a new, better way of doing things. The kelp helps sink carbon from the atmosphere, and it processes nitrogen pollution from land-based farms. It doesn't require fresh water, which gives it an environmental leg up on traditional crops. Plus, he expects it to be more resilient in storms and warmer waters.

But the future is still uncertain.

"Unless the fossil fuels industry reduces their emissions, my farm won't last," he said.

He sees oysters and other ocean creatures as the canaries in the coal mine for climate change. Most of us are so distant from the oceans we don't see the change.

When we were pulling into New York, I asked Bren what he would do if the United Nations and world leaders continued to fail to act on curbing global carbon emissions. The meetings next week are largely seen as gathering political will ahead of more-formal talks in 2015.

But what if no one cares?

"I don't know," he said, calmly. "I'll just keep doing my part."

It's just the kind of guy he is.

It would help if elected officials operated with similar resolve.

http://futurefood2050.com/seaweed-farming-reaps-trendy-new-ocean-borne-vegetables-audio/

Seaweed farming reaps trendy new ocean-borne 'vegetables'

10/23/2014

CYNTHIA GRABER: This is Cynthia Graber reporting for FutureFood 2050. Humans have eaten seaweed for thousands of years in coastal regions from Northern Europe to South America to Asia. Today, seaweed aquaculture is centered primarily in Japan, China and Korea. But Charles Yarish, a marine scientist at the University of Connecticut, wants to change that. He's an expert in seaweed biology—he co-wrote a book on the topic—and he's applied that biological knowledge to devising new, improved ways to create more effective and efficient seaweed farms in coastal waters in the United States. In these farms, seaweed is grown around ropes that are anchored to the ocean bottom about 20 feet down. They thrive on excess nutrients in coastal waters that flow in part from wastewater treatment in agriculture. And the end result can be eaten fresh, frozen and then thawed, or dried, much like most other vegetables. Charles Yarish has improved the system by dramatically speeding up the time in which seaweed like kelp produce new spores—basically, seaweed seeds.

CHARLES YARISH: If you just let a kelp plant release its spore in the environment, that kelp plant will have to find a suitable substrate. It'll have to have the right amount of light. It will have to be the right temperature. It will also have to deal with real-world problems like something wanting to eat it, while in our laboratory, we don't have anything eating it. We're growing it at optimal temperature of light and also optimal light conditions. And all these enabled us to march it through its life cycle. All this is done in 28 to 30 days. If we would wait and look at this in the real-world environment, it could take four or five months.

While [seaweed is] growing in the environment, it's…removing [excess] nutrients from coastal waters. And you're getting a food crop as well as other opportunities for application. So that's what sustainability is all about."

— Charles Yarish

GRABER: Oh, wow.

YARISH: We have an efficient operation.

GRABER: So what role can seaweed aquaculture play, do you think, in sustainable agriculture?

YARISH: Well, basically you're getting material that is obviously with a whole suite of unique carbohydrates there. Some seaweeds are also high in proteins. Some seaweeds are having the right types of lipids. You're looking at a crop that

could be sustainably grown in the environment. And while it's growing in the environment, it's doing ecosystem services, which to me is very, very important, removing nutrients from coastal waters. And you're getting a food crop as well as other opportunities for application. So that's what sustainability is all about, and you can do this with minimal input of energy, which is also very important.

GRABER: So what kinds of technology are involved in seaweed aquaculture?

YARISH: The critical technology is understanding nursery cultivation. How do you get a source of seed stock? Growing that seed stock quickly so you can then move that seed stock into open water cultivation. So that's a challenge: understanding how to process the product that you're growing.

Processing technology is going to be important. How do you process it for the American tastes? We're not dealing with Asian tastes. We want to be able to deal with products that are high quality, good-tasting, that Americans would like to eat. And I would call your attention to a company like Ocean Approved out of Portland, Maine. They have lots of recipes that they've worked on that are actually very good-tasting. So you've got to make sure that the products are going to be unique for the American palate.

GRABER: Do you see any promising new technologies on the horizon that could help expand or improve the methods that you were describing for seaweed aquaculture?

YARISH: Processing is the big issue right now, in my mind. China is the largest seaweed producer in the world for the top five seaweeds. We can't compete with them, and they're producing, in many cases, dried products. What we want to do is produce products that are not the dried product, but ones that are innovative.

GRABER: What are some ideas you have about that?

YARISH: Well, I mean, you want to make sure that if you can take your product and produce, say, a blanched product and then maybe fresh frozen products so you can be able to distribute it throughout the year. Because you're going to be doing cultivation of, say, something like kelp, the harvest takes place normally in the springtime. And you get all that harvest.

GRABER: So we could get fresh frozen seaweed instead of dried seaweed?

YARISH: That's right. And it will have a higher nutrient content as well. And it will taste much better. I'm really…I'm excited about the…having seaweed that tastes great.

GRABER: I noticed from your research that, or from reading about your work, that it can also be integrated into other aquaculture efforts. I'm wondering how this works and if there are specific technologies that are involved with that or science involved with that.

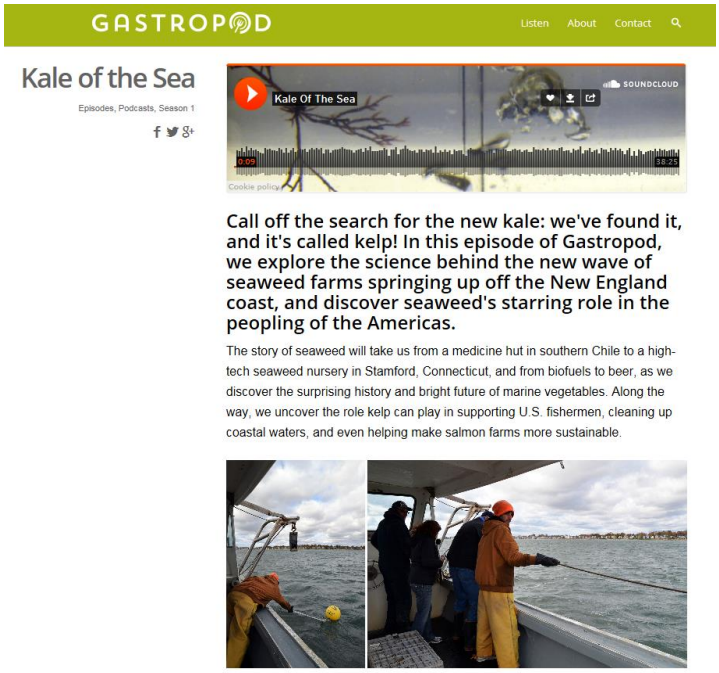
YARISH: Well, there is. And what…one of the areas of aquaculture that we've been advocating is growing seaweeds which extract inorganic nutrients from coastal waters like nitrogen and phosphorous, and taking the seaweed aquaculture and combining it with aquaculture which is called "fed" aquaculture. You know, if you're dealing with growing salmon and you're dealing with growing shrimp, you're feeding them. And any animal produces waste products. So the waste products that they are producing in coastal waters can be rich in nutrients.

And what we try to do is take fed aquaculture, and we use organisms that are extracting nutrients from coastal waters. Seaweeds extract nutrients from coastal waters, as well as shellfish. Shellfish extract nutrients from coastal waters. They extract nutrients that are organically bound. So these two different nutrient pools are being extracted by seaweed aquaculture, by shellfish aquaculture. And if we can balance what's coming out of fed aquaculture, we will be able to develop more sustainable systems.

GRABER: What role do you see—or do you see a role—for seaweed farming in helping to feed the perhaps more than 9 billion people that might be around by 2050?

YARISH: Well, I think the important part to understand, when you're doing seaweed cultivation, you're not using freshwater. And not using freshwater, which is a very valuable resource. That's going to be a very important economic driver. You know, freshwater is a finite resource. Saltwater is readily available. This is very important for seaweed cultivation. That's what it offers to other countries, whether it's in Western Europe or Western developed countries. If you can work with seaweeds that are definitely edible, that's great. You're not using freshwater to grow these crops.

GRABER: That was Charles Yarish, a marine biologist at the University of Connecticut. Thanks for listening to this podcast for FutureFood 2050. More information on this subject can be found at www.futurefood2050.com. I'm Cynthia Graber.



http://gastropod.com/kale-sea/

Kale of the Sea

Call off the search for the new kale: we've found it, and it's called kelp! In this episode of Gastropod, we explore the science behind the new wave of seaweed farms springing up off the New England coast, and discover seaweed's starring role in the peopling of the Americas.

The story of seaweed will take us from a medicine hut in southern Chile to a high-tech seaweed nursery in Stamford, Connecticut, and from biofuels to beer, as we discover the surprising history and bright future of marine vegetables. Along the way, we uncover the role kelp can play in supporting U.S. fishermen, cleaning up coastal waters, and even helping make salmon farms more sustainable.

D. J. King's crew haul up the kelp line, attached to a buoy. Photo by Nicola Twilley.

As a wild food, foraged from the rock cliffs and littoral strand of the world's coastlines, seaweed has been an important food, fuel, and fertilizer since ancient times. In Japan, seaweed was such an crucial part of the diet that legislation in AD 703 confirmed the right of the Japanese to pay their taxes to the Emperor in kelp form. According to Scottish kelp scientist Iona Campbell, traces of it have been found in Orkney island cremation sites dating back to the Bronze Age. Even further back in history, archaeozoologist Ingrid Mainland has confirmed that the use of seaweed as a fodder for sheep in the Orkneys, which still continues today, dates to the Neolithic period, roughly 5,000 years ago.

"Irish Distress: gathering seaweed for food on the coast of Clare," from the Illustrated London News, May 12, 1883.

Surprisingly, scientists have found even older seaweed remains in the Americas, from 12,500 years ago. Five chewed cuds of *Gigartina*, a red seaweed, mixed with Boldo leaves, a medicinal herb and mild hallucinogen, were found on the floor of a medicine hut at Monte Verde, Chile—one of the oldest human habitation sites in the Americas. In the episode, Jack Rossen, the archaeobotanist who excavated the site's fragile plant remains using dental picks, explained how the site's age and location, combined with the four different species of seaweed found in the medicine hut and in residential areas, led to the development of an entirely new theory to explain how humans arrived in North America.

Rossen also pointed out that the Monte Verde findings led to a re-evaluation of the importance of plants in the diet of hunter-gatherers—and thus also of the role of women in those early human communities.

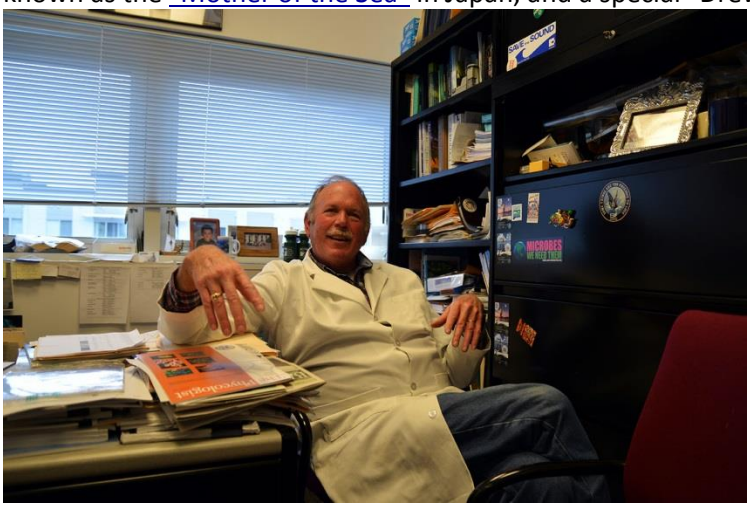
We've always had the stereotype of early people being hunters, big-game hunters. And now we're thinking more that plants would have been a much more reliable resource; they just didn't get preserved as well at most sites. And maybe archaeologists, when archaeology was dominated by men, just liked the idea of being big tough hunters, instead of wimpy plant gatherers.

As it turns out, women have also played a pivotal role in transforming kelp from wild to farmed food. Basic seaweed cultivation techniques began to be developed in Japan beginning in the mid-seventeenth century. But, despite becoming a staple food of the Japanese, the basic biology of edible seaweed species remained almost completely unknown until two centuries later, when pioneering British scientist Kathleen Drew-Baker saved the country's nori farming industry.

Cynthia recording the sound of seaweed sex in Charles Yarish's lab. Photo by Nicola Twilley.

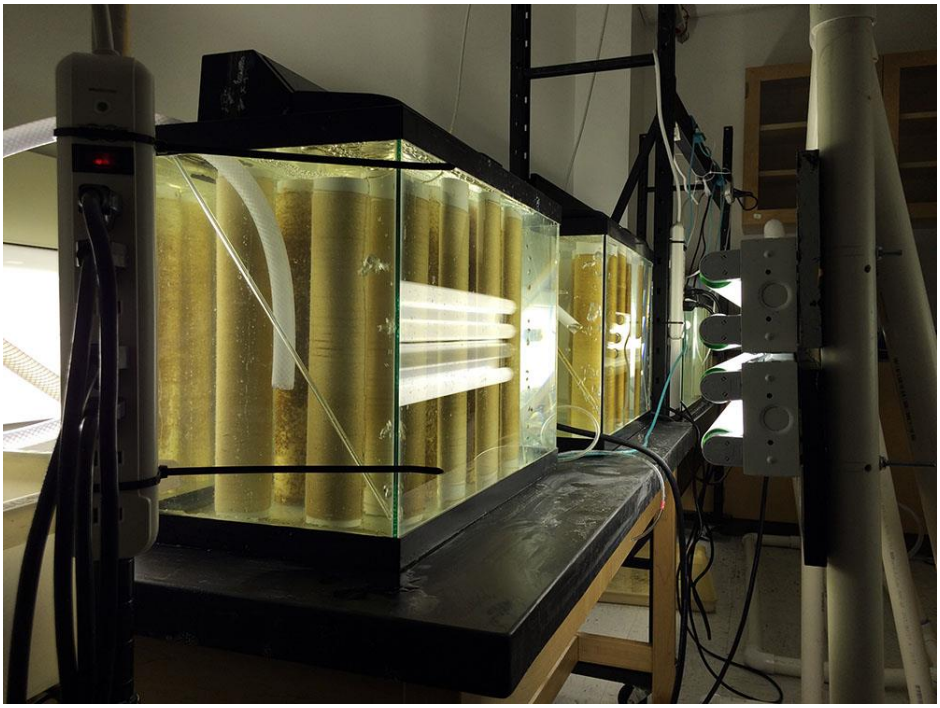
In 1948, a series of typhoons combined with increased pollution in coastal waters had led to a complete collapse in Japanese nori production. And because almost nothing was known about its life cycle, no one could figure out how to grow new plants from scratch to repopulate the depleted seaweed beds. The country's nori industry ground to a halt, and many farmers lost their livelihoods.

Meanwhile, back in Manchester, Dr. Drew-Baker was studying laver, the Welsh equivalent to nori. In 1949, she published a paper in *Nature* outlining her discovery that a tiny algae known as *Conchocelis* was actually a baby nori or laver, rather than an entirely separate species, as had previously been thought. After reading her research, Japanese scientists quickly developed methods to artificially seed these tiny spores onto strings, and they rebuilt the entire nori industry along the lines under which it still operates today. Although she's almost unknown in the U.K., Dr. Drew-Baker is known as the "Mother of the Sea" in Japan, and a special "Drew" festival is still held in her honor in Osaka every April 14.



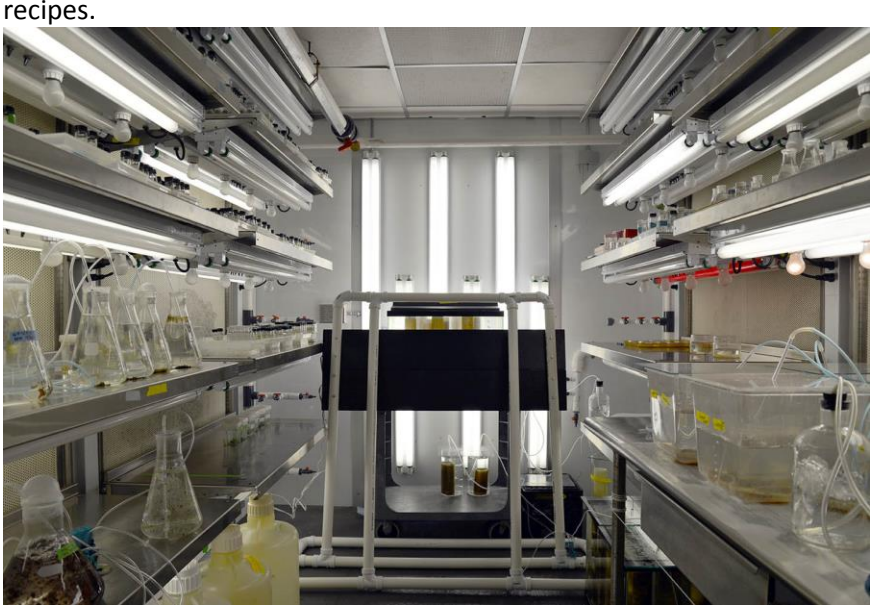
Charles Yarish in his office. Photo by Nicola Twilley.

In the United States, Charles Yarish should probably be called the "Father of the Sea." The University of Connecticut marine biologist has spent the past forty years studying the biology of seaweeds, and then applying his research to develop revolutionary new techniques for growing seaweed off the coast of North America. His innovations have helped make make kelp an economically viable crop for the fishermen and shellfish farmers of New England, whose livelihoods have been threatened by a combination of over-fishing, pollution, and warming waters.



Spools seeded with baby kelp, growing in Charles Yarish's lab. Photo by Nicola Twilley.

Listen to this episode of Gastropod for a visit to Yarish's lab to learn what he accomplished, and how seaweed farms can help soak up pollution from aquaculture, such as salmon farming, as well as from agricultural run-off and sewage. You'll also hear how seaweed is something of a superfood; research in China has even demonstrated that it contains compounds that lower cholesterol and blood glucose levels in mice. Now the only remaining challenge is to convince Americans to eat it: Gastropod visits chef Elaine Cwynar's kitchen at Johnson & Wales University to sample creative new recipes.



Charles Yarish's seaweed nursery. Photo by Nicola Twilley.

Charles Yarish's seaweed nursery. Photo by Nicola Twilley.

Charles Yarish's seaweed nursery. Photo by Nicola Twilley.

Episode notes

Before we get to kelp, a note about our recent episode on subnatural cuisine. After listener Natasha Godard heard it, she recommended we check out Mikki Kendall's article on food gentrification at *The Grio*. It's a powerful piece about poverty and food appropriation, and we're glad Mikki could join us on the show.

Our New England seaweed adventures were made possible thanks to the loan of Cynthia's partner Tim Buntel's car: thanks for your wheels and your ears, Tim!

Iona Campbell's Seaweed Blog

Scottish kelp scientist Iona Campbell maintains a blog describing her research into the large-scale cultivation of kelp as a biofuel, as well as various other seaweed-related topics, including a recent "seaweed exchange" visit to China.

Ingrid Mainland's Seaweed-Eating Sheep

Archaeozoologist Ingrid Mainland discovered the telltale signs of seaweed-eating on Neolithic-era sheep skulls in the Orkneys. Her findings were published in a 2009 paper titled "Stable isotope evidence for seasonal consumption of marine seaweed by modern and archaeological sheep in the Orkney archipelago." The contemporary seaweed-eating sheep she used as a comparison are the unique North Ronaldsay breed.

Tooth-enamel sampling on Neolithic sheep molars. Photo from Ingrid Mainland's paper.

Jack Rossen, Monte Verde, and the Seaweed Trail

Archaeologist Jack Rossen helped excavate the Monte Verde site and, as a result, became completely obsessed with seaweed. With Tom Dillehay and others, he co-authored a 2008 paper on the significance of the seaweed findings at the site: "Monte Verde: Seaweed, Food, Medicine, and the Peopling of South America."

Dr. Kathleen Drew-Baker

Dr. Kathleen Drew-Baker is most likely the only seaweed scientist to have a statue erected in her honor. You can read more about her work here and here, as well as in this PDF.

Charles Yarish and the Book on Seaweed Science

As we mention in the episode, Charles Yarish and his colleagues literally wrote the book on seaweed biology in 1990: a 600-page tome titled *Seaweeds: Their Environment, Biogeography and Ecophysiology*. Everything you ever wanted to know about seaweed—and more!

New England Seaweed Farms

Charles Yarish applied his research into seaweed biology and physiology into developing techniques for kelp farming along the United States' Atlantic Coast. He helped set up and continues to work with nine seaweed farms, including DJ King's in the Thimble Islands (the farm we visit in the episode) and Tollef Olson and Paul Dobbins' farm, Ocean Approved, in Maine.

Another farmer who's received a lot of attention for his multi-species "3D ocean farms" is Bren Smith of Thimble Island Oysters, who also relied on Charlie's help to create his floating ropes and cages that combine seaweed, mussels, oysters, and clams.

Kelp farmer D. J. King talking to Gastropod co-host Cynthia Graber aboard his boat. Photo by Nicola Twilley.

How to Get Hold of Some New England Seaweed

Bren Smith works with several popular restaurants in New York, and Tollef Olson's Ocean Approved sells kelp to chefs, universities, and other institutions. As Tollef admits, there's still work ahead to develop the market for fresh/frozen seaweed. The only retail stores that carry his products at this time are in his hometown of Portland, Maine. But don't despair: Tollef does sell kelp online! It's only available in bulk, however, in amounts ranging from 2 to 3 pounds.

Tollef Olson and Elaine Cwynar at Johnson & Wales. Photo by Cynthia Graber.

Kelp Recipes

If you do ever get your hands on some of this seaweed, you'll want to figure out what to do with it. (Other than eat it plain, of course. Cynthia insists that it probably wouldn't last long enough in her apartment to make it into any recipe.) Chef Elaine Cwynar of Johnson & Wales hasn't published her recipes online, but she and her students have worked closely with Tollef, and he has a variety of recipes on the Ocean Approved website.

You'll find instructions on how to make everything from smoothies pumped up with pureed seaweed to veggie and kelp meatballs. And, of course, you'll find the recipe for the carrot-kelp cake that Cynthia loved and her partner Tim's colleagues refused to try. Cynthia recommends blending a bit of the puree into the frosting just for the gorgeous, green-flecked effect.

Kelp and carrot cupcake. Photo by Cynthia Graber.

WILD FOOD GIRL
Foraging the wild for plants and stuff to eat.

NOVEMBER 7, 2014
BY WILD FOOD GIRL

If you're planning to make blancmange—a traditional milk pudding thickened with Irish moss seaweed—don't forget a splash of brandy, says Dr. Charles Yarish, professor of ecology and evolutionary biology at the University of Connecticut (UConn). "The French always add a little brandy."

Dr. Yarish is also a fan of *Gracilaria* or "ogonori," a hairy sea vegetable that he farms in Connecticut's coastal waters. He grows the native species, *Gracilaria tikvahiae*, though there is also a non-native *Gracilaria* that's made its home on the U.S. east coast in recent years. Both species are edible, but the only way to tell them apart is a DNA fingerprint.

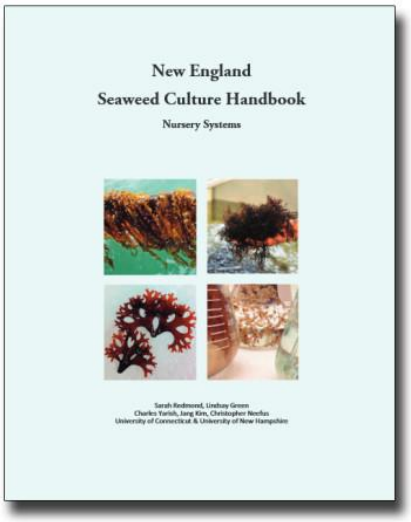
SEAWEED FOR HEALTHY WATERS

Yarish is a lover of seaweeds, not only for the dinner plate, but for the role they play in coastal ecosystems. His research dates back to the 1980's and involves growing various species in his lab and at field sites off the coast.

One site is at the confluence of the Bronx and East Rivers in New York City, where his kelp farm helps to remove nitrogen and other excess nutrients caused by agricultural run-off, over-fertilized lawns, and even air pollution. A certain amount of nutrients in the water is a good thing, but too much can tip the balance, upsetting coastal ecosystems and causing die-offs of plants and animals, or unwelcome algal blooms like "red tide," which render shellfish toxic for human consumption. "If we can use aquaculture systems to manage these nutrients, this is an exciting breakthrough," Yarish said. "And we've shown we can do that."

While his goal is ecosystem services, Yarish believes economic value is what will drive seaweed farming, which he sees as a solution to improving the health of coastal waters. In the case of the Bronx site, the kelp is unfit for human consumption. "We've tested the product to try to understand what we can do with it," he said. Both biofuel and fertilizers prove to be promising solutions.

But seaweed grown in clean waters is another story. Aquaculture systems still benefit; and the seaweed can be harvested and eaten. Although the industry is in its infancy in the northeastern United States, nearly 16 million tons of seaweed were farmed worldwide in 2008, primarily in Asia, according to a United Nations report.



Yarish has been helping to lay the groundwork for operations in the northeast. In 2006, he helped Ocean Approved start the first open-water kelp farm in the United States off the coast of Maine. After the Fukushima Daiichi nuclear disaster in Japan, which compromised the kelp (kombu) industry in Hokkaido, Ocean Approved started receiving requests to ship their product to Asia, he said.

Since then he has since turned his sights to Long Island Sound, where he's been helping shellfish farmer Bren Smith of Thimble Island Oyster Company grow seaweed off Branford's Thimble Islands. "Thimble Island is producing healthy, high quality, high value product that can go for human food consumption," Yarish said. "You can have a nice, nitrogen-rich vegetable that takes in nitrogen available to it in coastal waters."

Seaweed products from Long Island Sound and the Gulf of Maine have met FDA guidelines, and even made France's stringent guidelines. "Plus they taste good, which is more important," Yarish said.

In 2013, Connecticut passed legislation that allows for fee-based licenses to farm seaweed on a per-acre basis. To assist farmers, Yarish and his colleagues released a 92-page handbook to growing four species of economically and ecologically valuable native seaweeds—kelp, *Gracilaria*, nori, and Irish moss. The guide can be downloaded free of charge at http://s.uconn.edu/handbook.

Dr. Charles Yarish (right) and Dr. Jang Kim (left) helped two aquaculture farmers seed this year's crop last week in Branford, CT. They are holding a spool of kelp seedstock.

More recently, the USDA's National Institute of Food and Agriculture (NIFA) awarded Yarish and colleague Jang Kyun Kim a prestigious $313,000 grant to support their work to develop an environmentally and economically sustainable sugar kelp aquaculture industry in southern New England from seed to market. Among other components, the grant provides for a resource economist to help strategize the new seaweed economy. Growing operations are expanding into Massachusetts, and will include a mobile processing unit for use by certified growers.

SUGAR KELP

One of Yarish's favorite seaweeds is sugar kelp, or sugar wrack (*Saccharina latissima*). This is Long Island Sound's characteristic long, brown seaweed. It's flat in the middle and ruffled on the edges, and attaches itself to rocks and other substrates with a long, round stem.

After coaxing the juvenile sugar kelp through a microscopic stage at the UConn lab, they grow the seaweed on taught lines strung deep enough under water that the kelp grows 3-6 feet below the water level. It takes in nutrients from December to January, Yarish said, and then when the sunlight increases from late February through May there is rapid growth, with individual plants growing as long as 8-9 feet in 5-6 months.

Long Island Sound is the southernmost distribution of *S. latissima*, which is found north to the Arctic, east to Scandinavia, and down the coast of Europe to Portugal. In Asia, the related *Saccharina japonica* is cultivated and sold as kombu.

"What's very nice is that *S. latissima* is the first cousin of *S. japonica*, but sweeter," Yarish said. "Just imagine—you can get this fresh product locally—grown any place in the northeast from people who have a permit—and it's a nice substitute for kombu from Asia."

Sugar kelp, or sugar wrack (Saccharina latissima) is the predominant long, brown kelp in Long Island Sound.

The best time to collect and eat fresh *S. latissima* is late spring. That's when the sugar content is highest and the nitrogen content is lowest. "It's soft and delicious—and not too salty," he said.

Though his work involves research on seaweed farming, Yarish is also a fan of wild-food foraging. "There's a pretty good chance the coastal seaweed in Long Island Sound is safe to eat," he said. However, he prefers to pick from material attached to its substrate—in other words, cutting seaweed where it grows instead of collecting it from the beach. That way you know it's fresh, and you know where it came from, he explained. "Once it's on the beach, who knows how long it's been rolling around in the water?"

For sugar kelp, which likes cold water, he recommends heading north to a rocky beach and diving for it in 10 or 15 feet of water.

SEAWEEDS ARE SEASONAL

Each seaweed has its season. Sugar kelp, he said, is best foraged in late winter or spring. "By summer, I wouldn't want to forage for kelp—by then they have broken off and are degrading," he said. He can taste seasonal differences in nori, and recommends collecting Irish moss in late fall, winter, and early spring—any time but in the dead of summer, especially in locations where coastal waters start to warm up. The various sea lettuces (*Ulva spp.*) have different schedules and can be found at various times throughout the year.

Long Island Sound alone has more than 250 species of seaweeds, many of which are documented in a 100-page PDF, "Seaweeds of Long Island Sound," put together by Yarish's student, Margaret Stewart Van Patten, who serves as communications director for Connecticut Sea Grant at UConn. The booklet includes a species key and color photos and is available at http://seagrant.uconn.edu/publications/marineed for $5 plus $2 shipping, with single copies available free to K-12 teachers who request it on their school's letterhead. There is also a specimen collection online at the Benthic Marine Algal Herbarium of Long Island Sound.

For wild-harvested seaweeds and recipe ideas, Yarish said you can't beat Maine Seacoast Vegetables, a family-owned operation led by macrobiotic engineer Shep Erhart. The company grew from two people producing 200 pounds in 1971

to 40 people handling 100,000 pounds of sea vegetables annually, along with a 15-member year-round crew that sorts, packs, and markets the sea vegetables. Among the goodies available online are Sea Chips, “the only seaweed-flavored tortilla chip,” Kelp Krunch sesame energy bars, Seaweed Support food supplement capsules, and six blends of Sea Seasonings. Maine Seacoast Vegetables is also a proponent of aquaculture as a way to sustainably meet growing demands for seaweed, Yarish said. Ultimately, he hopes seaweed cultivation will contribute to healthier systems, both at home and abroad.

Dr. Jang Kim works into the night with seaweed grower Donald King to seed this year’s kelp crop.

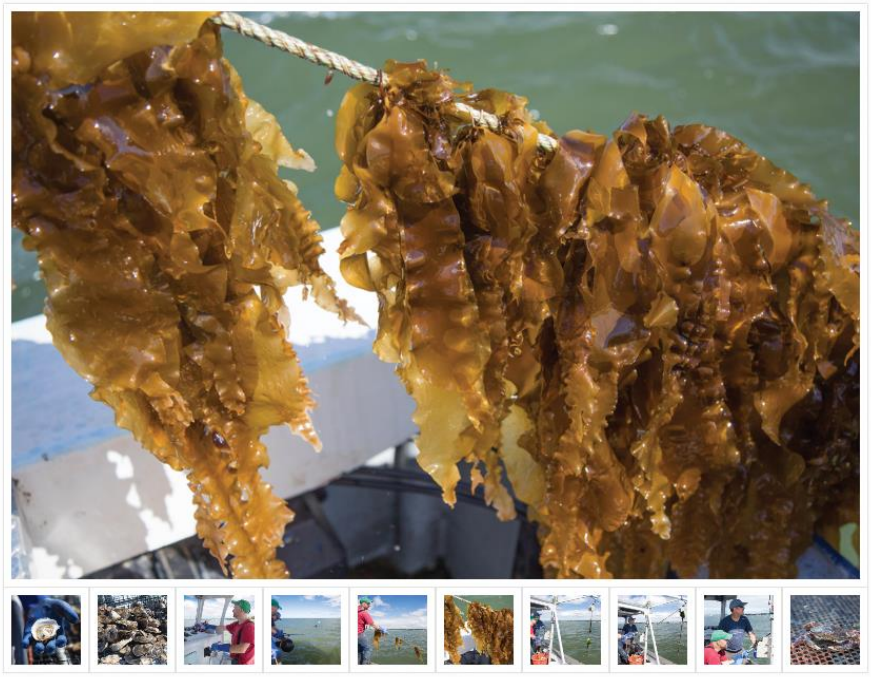
Sugar Kelp Pasta

As for his favorite sea vegetable dish, Yarish prefers seaweed pasta. The recipe came from the Culinary Institute of America (CIA), which created it as part of a contract with the Korea Agro-Fisheries and Food Trade Corporation to come up with a collection of recipes that would introduce Korean *Porphyra* (“gim” or “nori”) to Western palates. The recipes were initially released at the DeGustibus Culinary School in New York City and then at the CIA headquarters in Hyde Park, New York.

Of course, Yarish is partial to pasta made with Long Island Sound-grown sugar kelp—a product which, having undergone food product testing and HACCP certification, was made available to consumers by the Bridgeport Regional Aquaculture Science and Technology Education Center through the Thimble Island Oyster farm for the first time last spring.

Thimble Island began seeding for next year’s crop last week, as did grower Donald King, and two more kelp farmers are slated to come on line any day now, Yarish said.

Now the challenge that remains is to develop a large enough cultural appetite for seaweed aquaculture to thrive on the east coast, benefiting coastal ecology in the process.



http://inkct.com/2015/07/ocean-farming-the-wave-of-the-future/

Ocean Farming – The Wave of the Future

Photos and profile by Caryn B. Davis
July 31, 2015

Bren Smith hails from a tiny outpost in Newfoundland where most of the 970 inhabitants work in the fishing industries. So it wasn't that unusual at age 14 he should leave home to pursue a life of adventure on the high seas. But what does make his story unique is how he used those experiences decades later to pioneer a new kind of aquaculture.

Smith fished out of Gloucester, the Bering Sea, and the Grand Banks, catching everything from tuna to lobster to cod to crab. It was the heyday of the McDonald's fish sandwich and Gordon's fish sticks, and a lot of what he caught ended up in these mass markets.

He worked at the height of the commercial fishing industry before any credence was given to environmental impact. Trawler nets caused significant damage, as did overfishing. As the nets drag across the bottom, it not only tears up entire ecosystems, but also leaves thousands of dead fish and sea mammals in its wake.

"That was the state of the industry then. We knew we were pillaging, but even so, it was the best days of my life. I miss them still. I miss the camaraderie, being at sea for three months, the 20-30 hour shifts, the high skill, chasing things and being a hunter, and the humility of being at sea. It was really rewarding," says Smith. "There are certain jobs you get a real sense of meaning from, and I was proud to help feed the country. I think land-based farmers are the same way. There are certain professions that are more than just a job, but a cultural identity."

Overfishing also depleted the fish stocks, especially cod. Global fleets appeared at the international waterline off Newfoundland waiting for the cod to pass. These vessels were not the small family run fishing boats, but floating factories, hundreds of feet in length with the ability to process and freeze the fish on site.

Smith's "wake up call" came in 1992 when the cod stocks crashed in Newfoundland. The government declared a moratorium on the Northern Cod fishery for the first time in 500 years. The Canadian government began buying back fishing licenses to take offline. Over 35,000 fishers and fish plant employees were suddenly out of work; entire families were ejected from the only lives they had ever known.

"Canneries closed and boats were beached. You build an economy and a culture for generations; and it gets wiped out overnight with one environmental disaster," says Smith. "It really shifted the politics of Newfoundland because there wasn't any process to work with the fishermen, just massive buyouts. In the United States they created a quota system.

You are allowed to catch a certain amount, but with no limit on how many quotas there are, so commodities and Wall Street companies with no relationship to fishing, bought them up. For example, forty percent of the Peruvian fish docks are owned by the second largest private equity firm on Wall Street."

Smith, like others of his generation, was determined to find a sustainable way. He began salmon farming in Newfoundland but soon discovered it was just a new type of environmental destruction.

"We were pumping the fish full of pesticides and antibiotics and packing them so they could barely swim. Their feces created a lot of pollution, and they tasted terrible. It was neither fish nor food, " he says.

Smith made his way to Branford, Connecticut because by chance, for the first time in 150 years, the shell fishing grounds were opened up to attract younger fishermen back into the industry.

"I started oyster fishing knowing nothing about it and not realizing it is farming," says he.

This started the wheels turning, and he soon invented a process he calls Vertical Ocean Farming. It's similar to aquaculture except instead of growing salmon and tuna, species people traditionally eat, he grows what is native to the area.

"We need to grow what the ocean can provide within its natural limits and help remake and rethink the seafood dinner plate based on sustainability," says Smith.

It is simple and affordable. A farm can be set up within a week with $20,000 and a boat. Smith leases 20 acres and grows kelp, mussels, oysters, scallops, and clams and harvests salt through his company, Thimble Island Oysters. He uses hurricane- proof mooring buoys which are tethered to the sea floor with floating horizontal long lines at the surface. The same gear is used to farm all the species. The farms are also designed with the recreational boater in mind who can pass over them without disturbing them. But there are other benefits as well. Oysters soak up nitrogen, and kelp soaks up carbon, which has been problematic in our waterways. The farms act as reefs attracting fish and seals and as storm surge protectors; and jobs are being created.

Smith goes out daily with farm manager, Ron Gautreau to check the progress. The farm yields about 10 pounds of kelp per acre and roughly 200,000 shellfish. Smith does a rotational crop just like on land, so if all his oysters fail, he can still sell mussels.

But he has found that seaweed will be key to our future survival. It is fast growing and is chock full of vitamins, omega threes, and protein. It can be turned into animal feed, and it reduces methane production by ninety percent in cattle. It can be used to make bio fuel, beer, fertilizer, and cosmetics which can become other sources of revenue for fisherman.

"In time it will be the cheapest food on the planet. It doesn't require fresh water, fertilizer, or land use. All the things that make land-based farming expensive especially with droughts," Smith says.

Smith is creating a new kind of ocean vegetarianism where seaweed becomes commonplace to the palette and dinner plate. There are more than 10,000 edible varieties, but we only consume a fraction. The goal is to make kelp the new kale, reduce the pressure on the fish stocks, and craft undiscovered cuisine from it like pasta noodles.

The vertical farming model is available through open source so anybody can learn how to do it, but Smith helps others get their farms off the ground and works in partnership with UConn, the Woods Hole Oceanographic Institution, and Charlie Yarish, a professor at UConn and the world's expert on seaweeds. He also works with the Sound School to train young people in this new industry whom he hopes will also develop a taste for these new flavors.

Smith also supports the aquatic community with his NGO Green Wave that is building the first Seafood Hub in Connecticut to "aggregate, process, and market ocean farm products; serve as a job-creator and engine for local economic development in an underserved region; provide subsidized processing and storage infrastructure for ocean farmers and fishers; develop value-added products ranging from kelp noodles and sea salt to organic fertilizers and animal feed, and create a stable and above-market price structure for farmer co-op members. The Hub also hosts a Community Supported Fisheries program, supports regional climate and ecosystem research, and incubates new ventures. Most importantly, it's a community space for job training, cooking classes, apprenticeship programs, and more."

But the sea still pulses through Smith's veins; and in time, he wants to get back to the waterways and leave behind this role that has chosen him.

"I don't want to be that pioneer. I will have succeeded if there are tons of people representing the industry, innovating way past me. If ten years from now I can disappear and be quietly farming again, I will have succeeded," he says.

For more information log onto thimbleislandoysters.com and greenwave.org.

THE NEW YORKER

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A NEW LEAF

Seaweed could be a miracle food—if we can figure out how to make it taste good.

BY DANA GOODYEAR

SHARE TWEET

I stared for a while at the placid face of Long Island Sound before I could make out Bren Smith's farm. It was a warm, calm morning in September. Sixty buoys bobbed in rows like the capped heads of synchronized swimmers. It wasn't until Smith cut the engine of his beat-up boat, Mookie, that I knew for sure we had arrived. The farm, a three-acre patch of sea off Stony Creek, Connecticut, starts six feet underwater and descends almost to the ocean floor. From the buoys hang ropes, and from the ropes hang broad, slippery blades of sugar kelp, which have the color and sheen of wet Kodak film.

PHOTOGRAPH BY KIM KEEVER FOR THE NEW YORKER

A New Leaf

Seaweed could be a miracle food—if we can figure out how to make it taste good.

November 2. 2015

By Dana Goodyear

I stared for a while at the placid face of Long Island Sound before I could make out Bren Smith's farm. It was a warm, calm morning in September. Sixty buoys bobbed in rows like the capped heads of synchronized swimmers. It wasn't until Smith cut the engine of his beat-up boat, Mookie, that I knew for sure we had arrived. The farm, a three-acre patch of sea off Stony Creek, Connecticut, starts six feet underwater and descends almost to the ocean floor. From the buoys hang ropes, and from the ropes hang broad, slippery blades of sugar kelp, which have the color and sheen of wet Kodak film.

At first, the local fishermen thought that Smith was growing some kind of marine hemp; that seemed cool. When they found out it was seaweed, they ribbed him relentlessly. Smith, in any case, prefers to call his produce "sea vegetables." He also raises mussels, scallops, clams, and oysters in lantern nets shaped like accordions and stacked pyramids. He pulled up a lantern net full of twenty thousand black-and-orange scallops, two months old, the size of M&M's. The net was covered in murky, greenish clumps of seaweed, crawling with sea squirts, little crabs, and translucent shrimp. "The farm is a reef for hundreds of species," he said, cutting off a hank of seaweed—*Gracilaria*—for me to try. It crunched, filling my mouth with the taste of lobster juice. "This is what you want to see," he said. "This is good, restorative ocean farming."

Seaweed, which requires neither fresh water nor fertilizer, is one of the world's most sustainable and nutritious crops. It absorbs dissolved nitrogen, phosphorous, and carbon dioxide directly from the sea—its footprint is negative—and proliferates at a terrific rate. Smith's kelp can grow as much as three-quarters of an inch a day, maturing from pinhead to ten-foot plant in the course of a winter, between hurricane seasons. It is resilient, built to take a lashing, but if a storm wipes out the crop he can just start over. Every year, he harvests between thirty and sixty tons of it, about the same per-acre yield as a potato farmer. Plentiful, healthy, and virtuous, kelp is the culinary equivalent of an electric car. "You're not just gaining nutrition, you're also gaining absolution from guilt," Mark Bomford, the director of the Yale Sustainable Food Program, says. "This is your get-out-of-anxiety-free card."

As industrial land-based agriculture becomes increasingly untenable—environmentally destructive and at the same time vulnerable to drought and changing weather—we are being pushed out to sea. Smith says, "The question is, Are we going to do it right or wrong?" He calls his system, which uses the entire water column, a "3-D farm," and he would like

to see it become the dominant form of aquaculture. He would like to see kelp—a potential source of human food, biofuel, and animal feed—supplant crops like corn and soy. In October, his farm design, which he has made open-source, won a prize given by the Buckminster Fuller Institute for innovative solutions to urgent global problems. Not long before that, he was honored by Bill Clinton at the Clinton Global Initiative meeting in New York, where he showed up without realizing that he had a twelve-inch fillet knife in his backpack.

But Smith's ambitions extend beyond reshaping an industry. In his vision, kelp farming can rehabilitate the ocean's threatened ecosystems, mitigate the effects of climate change, and revive coastal economies. With thirty thousand dollars of start-up money and a boat, he figures, an out-of-work fisherman can make seventy thousand dollars a year. "There are no jobs on a dead planet," he likes to say. Two years ago, he started GreenWave, a nonprofit through which he trains fishermen to be kelp farmers. Smith plans to form a twenty-five-farm co-operative revolving around a seafood hub near New Haven, with processing equipment, a seed bank and hatchery, value-added venders making kelp smoothies, and a Beyond Fish market, where the only fish available will be barramundi, fed on seaweed. In the often overwhelmingly grim conversation about ocean health—some scientists predict fishless oceans by 2050—Smith's hopeful narrative is good for morale, promising that we can eat and thrive in an ever more populous and warming world. "It's important to know that there's a way to still sustainably work within the ocean," May Boeve, the director of the climate-focussed advocacy group 350.org, says. "It's not a lost cause."

All Smith needs to do is to invent a new cuisine based on filter feeders and seaweed. He is starting with the East Coast offices of Google. "I use ocean vegetables at the center of the plate and garnish the plate with those restorative water-cleansing shellfish," Michael Wurster, the culinary director, told me. "My users are conscious about what they eat, where it comes from, and how it was raised." For others, though, there are some challenges. Sliminess is not a property that most Americans appreciate in food. "What is that disgusting oobleck?" was the comment that greeted the slick heap of kelp spaghetti I served to a preschooler not long ago. Howard Fischer, a hedge-fund manager who personally invests in regenerative agriculture and restricts himself to foods that meet those criteria, told me, "People who are eating with their minds first will be the early adopters, but there are no guarantees here." When I asked Boeve about her taste for kelp, she said, "I need a little more time with it. I'm more of a bivalve person myself."

The morning after taking me to the farm, Smith was back in Stony Creek to meet a fisherman he was recruiting to grow kelp for the co-op. Smith, who is five feet five, bald-headed, and bulk-shouldered, like the lobsters he spent his adolescence hauling from the sea in traps, was wearing dirty jeans, suspenders, and a blue T-shirt that said "Kelp Is the New Kale." He was drinking water from an old whiskey bottle. He has epilepsy, triggered by two things he likes and one that he can't avoid: alcohol, caffeine, and not getting enough sleep. Before he was a full-time farmer, he drove a lumber truck and sold pieces of the Coney Island boardwalk stencilled with obscure words like "petrichor" (the smell of rain on dry earth) and "limerence" (tingly infatuation) to tourists in Union Square. Once, while he was working at a table saw, a board flew in his face and knocked him out. He still has a scar running across the bridge of his nose. After the accident, he found that he had developed an allergy to shellfish. He has never learned to swim.

The fisherman, David Blaney, had driven down from Point Judith, Rhode Island, where his family has been farming and fishing the coast for three hundred years. His people used to fertilize their crops with seaweed, insulate their houses with it, and eat it in hard times. He is sixty-seven, white-bearded, taciturn; around his neck he wore the tooth of a mako shark that tried to kill him when he caught it while long-lining for tuna off the Grand Banks. In the course of his career, he said, he'd trawled for cod on huge boats known as Big Green Dump Trucks and, when the cod ran out, for swill like butterfish and whiting; then there was only squid to catch, then nothing much at all. "The past ten years, the way fishing's been, I've branched out," Blaney said, stepping onto Smith's boat. "Marine survey, marine safety. But I've got nephews and kids myself who would like to go back to making a living from the sea."

Smith threaded his boat through the Thimbles, a collection of tiny private islands, some big enough for only a single house. It was low tide. An osprey sat on top of a long stick that served as a mooring. We passed the rusty barge where Smith proposed to his wife, Tamanna Rahman, a graduate student in nursing at Yale, last year. Smith and Blaney talked shop: to anchor the buoys, Smith recommended mafia blocks and mushrooms; Blaney, a diver, thought he might secure them with giant screws. When they got out to the farm, Smith stopped the boat and, using a hook, hauled up a line of kelp. He explained the process of thinning out the growth. "It's just like, you know, farming," he said, abashed before a man who had spent his career chasing monsters. "The smaller ones we sell as baby leaf kelp—it's real thin, sort of translucent, and has a subtler, slightly sweeter base."

"I've got a lot of fishermen looking at me like, You're gonna do *what*?" Blaney said. "The other day in the coffee shop, someone referred to me as Captain Kelp, and I'm thinking, I don't think I like that." But, he said, with the warmer water driving lobsters from southern New England and the glory days of fish-hunting over, some of his skeptical colleagues

might be persuaded to follow him. (Two-thirds of Rhode Island's commercial lobstermen have left the business in the past decade.) He had credibility, he said, by virtue of still being alive after decades at sea. "Kelp noodles—it's an economical and clean way to produce good protein," he said. "What's the problem?"

Blaney pulled off a piece of kelp and bit into it. To most fishermen, seaweed is a net-fouler, inimical. He chewed thoughtfully. "I know this old captain who used to say, 'Now we're going to shake weed till our heads fall off,' " he said. Smith said, "It might be better than the fish in the net."

In kelp, Smith has found what he calls "ecological redemption." He was born in 1972 in Newfoundland, where his American parents had gone during the Vietnam War. His father, a linguist, wrote one of the first contemporary Inuttut dictionaries. His mother, who graduated from the Sorbonne, raised him and his sister and later became the managing editor of the French-textbook division at Houghton Mifflin. When Smith was in grade school, the family moved to Massachusetts; his parents divorced, and Smith, then fourteen, dropped out of school and moved in with his girlfriend and her mother in Section 8 housing. He worked as an emergency-room janitor on the night shift at a hospital, dabbled in selling acid and cocaine, and hung out on the docks with Hell's Angels. "Bren was a tough kid who could take care of himself," Sylvia Madrigal, his mother's partner, wrote to me in an e-mail. (His mother died in December.) "The more dangerous the task, the better." Talking up his "Newfie" roots, Smith found it easy to get work on boats. He started on a lobster boat out of Lynn, up the coast from Boston. It went out every day at 3:30 A.M. and returned at 5 P.M., after which he'd bring lobsters to his mother's office and sell them at a markup.

At seventeen, Smith says, he went to Alaska, where he fished for cod in the Bering Sea and in illegal waters off the coast of Russia; the cod went to McDonald's. "We were throwing millions of pounds of bycatch over because we only had permits for a couple of kinds of fish," he told me. "It was like a sea of death around the boat. I'm not an environmentalist"—he considers conservation alone to be an inadequate response to climate change, and insensitive to people's need to eat and work—"but I loved the sea, and wanted to spend my whole life working at sea. It was just clearly not sustainable." When the cod stocks crashed and Newfoundland's job market went with them, Smith saw it as the beginning of the end of wild fish. He returned to Newfoundland to try aquaculture, which promised both a solution to a food problem and a familiar way of life, but he was quickly disillusioned. "It was Iowa pig farming at sea," he said.

Between fishing gigs, Smith finished high school and enrolled at the University of Vermont; he graduated in 1996 with a degree in English and religion. By 2000, he was living in an Airstream in the woods near New Haven, trying to feed himself by growing fish from pet-store stock in plastic tubs. One day, he read in the paper that some of the historic shelling leases near the Thimble Islands—so-called king's grants, which had gone fallow after an oyster die-off in the nineties—would be made available. He got one, for fifty dollars an acre, and dropped some oyster cages on the seabed. During the next decade, he built a business, Thimble Island Oyster Company, around the allure of artisanally produced, eco-friendly filter feeders from an idyllic spot. He added clams, scallops, and mussels, and started a community-supported fishery program, with subscription customers.

Then came the one-two punch of Hurricanes Irene and Sandy, with storm surges that buried his entire crop in three feet of mud. He lost years' worth of produce and half his gear, and nearly drowned trying to recover the rest. "I decided that this was the new normal—I was going to exist in extreme weather and changing water temperatures," he said. "I started searching around for different species to grow and different ways of growing them." He pulled the lantern nets off the seafloor and hung them in the water column so they could swing in a storm and not get swamped. He drew a line around the farm: he would grow only species, like his filter feeders, that were delicious and restorative.

That is how he found kelp. Charles Yarish, a leading seaweed expert at the University of Connecticut who has successfully manipulated the life cycle of sugar kelp and studies its bioextractive capabilities, agreed to breed the plants in his lab. Yarish's lab is a library of species, a series of chilly walk-ins with brightly lit shelves of flasks holding acid-green tendrils, mossy puffballs, scab-red tufts. Smith picks up the seedlings, on thin twine wrapped around PVC pipe, and unspools them on his underwater lines when the water temperature drops into the low fifties, usually by late fall. There could come a day when the water in the Sound is too warm for kelp to thrive; Smith will adjust. "It wasn't just adding another species," he told me. "It was the beginning of adding another ten thousand species."

One afternoon, Smith invited me to the house that he and Rahman recently bought in Fairhaven, a neighborhood of New Haven that was once known as Clam Town, back when it was the nexus of the booming East Coast oyster trade. The house, a Victorian Gothic overlooking the river, was built in 1875 by an oyster kingpin; there is a shucking room in the basement, and Smith and Rahman still find shells in their garden. Smith took off his boots on the back porch before entering the kitchen, where Rahman was cleaning mussels at the sink. Her family is from Bangladesh; she grew up in L.A.'s Koreatown, eating the kinds of things that Smith pulls off his nets. She met Smith at a dinner party thrown by one

of his customers. “Bren tried to woo me with his clams,” she said. “I made this amazing Thai dish and then an hour later broke out in hives. It was my first allergic reaction.” They have EpiPens placed strategically around their house.

Soon it was time to eat, at a table laden with seaweed and its cohabitants. There were bright-green flakes of roasted sea lettuce on cucumber, seasoned with salt that Smith harvests from the farm. The butter was flecked with yellow-green chunks of kelp, like the terrazzo floor in an old bank. Rahman found a tiny slipper shell in her mussels; Smith told her she could eat it, a bonus delicacy. The main course was fra diavolo, but instead of linguine it was made with kelp noodles. It tasted fresh and briny, like the breath in your nose on a windy day at the beach. “There’s a learning curve with it,” Rahman said delicately. She is the foodie of the family, but it was clear that she still had her doubts.

“We’re picking one of the toughest food types to convince Americans to eat,” Smith said. “But we have no choice.” In his opinion, there is nothing inherently delicious about kale, so bitter, tough, and leathery; we learned to love the stuff because Gwyneth Paltrow told us to and Dan Barber gave us recipes. But, much as kale needed Barber and his ilk to turn it from a T-bone garnish into a way of life, kelp will need a chef to make us desire it.

Seaweed is the unlovely name for marine macroalgae, an enormous, varied family of more than ten thousand species. Most are benthic: they attach to rocks, seabed, or other seaweeds with a clamplike structure called a holdfast. They come in brown, red, and green; some iridesce. Mating, they use eyespots, release pheromones, or extrude slime. Certain species can reproduce vegetatively. They can come equipped with floats so that their leaves—called blades—stay close enough to the surface to photosynthesize. Instead of rigid cell walls like those found in land plants, seaweeds’ cell walls are rich in sugars to help them bend rather than break in swells. These sugars—known as alginates, carrageenans, and agars—thicken, bind, and emulsify toothpaste, shampoo, skin cream, and countless industrial foods, including most ice cream.

The ocean covers seventy per cent of the earth and produces less than two per cent of our food. To grow the rest, we use almost forty per cent of the world’s land and nearly three-quarters of our fresh water. “We haven’t begun to explore the ocean as a food source,” Mike Rust, an aquaculture scientist with the National Oceanic and Atmospheric Administration, told me. “If you want a glimpse of the future, the best one is Jules Verne’s ‘Twenty Thousand Leagues Under the Sea’ ”—where Captain Nemo feeds his crew exclusively on food harvested from the ocean. Nearly half the world’s ocean-farmed product is seaweed. Most of the industry, which is worth some six billion dollars, is in Asia, where seaweed has long been welcome on the plate. “If you were to extrapolate one of those Asian seaweed farms, it becomes incredible pretty quickly,” Rust said. “You get speculative numbers, like, you could replace all agriculture with less than one per cent of the oceans’ surface area.”

Seaweed can be rich in protein, Vitamin B_{12}, and trace minerals. Iodine and omega-3 fatty acids, which many seaweeds have in abundance, are essential for brain development; some researchers believe seaweed may have played a role in the rise of *Homo sapiens*. Archeologists have posited a “kelp highway,” to describe the coastal migration of the early Americans, some fourteen thousand years ago. Among modern Westerners, it has largely been treated as the food of last resort, a hedge against starvation that lingers nostalgically in corners of authentic cooking after the crisis wanes. An exception to this is purple laver (nori, in Japan), which the Welsh make into cakes and cook in bacon fat, and which the British food writer Jane Grigson said is “the one seaweed we can decently count in English or Welsh cooking as a vegetable.” Now that our brains are big enough to have devised a million ways to eat too much, seaweed could come to the rescue again. A recent study from the University of Newcastle found that the alginates in brown seaweed may inhibit the uptake of fat. Jamie Oliver, the British chef, recently lost almost thirty pounds and attributed it to seaweed, and to drinking only on weekends.

But seaweed’s most compelling property may be its ability to scrub, absorbing excess nitrogen and phosphorous, deposited in the water by agricultural runoff and wastewater, and dissolved carbon dioxide from combusted fossil fuels. (More than a quarter of the CO_2 released into the atmosphere is absorbed by the ocean.) Too much nitrogen and phosphorous can cause algal blooms, which, when they go bust, leave deoxygenated dead zones where little can survive. Excess carbon contributes to ocean acidification, which dissolves coral reefs and harms shell-forming creatures on which many of the fish we eat depend. Research on aquaculture in Asia has shown that one ton of dried kelp can contain as much as a third of a ton of carbon. Rust has estimated that if we can accelerate seaweed production by fifteen per cent a year (the current growth rate is nine per cent) by 2050 that biomass will be able to remove eighteen per cent of the nitrogen and sixty-one per cent of the phosphorous contributed to the ocean by fertilizers annually, and will take up six per cent of the ocean’s emissions-related carbon.

Still, it would take decades of aggressive planting to lower atmospheric CO_2 below three hundred and fifty parts per million, the level that most climatologists say is necessary to avert planetary disaster. Seaweed might have a more meaningful influence in highly sensitive areas, such as coastal waterways. In Puget Sound, where the pteropods—tiny

marine snails known as sea butterflies—are showing signs of dissolution from intensifying acidity and dead zones have been spotted, a study is under way to measure how seaweed cultivation may alter the local chemistry. The study will also look at potential problems associated with seaweeds' spongelike powers. Hijiki, the spiky brown seaweed often served at Japanese restaurants, is known to have elevated amounts of arsenic; according to Kelp Watch, which was established after the Fukushima nuclear disaster to monitor radioactive isotopes in kelp from Mexico to Alaska, kelp is a powerful concentrator of cesium. A primary goal of the research in Puget Sound is to propose ways to safely direct seaweeds into the human food stream. "We need to create a culinary bow wave for sea vegetables," Betsy Peabody, one of the investigators, told me.

An era of seaweed eating can start to seem inevitable—penance for the golden days of corn and cars and cows. Paul Greenberg, who has written extensively about the collapse of fish stocks, told *Business Insider* last year, "If I could buy kelp futures, I would." Given the exigencies of feeding the planet, it might be preferable to other available alternatives. "It's not worms and it's not bugs, so that's positive, right?" he said to me. "I don't think anyone is going to stick their finger down their throat and say, '*Blech*, kelp—I don't want to eat it.' " Cheryl Dahle, the founder of Future of Fish, says, "We eat things now we never would have imagined eating twenty years ago. We eat dogfish. It's called *dogfish*, for crying out loud! If we can develop a market for snakehead fish—an exotic, invasive aquarium species—out of the Chesapeake, we can create a market for kelp."

At Oregon State University, researchers have decided that bacon might be a more effective marketing vehicle than guilt, idealism, or fear. In July, the university created a small media frenzy when it announced that it had patented a strain of dulse that tasted like bacon when cooked. It was a bit like announcing that you'd discovered a variety of orange that could be squeezed into juice—vegan restaurants have been selling "D.L.T.s" for years—but that didn't stop ABC News from calling dulse "the Holy Grail of seafood."

"It's bacon or sex, those are the two things that drive the world, as far as I can tell," Christopher Langdon, the marine biologist who grew the dulse, told me when I visited him at the Hatfield Marine Science Center, in Newport, Oregon. He is British, with rosy cheeks and a subdued twinkle. Twenty years ago, he started cultivating dulse in tanks of bubbling seawater to see if it would make an effective feed for farmed abalone. He observed some unusual traits—rapid growth, a distinct pompom-like morphology—and continued to experiment with nutrients, population density, and turbulence. The strain that he patented, called C3, grows by eighteen per cent a day.

Dulse is a delicate pinkish-red seaweed, sometimes called red kale, which the Irish ate during the famine. It is still wild-harvested in Ireland and the United Kingdom. "I've had a wonderful call from someone in Ireland who told me he only collects dulse when the moon is full," Langdon said. "He had all these recipes—they add dulse to potatoes, and that's apparently one of their favorite combinations."

A year ago, Chuck Toombs, a boisterous instructor at Oregon State's business school, stopped by Langdon's lab. When he learned that dried dulse sold for sixty dollars a pound at Whole Foods, he got inspired. "I kept thinking about it, driving home to Portland," he told me. "Sixty dollars a pound! How much can we grow, and what can we make of this stuff? I want to sell bales to Costco." Toombs quickly ran some numbers and estimated that eleven thousand acres of kale were planted in the United States last year. "Producing indoors under artificial light, we think we could produce the same amount of dulse in a building the size of Home Depot," he said. He recently launched a business selling dulse salad dressing at natural-food stores.

Langdon took me to see the tanks—turbid vats roiling with tangles of dulse. "Here's the C3," he said, breaking off a piece for me. I took a bite. It was ticklish, like escarole, with the toothfeel of a Twizzler; beneath the strong salt flavor, it tasted slightly nutty. "Our next project is to develop a culture system where you can grow dulse on land, without a continuous supply of new seawater. The idea is a dulse farm outside London, Berlin, Paris, or Tokyo to supply restaurants with fresh dulse every day."

For the U.S. market, seaweed snacks may prove to be the point of entry—and the first battleground with kale. According to *Food Navigator*, an industry publication, the category is growing by about thirty per cent each year, with sales for 2014 as high as five hundred million dollars, compared with the kale-chip business, which is worth two hundred million. SeaSnax—organic, non-G.M.O.-certified nori sheets basted in olive oil and dusted with salt—have edged out cheddar bunnies on certain West Coast playgrounds. Ocean's Halo seaweed products have made it even further: at Whole Foods they're sold in the chips section. The company, in Burlingame, California, was founded by Mike Shim, a Korean-American former Yahoo employee, and Robert Mock, a Texan who became addicted to the nori sheets his son snacked on but wished that they were crunchy, like Doritos. With the natural-foods market growing faster than the conventional one, Shim thinks the seaweed-snack business can develop along the lines of coconut water, which is now a billion-dollar

industry. “We’re only two years old and we’re selling millions of dollars’ worth of seaweed snacks a year,” he says. “We’re really focussing on mainstreaming seaweed for the American consumer.”

In Portland, at Oregon State’s Food Innovation Center, a young chef with a large mustache had been assigned to create dulse-related products to introduce to the public. (His previous post was at the Nordic Food Lab, an offshoot of Rene Redzepi’s restaurant Noma, where he ate a lot of jellyfish, wild herbs, and dulse ice cream.) To emphasize dulse’s bacon flavor—from naturally occurring glutamates—he cold-smoked it and then fried it in grapeseed oil. “This could be a big part of pushing meat to the side of the plate,” he said. It was a greasy dark green—heat brings out the chlorophyll—and intensely salty. Using meat glue to create a slab, he’d managed to get it chewy. It wasn’t bacon, but it wasn’t bad.

Bren Smith believes that seaweed can be the cheapest food on the planet, the fish sticks of the future. “We are going there,” he said. “The question is, Will it be cod-liver oil, or will it be delicious?” In late August, he had a breakthrough: he met Brooks Headley, a punk drummer turned pastry chef who recently opened Superiority Burger, an un-earnest vegetarian burger joint in the East Village.

At the end of the first week of September, Smith was at the train station in New Haven, wearing clean jeans and a green hat, swaggering like Popeye. He had two Whole Foods bags, each containing a box labelled “Sea Greens: Baby Kelp Leaf,” looped over his arms, and a tray of Dunkin’ Donuts coffee balanced in his hands. We were on our way to see Headley. “I bet this is the first time domestically grown kelp has ever been on Metro North,” he said.

A few days earlier, the *Times* had given Superiority an impassioned review, comparing it to Momofuku in the early days. Tonight, Headley was going to serve Smith’s kelp, both the fresh product Smith had with him and some frozen noodles he’d been working with all week. Smith showed me a picture of a five-dollar side that Headley had designed: a scribble of bright-green kelp noodles and roasted carrots in barbecue sauce, served with bread crumbs and a dash of lemon in a paper boat. “Maybe exactly what kelp needs is a little punk rock,” Smith said. “Not hippy vegans.”

The restaurant is tiny, six seats in three hundred square feet, including the kitchen. Headley, wearing a black knit cap, greeted us among boxes of the day’s produce. “When we started playing around with the kelp, I didn’t expect it to be so sturdy,” he said. “It seems like it’s going to wilt into spinach. But the texture is still there, even after it’s seared on the flattop.” He was practically bouncing. “I’m so excited,” he said. “This is, like, *new*.”

Smith said, “The reason the structure is so good is that in the winter it’ll freeze-thaw-freeze-thaw-freeze.”

A skinny cook with white-blond hair and an Orioles cap said, “It reminded me of pad-Thai noodles.”

Headley agreed. “There’s also like a gummy-bear quality to it. That gelatiny snap. Texture and mouthfeel is a huge thing for us. We try to do things that are gut-level fast-food satisfying without being meat.” He gave us some kelp to try: one extremely long noodle piled like cat-mauled knitting yarn, topped with a heap of carrots and smothered in a re-creation of K.C. Masterpiece.

Superiority is open from six to ten and serves two hundred and forty people—one a minute—every night. Around five, a mob started to form outside the door. A ten-year-old boy with fair curly hair and braces, wearing a Decemberists T-shirt, pushed his nose against the glass. When he finally got in, he was giddy with delight. He had made his family come from Carroll Gardens to try the food. Of course he had ordered the kelp. “Everyone in my class thinks seaweed is disgusting,” he said. “They’re horrified.” He went on, “I’m the adventurous eater in the family. I hate the SeaSnax. It’s not like *real* seaweed. It’s over-salted, over-olive-oiled. My sister likes anything that tastes *normal*. True story: if we put a plate of SeaSnax in front of her she’d eat the whole thing.”

“You used to like them, too,” his mother said.

“I *used* to like them.”

“Seaweed’s very mainstream now,” his father added. “Well, mainstream in Brooklyn.”

The kelp and carrots sold out in three hours. Smith seemed to have found his man: a crowd-pleaser with indisputable anti-establishment bona fides. “I’ve never had any kale in house,” Headley said. “I’m actually not a big fan of raw kale.”

As much as we need seaweed, it may need us more. Tom Ford is a marine biologist and the director of the Bay Foundation, which works to reforest the giant kelp in Santa Monica Bay, three-quarters of which has vanished since 1950. I met Ford in his office, which is a trailer on the campus of Loyola Marymount University, where he also teaches. Scuba gear hung on the walls.

On his computer he showed me a presentation called “Kelp! I Need Somebody.” It opened with an aerial shot taken two years ago of light-blue, kelpless water off Honeymoon Cove, at the southern end of the bay. Like others around the world, this kelp forest had been devastated. Around the time of the Second World War, industrial harvesters came in, seeking alginates, and unwittingly took off the growth zone of the plants, slowing their recuperation. (The harvesters pulled out in 2006.) Now there is the additional stress of sewage and storm runoff from a megalopolis. But the largest problem is the purple sea urchin, which loves to eat giant kelp. In the eighteen-fifties, with sea otters, the urchins’

primary predators, hunted nearly to extinction for their fur, the purple urchins began experiencing a population boom. The dead kelp forest, these days, is called an urchin barren.

Ford refers to seaweed-sequestered carbon as “gourmet carbon,” but not because he’s trying to get people to eat it. The kelp forest is a potential carbon sink—problematic carbon, embodied, makes its way up the food chain until it reaches an apex predator, such as a shark, which when it dies sinks to the ocean floor—and it also rebuilds a decimated ecosystem, providing a place for fish to breed and feed, and for migrating gray whales to hide their young. The fishermen get reëmployed, and the coast is protected from storm surges and erosion. Besides, a kelp forest is an ecological refuge that can be installed in the only real estate that is readily available. “Where am I going to plant the giant forest in the middle of L.A. to sequester carbon?” Ford said.

For the past two years, Ford and his colleagues have been bringing the forest back to life. Their method is simple: dive down with a hammer and smash most of the urchins they see. It has been remarkably effective, and thirty-four acres have been restored. One socked-in morning this fall, Ford picked me up in a truck to take me to Honeymoon Cove so I could see it for myself. He is from eastern Pennsylvania. The first time he saw giant kelp while diving, he was terrified. “It was the biggest, darkest, shadowiest thing I’d ever seen in the ocean,” he said. “Scared the hell out of me.”

We drove through a neighborhood of gracious houses with deep lawns, where the for-sale signs were from Sotheby’s, and parked by a steep cliff. Below us was a rocky beach and the Pacific, spit-white at the edge, then chalky, then blue. In wetsuits, we picked our way down a hundred and fifty feet of switchbacked trail. Ford stepped gingerly; he is afraid of heights. On the beach, he walked me to the water’s edge, which was piled with gloopy decomposing kelp. Flies buzzed all around. “This is how most people experience kelp,” he said. He picked up a dried-out holdfast, like a nest. Inside it was a small sea star.

Diving in the kelp is a biologist’s dream. “You can be sixty feet down, looking up at these giant columns of kelp spreading out on the surface, and these golden shafts of light, like light through a stained-glass window,” he said. “There are hundreds of species around you. It’s like flying through the forest.” We waded into the water and put our flippers and masks on. I ducked my head under and gazed. Two years ago, it was rocks and urchins. Now kelp was everywhere, ochre-colored, thirty feet tall, flailing like tube dancers outside a car wash. Three bright-orange Garibaldi fish swam past, then a group of opaleye, then five kelp bass. I came up to the surface and dove down again, plugging my nose with one hand and using the other to pull myself down the length of a plant. The water was milky with kelp slough. Southern sea palms swooshed and swayed as the waves tumbled over them. At the surface, Ford held up a loose piece of kelp, shaggy and decrepit with a small holdfast—it was sporifying. “More spores,” he said. “Go, go, go.” ♦

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Moorish Stew

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Dixie D. Vereen for The Washington Post

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Moorish Stew

OCT 26, 2015

Here, chef Barton Seaver has replaced the wilted spinach in a traditional Spanish recipe with seaweed -- or, as he likes to call it, seagreens. He also uses seaweed to create an umami-rich vegetable broth that's the base of the stew.
Make Ahead: The broth needs to steep for 1 hour; it can be cooled, then refrigerated for up to 4 days in advance. You'll have leftover broth, which can be frozen for up to 1 month. The stew tastes even better after a day or two of refrigeration; reheat before serving.
Where to Buy: Dried kombu (kelp) is available on the international/Asian aisle of larger grocery stores.

SERVINGS: 2 4 8 12
Tested size: 4 servings; makes 8 cups
INGREDIENTS

- FOR THE BROTH
- 8 cups water
- 1/2 onion, peeled and sliced
- 1 rib celery
- 1 ounce dried kombu (see headnote)
- 1 quarter-size slice fresh ginger root
- 1/4 cup chopped dried mushrooms, preferably shiitake
- FOR THE STEW
- 3 tablespoons olive oil
- 1 1/2 pounds small red potatoes or russet potatoes, peeled and cut into 3/4-inch chunks
- 1 medium onion, chopped
- 2 cloves garlic, minced
- 2 teaspoons Spanish smoked paprika (pimenton)

- 1/2 teaspoon kosher salt, or more as needed
- 1 ounce dried kombu, rehydrated (see NOTE; may substitute 3 cups fresh/frozen seaweed
- One 14.5-ounce can no-salt-added chickpeas, rinsed and drained (may substitute about 1 1/2 cups cooked/homemade chickpeas)
- One 14.5-ounce can diced, no-salt-added tomatoes
- 4 large eggs, for garnish (optional)

DIRECTIONS

For the broth: Combine the water, onion, celery, dried kombu, ginger and dried mushrooms in a large, heavy-bottomed pot over medium-high heat. Bring just to a boil, then reduce the heat to medium-low; cook for 20 minutes, then turn off the heat and let it steep for 1 hour. Strain, discarding the solids. The yield is about 8 cups.

For the stew: Heat the oil in a Dutch oven over medium-high heat. Once the oil shimmers, add the potatoes and onion, stirring to coat. Cook for about 5 minutes or until the potatoes start to pick up some color, then stir in the garlic, smoked paprika and 1/2 teaspoon of salt; cook for about 1 minute, then add the rehydrated kombu, chickpeas, 4 cups of the broth and the tomatoes and their juices, stirring to incorporate. Once the mixture comes to a boil, reduce the heat to medium, partially cover and cook for 15 minutes. Turn off the heat; taste, and season with salt, as needed.

For the optional garnish (just before you're ready to serve), grease a small nonstick skillet with cooking oil spray, then heat it over medium heat. Fry the eggs 1 at a time, seasoning them with a little salt and transferring the cooked eggs to a plate as you work.

Spoon the stew into individual bowls. Top each portion with a fried egg, if using. Serve hot.

NOTE: Rehydrate the kombu by soaking it in a bowlful of cool water for about 5 minutes. Drain before using

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Underwater Vertical Seaweed Farm Restores Our Oceans While Providing Food and Fuel Source

Cole Mellino
November 11, 2015

Bren Smith has set up what he calls “3D ocean farms,” which “utilize the entire ocean column” to grow “restorative species,” including scallops, clams, oysters and kelp. Smith says this makes the oceans cleaner, healthier and more habitable, while providing jobs and food.

He hasn’t always been fishing that way. His story is one of “ecological redemption,” Smith said in a TEDx Talk (see below) in 2013. He dropped out of high school when he was 14 to work on fishing boats, working “at the height of the industrialization of the oceans. We were ripping up entire ecosystems with our trawls. We were using evermore efficient technology to chase fewer and fewer fish deeper and deeper into the ocean. And I’ve personally thrown tens of thousands of pounds of dead bycatch back into the sea,” he said

Bren Smith calls his type of fishing “3D ocean farming,” and it recently won him the $100,000 2015 Fuller Challenge Prize from the Buckminster Fuller Institute. Photo credit: GreenWave

But that all changed about 15 years ago when he started growing seaweed in the Long Island Sound, where he now grows 30 to 60 tons of it per year. Seaweed has been described as a superfood, but it’s also really beneficial to the ecosystem.

“Seaweed farms also help clean the water from pollution like carbon dioxide and nitrogen,” explains FastCoExist. “They help with storm protection. And they provide a way for fishermen to do something other than fishing at sea: creating new forms of manmade coastal ecosystem—farms centered around seaweed.”

“Globally, the potential scale of seaweed farming is 600 times greater than any other method of cultivating algae,” says Quartz. “Seaweed is finding many uses beyond food, from medicine to fuels, and it may be that seaweed farms will offer refuges for marine species under threat from increasing acidification.” And scientists recently worked out how to cultivate green algae for biofuel in huge quantities at $50 a barrel, which is about the cost of crude oil.

It’s hard to understate the value kelp has as a food source and a fuel source, as well as the role it can play in restoring ecosystems. Smith’s kelp is even being used by Yale University’s farm as a fertilizer, serving as a “bridge,” as Smith puts it, between “land-based farming” and “sea-based farming.”

Smith’s Thimble Island Ocean Farm was created out of his project GreenWave, which just received a huge endorsement because it won the prestigious $100,000 2015 Fuller Challenge Prize from the Buckminster Fuller Institute.

Buckminster Fuller Insitute explains why Smith’s project is so groundbreaking:

GreenWave’s integrated model shifts the practice of aquaculture from growing vulnerable monocultures to creating vibrant ecosystems, which produce higher yields. The infrastructure is simple: seaweed, scallops and mussels grow on floating ropes, stacked above oyster and clam cages below. From these crops ocean farmers can produce food, fertilizers, animal feeds, pharmaceuticals, cosmetics, biofuels and much more.

Jang Kim, UConn assistant research professor, inspects a healthy kelp harvest utilizing the nutrients of Long Island Sound. Photo: C. Yarish

SEAWEEDS CLEAN LONG ISLAND SOUND

By Peg Van Patten

The Essential Services of Nutrient Bioextraction

Not everyone enjoys putting in the elbow grease for the annual spring cleaning at home, but it's an important task that most of us tackle. There's another type of cleaning happening right now that few people may be aware of, however. Long Island Sound waters are being cleaned, whether we are aware of it or not, by a process known as bioextraction.

Bioextraction is a fancy name for the practice of using biological means to remove something. In our case, it is the practice of removing nutrients, mainly nitrogen using the harvest of seaweed and shellfish production. Nutrients in the form of nitrogen compounds enter the Sound ecosystem via rivers, runoff, wastewater, and atmospheric discharge.

Historically, excess nitrogen has caused problems in the Sound by triggering phytoplankton and macroalgal blooms that, in the

Gracilaria being grown in Long Island Sound as an experiment.

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course of their dying and decay, lead to the depleted oxygen condition known as hypoxia. In that sense, n itrogen is a pollutant. However, nitrogen is also the most abundant gas in the air we breathe and part of the cells and DNA in our bodies. Without nitrogen, organisms could not form amino acids, which lead to proteins or even produce the building blocks of DNA. In aquatic ecosystems, nitrogen is literally too much of a good thing.

Enter seaweed. By simply growing, seaweed takes up nitrogen(where it may be a pollutant) by removing it from the water, and turns it into living tissue. That's what is known as an ecosystem service –improving conditions of the ecosystem for the benefit of living organisms and environment.

Charles Yarish, professor at the University of Connecticut Departments of Ecology and Evolutionary Biology, and Marine Sciences, has been a leader in developing this technology in the United States. He and colleagues Jang Kim (assistant research professor, UConn Marine Sciences) and George Kraemer (professor, SUNY Purchase) were curious about how much nitrogen could actually be removed by cultivating seaweed and harvesting it. Yarish and Kim were especially curious about how bioextraction could work in a heavily urbanized environment.

With support from Connecticut Sea Grant and the Long Island Sound Study, they set up three locations to grow seaweed for bioextraction. One site was in the waters off of Branford, Connecticut, one off of Fairfield, and the third in the Bronx River estuary, New York. Two native species were used; *Saccharina latissima* (sugar kelp) and *Gracilaria tikvahiae*, a bushy red alga. Kelp is a cold water crop, growing best from November to May, while *Gracilaria* is a warm water species growing from June to October, providing data for a year-round bioextraction study.

High School students at Bridgeport aquaculture high school and at Rocking the Boat in the Bronx have been part of the team involved in growing and harvesting kelp for nutrient extraction, improving water quality at Hunt's Point, NY and in Fairfield and Branford, CT.

Basically, these seaweeds, which can be grown along with shellfish (or even finfish), take up nitrogenous compounds in animal waste products (yes, poop), wastewater, or nonpoint pollution (land-based fertilizer runoff in the form of ammonium or ammonia and even aerial deposition), and turn it into healthy tissue, leaving the water cleaner. But how effective could this really be?

The researchers set out to quantify this question with real numbers, to answer the question of how valuable this service really is.

The results were impressive but not without challenges. In 2012, using a longline kelp farm placed off Fairfield in Long Island Sound, the researchers showed that a hypothetical 1-hectare kelp farm on longlines could remove 71 to 280

kilograms of nitrogen (equivalent to 156 to 617 pounds)—that's a lot of nitrogen. The following year was not as successful, being complicated by a January Nor'easter that slammed the experimental apparatus, resulting in lower amounts. Attempts to select the genetic kelp strains that are most efficient at removing nitrogen were thwarted as well, but not by Mother Nature—rather by human means. Someone vandalized the experiment by cutting off the long lines deployed to grow the kelp. Still, results show a lot of promise for this technology to gently improve the water quality of estuarine ecosystems.

Gracilaria, also an economically important seaweed species, was grown in the waters off of the Bronx, NY and in western Long Island Sound during the late summer months when eutrophication problems tend to occur. It was also successful at removing nitrogen. At the Bronx site, *Gracilaria* grew over 16 percent per day and accumulated nitrogen up to 6 percent of its dry weight. In Long Island Sound, *Gracilaria* grew up to 11percent per day with nitrogen accumulation in its tissue of up to 5 percent dry weight. In comparison, The sugar kelp accumulated nitrogen over 3 percent of its dry weight.

Using these measurements, Kim and Yarish estimated that if both species were grown in aquaculture operations, using just 1.5 percent of the Sound, 2.2 million kilograms (nearly 5.9 million pounds) could be removed per year. In addition, the seaweeds are effective at removing carbon dioxide, and together could remove about 2,000 kilograms of carbon per hectare (4400 pounds per acre) per year. The UConn School of Business developed an economic model that estimated the value at

Enter seaweed.

By simply growing, seaweed takes up nitrogen (where it is a pollutant) by removing it from the water, and turns it into living tissue.

"Sea vegetables" is a more apt description for kelp than "seaweed" — and it can also be called a nutrient scrubber!

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UConn's Charles Yarish (right) and Jang Kim (left) hold a spool with sugar kelp seedstring at The Thimble Island Oyster Company's seaweed farm in the Thimble Islands. The kelp farm (B. Smith, owner) was the first one in Long Island Sound.

about $3000 per hectare ($1200 per acre) for this service. Yarish and Kim received the Connecticut Quality Improvement Award (CQIA) Innovation Prize in June 2013 for their seaweed aquaculture and nutrient bioextraction research in Long Island Sound. This award is presented to honor advance innovative programs that improve quality performance and marketplace competitiveness.

So while you're wiping away pollen and winter grime from the windows or spraying your car chassis, wear a little contented smile because you know that uncomplaining seaweeds are steadily cleaning the Sound for you, bringing healthier waters all year round. As seaweed and multi-species aquaculture grows, water quality improves.

Captain Kenneth Tober (Bridgeport Regional Aquaculture Science & Technology Education Center; BRASTEC), with Yarish (center) and Kim (right). With Captain Tober, BRASTEC's students, teachers and staff have worked with UCONN to cultivate sugar kelp and the native red seaweed, *Gracilaria tikvahiae* at BRASTEC's lease site off Fairfield, CT.

ABOUT THE AUTHOR

Peg Van Patten is communications director for Connecticut Sea Grant and editor of *Wrack Lines* magazine.