Design & Operation of Aquaculture Production Systems

Grade Level:
9-12

Subject Area:
Computer skills, Aquaculture

Time:
Preparation: 30 minutes to prepare for lecture
Activity: 1-50 minute period to lecture, 5-50 minute periods to research and prepare presentations, 3-50 minute periods to present and review
Clean-up: NA

SPS (SSS):
01.02 Analyze the impact of agriculture on the local, state, national, and global economy (LA.A.1.4.1-4; LA.A.2.4.4; LA.B.1.4.1-3; LA.B.2.4.1-3; LA.C.1.4.1; LA.C.2.4.1; MA.A.2.4.1-2; MA.A.3.4.1, 3; MA.E.1.4.1-2; SS.A.3.4.3, 8, 10; SS.A.4.4.1, 6; SS.A.5.4.3, 5; SS.B.2.4.1, 4; SC.H.3.4.2-3, 5-6; SC.B.1.4.5; SC.D.1.4.1, 3; SC.D.2.4.1).
06.02 Explain the economic importance of animals the products obtained from animals (LA.A.1.4.1-4; LA.A.2.4.4; LA.B.1.4.1-3; LA.B.2.4.1-3; LA.C.1.4.1; LA.C.2.4.1; MA.D.1.4.1; MA.E.1.4.1; MA.A.1.4.1-4; MA.A.2.4.2; SC.D.1.4.1; SC.G.1.4.1).
10.05 List and describe the nature of five areas of aquaculture occupations (LA.A.1.4, 2.4; LA.B.1.4, 2.4; LA.C.1.4, 2.4; LA.D.2.4; SS.D.1.4, 2.4).
11.09 Develop an information file in aquaculture species (LA.A.1.4, 2.4; LA.B.1.4, 2.4; LA.C.1.4, 2.4, 3.4; LA.D.2.4; SC.D.1.4; SC.F.1.4, 2.4; SC.G.1.4, 2.4).
15.01 Identify the types of growing systems and important factors in their selection, design, and use (LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4; MA.A.1.4, 2.4, 3.4, 4.4, 5.4; MA.B.1.4, 2.4, 3.4, 4.4; MA.C.3.4; MA.D.1.4, 2.4; MA.E.2.4; SC.G.1.4, 2.4; SC.H.3.4).
15.03 Identify and describe important growing facility construction and site requirements (LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4).
17.01 Recognize and observe safety and sanitary practices in harvesting and processing aquaculture/mariculture species (LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4; LA.D.2.4; MA.B.4.4).
17.02 Determine harvesting practices recommended for commercially desirable aquaculture/mariculture species (LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4; LA.D.2.4; MA.B.4.4).
17.05 Determine equipment, labor, financial, and legal requirements for harvesting

(LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4; MA.B.4.4; SS.C.1.4, 2.4; SS.D.1.4, 2.4).
21.01 Identify and use basic computer programs (LA.A.1.4, 2.4; LA.B.2.4; LA.C.1.4, 2.4; LA.D.1.4, 2.4; SC.H.3.4)

Objectives:
1. Students will be able to define and describe various types of aquaculture production systems.
2. Students will be able to identify and describe types of extensive aquaculture.

Abstract:
Similar to other forms of agriculture, aquaculture can be categorized by the method of cultivation that determines the space, equipment, labor, and other inputs required to realize the desired production yield and economic returns. For aquaculture, these categories are defined as “extensive”, “semi-intensive”, and “intensive”; each has its own generic characteristics and expectations. This introduction will characterize these methods and provide examples for each, followed by specific examples of aquaculture in pond, tank, and open-ocean aquaculture systems.

Interest Approach:
Before describing each type of system in detail, here is an example to put the concept into context – using cattle farming. An example of “extensive” cattle farming would be large open ranching in Montana (few cattle over large areas of pasture); “semi-intensive” would be dairy farms in Wisconsin (more cattle per acre and supplemented with hay); and “intensive” would be a cattle feed lot in Illinois (cows reared indoors at high density with all their food provided by the farmer). Now, let’s define these categories in aquaculture terms.

Student Materials:
1. Paper
2. Pencil
3. *Aquaculture PowerPoint Guidelines* handout
4. Computer with internet access and PowerPoint

Teacher Materials:

Material	*Store*	*Estimated Cost*
Design and Operation of Aquaculture Production	NA	NA

Systems lecture notes		
Aquaculture PowerPoint Guidelines handout	NA	NA
Computers with internet access and PowerPoint	NA	NA

Student Instructions:

1. Spend 10 minutes researching specific types of aquaculture.
2. Select a specific type of aquaculture (i.e. clam farming Florida or catfish farming in the Mississippi delta, oyster production in Connecticut, Japanese seaweed cultivation, freshwater prawn production in China, etc.) for the presentation and approve the topic with your teacher.
3. Prepare a PowerPoint presentation about your selected type of aquaculture, following the provided guidelines.
4. Present to your classmates.

Teacher Instructions:

Preparations:

This activity is an overview of types of aquaculture and is intended to be used within a classroom lecture framework. Lecture notes and figures for this lesson are in the SUPPORT MATERIALS section. Additionally, there is guideline for the students to create a PowerPoint presentation on a specific type of aquaculture (i.e. clam farming Florida or catfish farming in the Mississippi delta, oyster production in Connecticut, Japanese seaweed cultivation, freshwater prawn production in China, etc.). Divide the class into groups of 2-4. Computers with internet access and PowerPoint will need to be secured for a few days while students research and prepare their presentations.

Activity:

1. Lecture on *Design and Operation of Aquaculture Production Systems*.
2. Approve topics for PowerPoint presentations.
3. Review guidelines for PowerPoint presentations.
4. Supervise students while they prepare their presentations.
5. Allow students time to present their presentations to the class.

Post work/Clean-up:

1. Discuss the various types of aquaculture presented.

Anticipated Results:

1. Students will become knowledgeable of the fundamental production concepts

used in aquaculture and their application.
2. Students will increase their skill base in Microsoft Office applications.

Support Materials:

1. *Design and Operation of Aquaculture Production Systems* lecture notes
2. *Aquaculture PowerPoint Guidelines* handout
3. *Design and Operation of Aquaculture Production Systems* figures
4. Exhaustive catalogue of aquaculture publications from the US Department of Agriculture: http://www.aquanic.org
5. http://www.msstate.edu/dept/srac/publicat.htm
6. "Types of Aquaculture Systems" — PowerPoint presentation – HBOI
7. Aquaculture Interactive – CD – HBOI
8. Offshore Net Pen Aquaculture – PowerPoint presentation – Univ. of Florida/IFAS (Ohs)
9. Avault, J. 1996. *Fundamentals of Aquaculture: A Step-by-step Guide to Commercial Aquaculture*. AVA Publishing Co., Baton Rouge, Louisiana. 889 pp.
10. Bardach, J.E., J.H. Ryther, and M.O. McLarney. 1972. *Aquaculture: The Husbandry of Aquatic Organisms*. Wiley-Interscience, John Wiley & Sons, New York, New York. 868 pp.
11. Beveridge, M.C.M. 1987. *Cage Aquaculture*. Fishing News Books, Oxford, England.
12. Fairfield, W.T. 2000. Net pen culture. Pages 583-586 in: R.R. Stickney (Ed.). *Introduction to Aquaculture*. John Wiley & Sons, New York, New York.
13. Landau, M. 1992. *Introduction to Aquaculture*. John Wiley & Sons, New York, New York. 440 pp.
14. Stickney, R.R. (Ed.). 2000. *Encyclopedia of Aquaculture*. John Wiley & Sons, New York, New York. 1063 pp.

Explanation of Concepts:

Aquaculture production systems
Ocean aquaculture

Support Materials

Design and Operation of Aquaculture Production Systems: Lecture Notes

<u>TYPES OF AQUACULTURE PRODUCTION SYSTEMS</u>

I. Aquaculture can be categorized by the method of cultivation
    a. Determines space, equipment, labor, and other inputs
    b. Divided into three categories, each with unique characteristics
        i. Extensive
        ii. Semi-intensive
        iii. Intensive

II. Extensive
    a. Characterized by very limited input by the culturist
    b. Often done in open water
    c. Most of the artisanal aquaculture practiced in developing countries around the world would be considered extensive
    d. Characteristics
        i. Farmer has little control of the environment
            1. With the exception of predator exclusion
        ii. Farmer does not provide food to the animals
            1. They forage for natural food or they are filter feeders (clams, oysters, and mussels)
        iii. Since food is limited to natural production, stocking densities are much lower than in more intensive systems and must be adjusted to food production
        iv. Growth, production, and harvest yields are typically lower than with more intensive systems
        v. Due to the limitation of inputs (particularly food), the cost of production is much lower than more intensive systems

III. Semi-intensive
    a. Characterized by higher stocking density
    b. Limited degree of environmental control
    c. Involves supplemental feeding
    d. Examples include pond culture of fish and shrimp
    e. Characteristics

i. Farmer has some control of the environment, usually in the form of water exchange (pumping water through ponds or raceways) and aeration
ii. Farmer provides supplemental feed but as in ponds (often fertilized to promote natural productivity) much of the animal's nutrition comes from natural production
iii. Better environmental control and supplemental feeding allow for higher stocking density
iv. Improved environmental conditions and adding feeds usually improve growth rate rates, survival, and harvest yields
v. Environmental control (i.e. pumping water and aeration), use of formulated feeds, or pond fertilization all will increase capital and production costs, but if done properly, production yields will more than offset the additional inputs

IV. Intensive
   a. Characterized by extremely high stocking density (much higher than would ever be found in natural systems)
   b. Substantial environmental control (i.e. temperature, dissolved oxygen, lighting, water quality requirements)
   c. Usually exclusively fed prepared formulated feeds
   d. RAS, utilizing a series of tanks, and water treatment processes (with very limited discharge of effluent into the environment) is an example
   e. Characteristics
      i. Farmer has virtually complete control over environmental conditions within the system
      ii. In most cases, intensive systems are indoors so that climate control does not have to be maintained for each individual system (e.g. tank or raceway)
      iii. Due to the high degree of control required, aeration and water retreatment systems are sophisticated (requiring skilled technicians to monitor and maintain them) and expensive
      iv. In order to avoid disease-causing pathogens that are inherent in high density culture, intensive aquaculture systems require clean water and holding facilities
      v. Stocking densities are very high in intensive aquaculture systems, producing the highest yield per square foot of production area
         1. However, the feed inputs required, that are purchased from feed suppliers rather than natural production, increases dramatically the cost of production
      vi. Intensive aquaculture systems, if correctly managed, provide optimum environmental conditions (e.g. temperature, water quality, photoperiod, current) that will ensure fast growth, high survival, and optimum production yield

1. However, these systems are inherently risky in that any system malfunction can have rapid and dramatic negative effects
2. Most intensive systems are equipped with expensive monitors, back-up power supplies, liquid oxygen, and alarm systems (these are necessary components because a system malfunction can result in a complete loss of crop in a short period of time)

vii. A properly designed and maintained intensive aquaculture system can provide the highest yield per unit volume or space of any aquaculture system

viii. Control of environmental conditions can provide a uniform product (in terms of size and weight), it can stage its production to reach market demand, and it can realize the highest value for the product based on market demands (i.e. direct retail, live product markets, and value-added niche markets)

EXTENSIVE AQUACULTURE

I. Background
   a. Farming shellfish (bivalve mollusks) is arguably the purest form of "extensive aquaculture" because bivalves, as filter feeders, derive all of their nutrition from the natural environment
   b. The most important considerations for shellfish farmers is choosing a site that provides adequate food (microalgae called phytoplankton), environmental conditions conducive to growth and survival (i.e. temperature, salinity, dissolved oxygen), and protection from severe sea conditions or exposure to storm events
   c. Most shellfish growing areas (certainly in Florida) are leased from state government (submerged land leases provided through Florida Department of Agriculture and Consumer Services) and are subject to monitoring and harvest regulations related to seafood safety and public health

II. Farming marine bivalve mollusks
   a. The culture of marine bivalves essentially defines "extensive aquaculture" because it is almost exclusively undertaken in open waters, such as estuaries, bays, lagoons, and even the open ocean
   b. Historically, much of the acreage of coastal waters (termed submerged lands) was privately owned, however in more recent times, submerged lands are owned by the state or federal government (usually determined by distance from shore – federal waters further offshore) and then leased on an annual basis to shellfish farmers
   c. A variety of state agencies have jurisdiction on the utilization of submerged lands for shellfish culture, including:

        i. Navigable waters and markers (i.e. Army Corps of Engineers, Coast Guard)
        ii. Environmental sustainability (FL Department of Environmental Protection, FL Fish and Wildlife Conservation Commission)
        iii. Water quality/public health
    d. Bivalve mollusks – oysters, clams, mussels, scallops, and a few other species
        i. Are reared in open water, and as filter feeders, derive all of their nutrition from the natural environment (unicellular, microscopic algae called phytoplankton)
        ii. Although this is a substantial savings for the shellfish farmer — it has not been demonstrated as economically viable to growth microalgae for shellfish or develop artificial feeds — it is not without risks
        iii. About the only control that bivalve farmers have over the culture environment is to exclude predators using a variety of bags, cages, and "off-bottom" culture
        iv. The only measure of control that shellfish farmers have on the environment is site selection
            1. Temperature
            2. Salinity
            3. Dissolved oxygen
            4. Pollutants
            5. Storm events
        v. The most critical aspect of extensive aquaculture is choosing a location that maintains these environmental conditions as close to optimum values for the species most of the time, outside of these ranges only infrequently, and rarely or never extreme enough to jeopardize the crop
            1. Protection from extreme storm events, such as the hurricanes which occur in Florida, is also important as an entire crop could be lost as well as the culture equipment

III. Ocean aquaculture—Fish culture
    a. Farming fish in floating cages has been applied to freshwater lakes, reservoirs, and ponds for decades, but in recent years, culture of marine fish in coastal bays and the open ocean (often called offshore aquaculture) has become very attractive
    b. Several reasons for the rapid development of ocean net-pen or cage culture
        i. The design, engineering, and materials for cages to withstand extreme sea conditions have greatly improved, in large part during the development of the offshore salmon farming industry in the turbulent and often stormy North Sea off Scandinavia

   ii. Increases in the size of net pens and fish stocking density required great volumes of water, and more importantly, significant water currents to dilute and disperse waste products and uneaten food
      1. Many coastal bays (and fjords in the early days of salmon farming) simply were too small, too shallow, and lacked currents, resulting in "self pollution" events — anoxic sediments below the cages that released toxic gases into the fish swimming above
   iii. Use conflicts in coastal waters have become more contentious over the years, often resulting in regulations that preclude marine fish cage culture
      1. Aesthetic issues were a primary concern — waterfront homeowners resisted working fish farms in view from their homes, forcing fish farms far enough offshore beyond the horizon line from the coast
   iv. As coastal areas become impacted by residential and commercial development the availability of abundant, high-quality water with appropriate chemical and physical characteristics is declining, while the demand for aquaculture species continues to grow
c. A critical component to net pen design is to maintain the volume and shape despite the effects of waves and currents, and despite their intrinsic differences in design and construction, the four classes of net pens achieve these goals
   i. Gravity pens
      1. Consist of a flexible net bag supported by a floating collar
      2. The shape and volume of the net bag are controlled by weights attached to the lower perimeter of the net
      3. Collars are usually round or rectangular
         a. Round net pens typically 15 – 30 m (49 – 98 ft) in diameter (@ 175 – 700 m^2 or 1,900 – 7,500 ft^2) and moored individually
         b. Rectangular net pens are as large as 30 m (98 ft) on a side (900 m^2 or 9,700 ft^2) and often moored together to form rafts
      4. The depth of the net bags range from 5 – 20 m (16 – 66 ft) depending on the requirements of the species in culture and the depth of the water beneath the pens
      5. Gravity pens are relatively low cost and easy to construct, often using flexible polyethylene
      6. Usually limited to more protected, low-current water because any increase in wave action or currents will require heavier weights to maintain the shape of the net

bag against horizontal flow, and an according increase in volume of the floating collar

ii. Anchor-tensioned pens
    1. Specifically designed for open-ocean, high-energy locations
    2. Unlike gravity pens that use a floatation collar, anchor-tensioned pens use fixed anchors (usually four vertical semi-submerged spar buoys) that form a rigid boxlike structure (the net bag has an attached cover to avoid the fish escaping during storm events – since the structure does not float)
    3. Advantages of these systems
        a. Line tensions tend to increase the resistance of the net bag to deformation proportional with current
        b. Hydrodynamic forces are evenly distributed along the perimeter of the net bag, reducing the risk of tearing
        c. Since there are no floating components the tensioned pens tend to submerge as current increases, reducing the risk of storm damage
    4. A major disadvantage of anchor-tensioned pens is that they are immobile
        a. They can't be towed to another location to facilitate harvesting and/or sorting or to avoid waterborne diseases or poor water quality
    5. Most damages to these systems are due to anchor movement during extreme storm events

iii. Semi-rigid pens
    1. Fully self-supported, unlike gravity pens and anchor-tensioned pens that require some external support structure to counteract currents and waves
    2. If you imagine a typical bicycle wheel, you have a vision of the semi-rigid pen
        a. A rigid steel rim (rim) is connected by equally tensioned cables (spokes) to a central, buoyant column (axle)
        b. All is enclosed with a taut net bag so that it can be fully submerged without losing fish (nice to have during a hurricane); this is accomplished by changing the buoyancy of the central column
    3. The volume of this style pen ranges from 1,000 – 20,000 m^3 (35,000 – 706,000 ft^3)
    4. Ideally suited for high current, exposed locations due to the following

            a. Internalized structure
            b. Lack of joints or articulations
            c. Resistance to net bag deformation
            d. Ability to be submerged during extreme storm events
        5. They also can be deployed from a single-point mooring that permits them to change position or automatically submerge in unusually high currents
        6. Disadvantages
            a. Slow in acceptance by the aquaculture industry due to its high initial cost for materials and construction
            b. Lack of a proven track record in the ocean environment (a situation that is rapidly changing)
    iv. Rigid pens
        1. Comprised of a system of jointed columns and beams that form a rigid boxlike or cylindrical structure to which the net bag is securely attached
            a. Characteristic that often results in the use of rigid wire rather than flexible synthetic materials (such as polyethylene or nylon mesh)
        2. Often use floatation buoys or collars, in some instances inflatable collars, that can move the structure up or down in the water column
        3. Highly resistant to current-induced net deformation, but usually steel frames are required because lighter-weight materials (e.g. polyethylene, PVC) cannot tend to bend under torsional forces encountered in high-energy conditions
        4. Disadvantages
            a. Although metal frame net pens utilizing metal mesh netting material are costly to build
            b. Sometimes susceptible to breakage in storm events
            c. Metal meshes (even those that are coated) are subject to corrosion in the marine environment
        5. They have proven useful in locations where predation from barracuda, sharks, and in particular marine mammals is problematic (e.g. Pacific northwest)
d. Mooring systems
    i. Purposes
        1. Hold the net pen in the appropriate position to maintain its structural integrity
        2. Allow for adequate water exchange
        3. Facilitate feeding and maintenance

ii. These systems include
   1. Anchors or dead weights
      a. Anchors types are dependent on bottom type and wind, wave, and current conditions
      b. Dead weights (large concrete blocks) work best in low-energy situation
      c. Embedded anchors (such as danforth anchors) are more effective in high-energy environments
   2. Lines, cables, or chains that connect them to the pens
      a. Usually chain is used close to the anchor to avoid abrasion, followed by nylon line to provide the elasticity necessary to absorb cyclic shock loads that occur at the surface
      b. Total length of the mooring line (or scope) is dependent on water depth, substrate composition, and the type of anchor used
   3. Floats or buoys that help compensate for tidal or sea state fluctuations

iii. A good mooring system absorbs shock loads and maintains the stability and structural integrity of the net pen during extreme weather conditions

iv. Two main types of mooring systems
   1. Single-point
      a. Can move to align themselves for least resistance to winds, waves, and currents
   2. Multi-point
      a. Most gravity pen systems use multi-point moorings if they are rectangular net pens rafted together or circular pens that rely upon opposing forces to maintain the shape of the floating collar

IV. Summary

a. Increasing demand for marine fish and a concomitant decline of appropriate coastal locations has stimulated the development of open ocean fish culture using net pens
b. Although ocean locations provide an abundance of high quality seawater, driven by currents to supply it and to remove pollutants, sea and weather conditions provide design engineering and operational challenges
c. New innovative pen designs, moorings, materials, and construction techniques are producing culture systems capable of withstanding the harsh conditions of the open ocean

Aquaculture PowerPoint Guidelines

In your group, prepare a PowerPoint presentation on your selected, and teacher approved, specific type of aquaculture. Research may be conducted online or in the school library. The presentation MUST follow the guideline below.

Slides 1: Title page (must include names, picture, and type of aquaculture)

Slides 2-4: Description of Species (including pictures)

Slides 5-6: Technology/Materials involved (Best Management Practices-BMPs)

Slides 7-8: Diseases/Issues

Slide 9: Economic importance

Slide 10: Ecological impact

Slide 11: Associated careers (and education)

Slide 12: Current news article

Slide 13: Recommendations you would make

Slide 14: Pictures