

Automated Management of Offshore Shellfish Farms

Program in Scientific Aquaculture Marine Resources Center Marine Biological Laboratory Woods Hole, MA

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Tasks for Automation are Similar for Shellfish and Fish • Cleaning fouled cages, flipping cages Buoyancy adjustments, gear orientation Monitoring gear and water quality Sorting product by size, quality



International context for mussel aquaculture

- 2 million metric tonnes of annual production (live wt of 6 spp.)
 China is largest producer 1/3 of total
- Next largest producers are Chile, New Zealand, Spain, Canada
 - Chile = 300K tonnes/yr
 - Spain = 200K tonnes/yr
 - N.Z. = 100K tonnes/yr (5,500 ha leased) export = \$185 M
 - Canada = 18K tonnes/yr, \$23M value (PEI alone = 4,000 ha)

Domestic Farmed Production and Market

- US = 1 K tonnes/yr
- Imports to US worth \$80 million per year

Submerged Longline System Design with Mussel Growout Harness



Catalina Sea Ranch – 100 acres off Southern CA

Offshore Shellfish Ltd – 6 square miles of mussel farms





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Permitted and unused sites

Nantucket Sound Mussel Farm Detailed plan for shellfish longlines

Novel cost-effective anchor installation

ROV-like operation with U/W cameras etc.

Offshore Mussel Farming

- Market size in ~ 1 yr.
- Robust, cost-effective anchor & buoy engineering

Dependent on natural seed supply

Automated Task #1 – Larval Sampling

- CPICS: Continuous Particle Imaging and Classification System
- Set up on a on-site buoy or AUV
- Predict better timing of seed set and
- When to hang collecting rope

ASV/Depth sounder for checking lines

Socks wrapped around the headrope after Super-storm Sandy

Low-cost accelerometer/current meter

Lowell Instruments, Falmouth MA

CATALINA SEA RANCH NOMAD BUOY

MONITORING SUSTAINABLE OFFSHORE AQUACULTURE NOAA is providing a NOMAD buoy which will be anchored in the middle of Catalina Sea Ranch. Its 20 x 10 x 7 foot, 16,000 pound aluminum alloy boatshaped hull can endure severe sea conditions for 24/7 real-time environmental monitoring and security protection.

METEOROLOGICAL DATA

An integrated weather sensor that measures an d relays wind direction, speed and rainfall.

ANTENNAS

High gain onmidirectional antenna to beam cellular signals to shore-based tower.

SOLAR PANELS -

Four 100-watt photovoltaic panels attached to a battery bank below deck.

RAILS -

Prevent seals and sea lions from coming aboard.

MARINE MAMMAL DETECTION

Acoustical receiver identifying marine mammals tagged with VEMCO transmitters passing near the ranch

SOLAR CONTROLLER AND STORAGE BATTERIES

The controller for the solar panels and batteries is located inside the buoy and furnishes power distribution and circuit breaker protection to the buoy's electronic devices.

ANCHOR-

A three-point attachment to a helical-screw anchor embedded in the ocean floor at a 150-foot depth using a chain and a double-braided polyester rope. WIDE BEAM LANTERN A self-contained light with 6-nautical-mile visibility.

Data transmitted from the NOMAD to Verizon's cellular network and Internet cloud for research and collaborative scientific analyses.

SURVEILLANCE RADAR widearea, all-weather sensing capability.

WAVE AND CURRENT MEASUREMENT

Measures and relays a wide variety of wave and current information.

VERTICAL WATER PROFILER

A winch assembly that lowers and raises the sonde to any depth from sea level to ocean floor. Fully controllable from shore-based remote and programmable for frequency of measurement, depth and duration.

WATER QUALITY SONDE

Advanced sonde with six replaceable smart sensors and a central wiper to clean biofouling. Measures conductivity, temperature, fluerescent dissolved oxygen, fluorescent dissolved organic matter, pH, total algae and turbidity.

Predation from Ducks

#1 concern for mussel farms
Ducks can eat or knock-off all
seed and large proportion of market-sized mussels
Non-automated ways of scaring are expensive
Need multi-modal ways to be effective?

Shock and Awe (light and sound)?

Green Laser in Action

Automated scaring with laser

			PATTERNS	TIMESLOTS	INTERVAL	SETTINGS	LOG OUT	
STATUS	Waiting for r	next burst	Selected Timesto	ts Pattern nan	e	Selected Timeslots	Pattern name	
Next burst Next pattern	03 min 29 se Pattern 03	c	100	Pattern 0	1 EDIT	000 >	Pattern 09	EDIT
TIME	11:36	Edit	026	Pattern 0	2 EDIT	0000	Pattern 10	EDIT
TIMESLOTS			123	Pattern 0	3 EDIT	0000	Pattern 11	EDIT
08:00-12:15	13:00-16:15	20:45-22:15	100	Pattern 0	4 EDIT	0000	Pattern 12	EDIT
BATTERY	65%		000	Pattern 0	5 EDIT	0000	Pattern 13	EDIT
LASER	Inactive		000	Pattern 0	6 EDIT	0000	Pattern 14	EDIT
POSITION	Bearing 142°	Elevation 4°	000	Pattern 0	7 EDIT	0000	Pattern 15	EDIT
WAYPOINT	1		000	Pattern 0	8 EDIT	0000	Pattern 16	EDIT

If pattern and time settings are completed, press start to activate the Shelfish Saver Automat The active patterns will be executed in consecutive order.

Marine Energy and Aquaculture Farms

Marine Energy Generation

- Need to look at appropriate scales of energy generation to keep batteries charged on robotics and automated functions
- <u>Compressed air</u> generation may
 be viable power
 storage and use

Remotely adjustable buoyancy?

Sugar Kelp Farming
Gaining popularity in US food markets
MBL piloting sugar kelp farming this winter
Big automation and materials handling challenges

Seaweed Farm of the Future

Clifford Goudey design

Automated Mussel Husbandry Practices Declumping and Grading Seed

Automated Mussel Seed Socking

Automation at Work

Acoustic Ranching?