

Hatchery culture of bivalves

A practical manual



Cover photographs:

Clockwise from top left – fibreglass cylinders used for microalgae culture; interior of a small bivalve hatchery; raft nursery for bivalve spat; photomicrograph of *Crassostrea gigas* D-larvae (courtesy Michael M. Helm); a spawning female Manila clam (courtesy Brian Edwards).

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A practical manual

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Preparation of this document

This manual is part of the publications programme of the Fisheries Department Inland Water Resources and Aquaculture Service of the Food and Agriculture Organization of the United Nations. It is a synthesis of the current methodologies applicable to the intensive hatchery culture of bivalve molluscs covering similarities and differences in approach in rearing clams, oysters and scallops in different climatic regions. All aspects of the culture process are described, together with considerations in choosing a site for hatchery development and in the design of suitable facilities. The manual also includes the post-hatchery handling of “seed” bivalves in land- and sea-based nursery culture preparatory to on-growing. This publication is intended to assist both technicians entering this field as well as investors interested in evaluating the complexity of intensive hatchery production.

The authors bring together a combined 80 years of experience in the biology, management and operation of hatcheries encompassing a range of the more commonly cultured bivalve species in different parts of the world. Preparation of the manual has been under the overall coordination of Alessandro Lovatelli, Fishery Resources Officer (Aquaculture).

The authors wish to acknowledge the contributions of their many colleagues past and present and industry leaders, without which this publication would not have been possible.

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Abstract

Bivalve mollusc culture is an important and rapidly expanding area of world aquaculture production, representing approximately 20 percent of the sector's output at 14 million tonnes in 2000. The majority of production is from natural populations although increasingly stocks are approaching or have exceeded maximum sustainable yields. Stock enhancement through the capture and relaying of natural seed in both extensive and intensive forms of culture is common practice worldwide but the reliability of natural recruitment can never be guaranteed, and conflicts over the use of the coastal zone are becoming ever more pressing. A solution to meeting the seed requirements of the bivalve industry, applicable to the production of high unit value species such as clams, oysters and scallops, is hatchery culture. The production of seed through hatchery propagation accounts at the present time for only a small percentage of the total seed requirement but it is likely to become increasingly important as work continues to produce genetically-selected strains with desirable characteristics suited to particular conditions.

The advent of bivalve hatcheries was in Europe and the United States in the 1960s. Since those early pioneering days, knowledge of the biological requirements of the various species that predominate in worldwide aquaculture production and the technology used to produce them has grown and continues to improve. This manual brings together the current state of knowledge in describing the various aspects of hatchery culture and production from acquisition of broodstock to the stage at which the seed are of sufficient size to transfer to sea-based growout. Focus is on intensive methodology in purpose-built hatchery facilities rather than on more extensive methods of seed production in land-based pond systems. For a complete view, the intermediate nursery phase of production, which is the interface between the hatchery and sea-based growout, and the concept of remote setting are also described and discussed in some depth.

This manual is not intended as a scientific treatise on the subject. Rather, it provides the reader with a practical insight as to what is required in the way of resources and details of how to handle and manage the various life history stages of bivalves in the hatchery production cycle. Examples are largely drawn from the more commonly cultured temperate climate species including the Pacific oyster, *Crassostrea gigas*, the American (Eastern) oyster, *Crassostrea virginica*, the European flat oyster, *Ostrea edulis*, the Manila clam, *Tapes philippinarum* and a range of scallop species. Consideration is also given to the culture of tropical bivalves. Methods described are equally as applicable to bivalves of lesser significance in terms of worldwide production.

The authors recognize that bivalve hatchery production is as much an art founded on science as it is a science *per se*. There are as many ways of operating and managing a hatchery as there are hatcheries in terms of the sophistication of the facility and the precision with which each part of production is approached. In this respect, many experienced hatchery managers will consider much of the detailed information as "overkill." However, the authors have considered the need for a thorough grounding for new entrants in this field, not just how the various procedures are done but the biological basis of why they are done in that way. Thus, the content is equally as appropriate to the operation of a closely controlled experimental hatchery as it is to a commercial-scale hatchery.

In addition to explanations of culture technology and methodology, the manual includes a brief discussion of the processes of identifying a suitable site for locating a hatchery

and considerations in planning and designing the hatchery. It also includes advances that are likely to improve the reliability and economic viability of the hatchery industry in the near future, featuring topics such as polyploidy, the development of selected strains, cryopreservation of gametes and the need for novel, non-living foods.

Keywords: marine aquaculture, bivalve culture, bivalve hatcheries, bivalve nurseries, bivalve seed production, oysters, clams, scallops

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Glossary

| | |
|------------------------|---|
| Adductor muscle | large muscle (or muscles) that pull the two shell valves together |
| Algae | aquatic plants that reproduce by spores |
| Anterior | front or head |
| Auricle | with respect to scallops, the ear or wing-like projections at the hinge of a scallop (can also refer to the chamber of heart that receives blood from the body) |
| Axenic | culture of a single species in bacteria-free conditions |
| Biting | condition where shell margins of two scallops become interlocked, and subsequently damage the inner soft parts |
| Bivalve | mollusc of the Class Pelecypoda, having a shell of two valves that are joined by a hinge |
| Byssus | thread-like filaments used by bivalves to attach themselves to a substrate |
| Cilia | hair-like structures whose rhythmic beat induces a water current in bivalves |
| Ctenidia | leaf-like appendages that function in respiration and filtration of food from water (used interchangeably with the term gills) |
| Cultch | material used to collect bivalve spat |
| Demibranch | single plate or leaf of a bivalve gill |
| Detritus | fragmented or decomposing organic material from plant and animal remains |
| Diatom | a single-celled alga of the Class Bacillariophyceae; cells are enclosed in a siliceous shell called a frustule, cells can form chains |
| Dimyarian | bivalves with two adductor muscles, e.g. clams and mussels |
| Diocious | organisms in which male and female reproductive organs occur in different individuals |
| Diploid | the normal number of chromosomes (2n) in cells |
| Dorsal | the back or part of an organism away from the ground |
| Downwelling | in hatchery terminology, a growing system in which the flow of water enters at the top of a spat holding container (compare with upwelling) |
| D-larva | the early veliger larval stage of bivalves, also known as straight-hinge larva |
| Embryo | organism in early stages of development; in bivalves, prior to larval stage |
| Exhalant | area of bivalve where water currents have an outward direction |
| Exotic | introduced from foreign country or geographic area |
| Eyespot | simple organ that develops near centre of mature larvae of some bivalves and is sensitive to light |

| | |
|---------------------------------------|---|
| Fertilization | union of egg and sperm |
| Flagellate | group of single-celled algae characterized by having a locomotory organ called a flagellum |
| Frustule | siliceous shell-like covering of a diatom |
| Gamete | mature, haploid, functional sex cell capable of uniting with the alternate sex cell to form a zygote |
| Gametogenesis | process by which eggs and sperm are produced |
| Gill | a leaf-like appendage that functions in respiration and filtration of food from water (see ctenidia) |
| Growout | the process of growing seed produced in hatcheries to market size |
| Halocline | a zone of sharp vertical salinity change |
| Hinge | dorsal area of bivalve shell where two valves are joined together |
| HUFA | a highly unsaturated fatty acid, referred to also as polyunsaturated fatty acid (PUFA) |
| Indigenous | native, not imported |
| Inhalant | area of bivalve where water current have an inward direction |
| Larva | a stage of bivalves from the embryo to metamorphosis |
| Ligament | fibrous spring-like material joining two valves of a bivalve at the hinge |
| Mantle | the soft fold enclosing the body of a bivalve which secretes the shell |
| Mean | average |
| Meiotic Division | process in which normal number of chromosomes (2n) is reduced to the haploid (n) number |
| Metamorphosis | in bivalves, the period of transformation from the larval to the juvenile stage |
| Microalgae | small cell-size algae, either single celled or chain forming diatoms, cultured as foods for larvae and spat in a hatchery |
| Microlitre (μl) | one millionth of a litre or one thousandth of a ml |
| Micrometer (μm) | one millionth of a metre or one thousandth of a mm |
| Monoecious | organisms in which both male and female reproductive organs occur in the same individual |
| Monomyarian | bivalves with one adductor muscle, e.g. oysters and scallops |
| Natural Set | in bivalves, obtaining spat from spawning of natural populations |
| Pallial Line | faint circular line on inner surface of shell of bivalves showing location of attachment of mantle to shell |
| Palp | a sensory appendage near the mouth used to assist in moving food into the mouth |
| Pedal | pertaining to the foot |
| pH | a measure of acidity |
| Plankton | floating or weakly swimming aquatic organisms, can be phytoplankton (plants) or zooplankton (animals) |
| Planktotrophic | organisms that feed on phytoplankton |

| | |
|-----------------------------|--|
| Polar Body | minute cells released during meiotic division of the egg after the sperm has penetrated the egg; contains excess chromosomal material to produce a haploid egg |
| Polyplloid | animals having more than the usual number of diploid (2n) chromosomes |
| Posterior | the rear, away from the head |
| Pronuclei | in the egg, the haploid nucleus after completion of meiosis but before infusion with the sperm nucleus |
| Pseudofaeces | false faeces, waste material not taken into the digestive tract |
| PSU | a measure of salinity, equivalent to parts per thousand |
| Resilium | internal portion of the ligament located centrally along the hinge of a bivalve; causes the valves to open when the adductor relaxes |
| Salinity | the salt content of seawater usually measured in parts per thousand (ppt) or practical salinity units (PSU) |
| Seed | a hatchery term for spat of a size ready for sale |
| Settlement | behaviourial process when mature bivalve larvae seek a suitable substrate for attachment |
| Shell Height | the straight line distance measured perpendicularly from the umbo to the ventral margin of the shell |
| Shell Length | the straight line distance from the anterior to the posterior margins of the shell |
| Spat | a newly settled or attached bivalve (also termed post larval or juvenile in bivalves) |
| Straight-hinge larva | early part of larval stage, sometimes termed D-stage |
| Tentacle | long, unsegmented threadlike protuberance from edge of mantle that has specialized sensory function |
| Tetraploid | polyploid animal with twice the normal complement of chromosomes (4n) |
| Thermocline | a zone of sharp vertical temperature change |
| Triploid | a polyploid animal with an extra set of chromosomes (3n) |
| Trochophore | planktonic stage of bivalve embryo |
| Umbo | beak-like projections at the dorsal part of the shell; it is the oldest part of a bivalve shell (also called the umbone) |
| Upwelling | in hatchery terminology, a growing system in which a flow of water is induced through the base of a spat holding container (compare with downwelling). |
| Urogenital System | system with organs concerned with excretion (kidney) and reproduction (gonad) |
| Valve | one of the two parts of a bivalve shell, two valves make up one shell |
| Veliger Larva | the larval stage of most molluscs, characterized by the presence of a velum |
| Velum | ciliated locomotory organ of the larva |
| Ventral | pertaining to the under or lower side of an animal |
| Zygote | diploid (2n) cell resulting from union of male and female gametes |

Abbreviations, acronyms and conversions

| | |
|---------------|---|
| BBSR | Bermuda Biological Station for Research |
| DHA | Docosahexaenoic Acid |
| DOPA | Dihydroxyphenylalanine |
| EDTA | Ethylene Diamine Tetraacetic Acid |
| EPA | Eicosapentaenoic Acid |
| FAO | Food and Agriculture Organization of the United Nations |
| FLUPSY | Floating Upwelling System |
| FSW | Filtered Seawater |
| GI | Growth Index |
| GRP | Glass-Reinforced Plastic |
| HUFA | Highly Unsaturated Fatty Acid |
| LDR | Light Dependent Resistor |
| MAFF | Ministry of Agriculture Food and Fisheries |
| NTM | Net Treatment Mortality |
| PHCD | Post-Harvest Cell Density |
| PUFA | Polyunsaturated Fatty Acid |
| PVC | Polyvinyl Chloride |
| RSR | Resistance Sensing Relay |
| SI | Système International |
| TBT | Tributyltin |
| TCBS | Thiosulfate Citrate Bile Sucrose |
| UV | Ultra-Violet |

Not all of the following abbreviations have been used in this manual. However, they are provided as reference when reading other documents.

| | |
|-----------------------|---|
| < | less than |
| > | greater than |
| n.a. | not analysed or not available (also written as N/A) |
| µm | micron |
| mm | millimetre |
| cm | centimetre |
| m | metre |
| km | kilometre |
| inch | inch |
| ft | foot |
| yd | yard |
| mi | mile |
| ft² | square foot |
| yd² | square yard |
| mi² | square mile |
| m² | square metre |
| ha | hectare |
| km² | square kilometre |
| cc | cubic centimetre (= ml) |
| m³ | cubic metre |

| | |
|-----------------|--|
| ft ³ | cubic foot |
| yd ³ | cubic yard |
| µl | microlitre |
| ml | millilitre (= cc) |
| l | litre |
| µg | microgram |
| mg | milligram (milligramme) |
| g | gram (gramme) |
| kg | kilogram (kilogramme) |
| mt | metric tonne (1 000 kg) (also written as tonne) |
| oz | ounce |
| lb | pound |
| cwt | hundredweight [value differs in UK ('Imperial') and US units - see weight conversions] |
| t | ton [value differs in UK ('Imperial') and US units - see weight conversions] |
| psi | pounds per square inch |
| psu | practical salinity units |
| gpm | ('Imperial' = UK) gallons per minute |
| mgd | million ('Imperial' = UK) gallons per day |
| cfm | cubic feet per minute |
| ppt | parts per thousand (also written as ‰) |
| ppm | parts per million |
| ppb | parts per billion (thousand million) |
| min | minute |
| hr | hour |
| kWhr | kilowatt-hour |

Conversions

This section of the annex should be used in conjunction with the abbreviations section. Please note that the words gallon and tonne have different values depending on whether the source of the text you are reading is 'British' or 'American' in origin.

Length:

| | |
|--------|--|
| 1 µm | 0.001 mm = 0.000001 m |
| 1 mm | 0.001 m = 1 000 µm = 0.0394 inch |
| 1 cm | 0.01 m = 10 mm = 0.394 inch |
| 1 m | 1 000 000 µm = 1 000 mm = 100 cm = 0.001 km = 39.4 inch = 3.28 ft = 1.093 yd |
| 1 km | 1 000 m = 1 093 yd = 0.621 mi |
| 1 inch | 25.38 mm = 2.54 cm |
| 1 ft | 12 inch = 0.305 m |
| 1 yd | 3 ft = 0.914 m |
| 1 mi | 1 760 yd = 1.609 km |

Weight:

| | |
|------|---|
| 1 µg | 0.001 mg = 0.000001 g |
| 1 mg | 0.001 g = 1 000 µg |
| 1 g | 1 000 000 µg = 1 000 mg = 0.001 kg = 0.0353 oz |
| 1 kg | 1 000 g = 2.205 lb |
| 1 mt | 1 000 kg = 1 000 000 g = 0.9842 UK t = 1.102 US t |
| 1 oz | 28.349 g |
| 1 lb | 16 oz = 453.59 g |

| | |
|----------|----------------------|
| 1 UK cwt | 112 lb = 50.80 kg |
| 1 US cwt | 100 lb = 45.36 kg |
| 1 UK t | 20 UK cwt = 2 240 lb |
| 1 US t | 20 US cwt = 2 000 lb |
| 1 UK t | 1.016 mt = 1.12 US t |

Volume:

| | |
|-------------------|--|
| 1 μ l | 0.001 ml = 0.000001 l |
| 1 ml | 0.001 l = 1 000 μ l = 1 cc |
| 1 L | 1 000 000 μ l = 1 000 ml = 0.220 UK gallon = 0.264 US gallon |
| 1 m ³ | 1 000 l = 35.315 ft ³ = 1.308 yd ³ = 219.97 UK gallons = 264.16 US gallons |
| 1 ft ³ | 0.02832 m ³ = 6.229 UK gallons = 28.316 l |
| 1 UK gallon | 4.546 l = 1.2009 US gallons |
| 1 US gallon | 3.785 l = 0.833 UK gallon |
| 1 MGD | 694.44 GPM = 3.157 m ³ /min = 3 157 l/min |

Concentration - dissolving solids in liquids:

| | |
|-------|---|
| 1 % | 1 g in 100 ml |
| 1 ppt | 1 g in 1 000 ml = 1 g in 1 l = 1 g/l = 0.1% |
| 1 ppm | 1 g in 1 000 000 ml = 1 g in 1 000 L = 1 mg/l = 1 μ g/g |
| 1 ppb | 1 g in 1 000 000 000 ml = 1 g in 1 000 000 l = 0.001 ppm = 0.001 mg/l |

Concentration - dilution of liquids in liquids:

| | |
|-------|---|
| 1 % | 1 ml in 100 ml |
| 1 ppt | 1 ml in 1 000 ml = 1 ml in 1 l = 1 ml/l = 0.1% |
| 1 ppm | 1 ml in 1 000 000 ml = 1 ml in 1 000 l = 1 μ l/l |
| 1 ppb | 1 ml in 1 000 000 000 ml = 1 ml in 1 000 000 l = 0.001 ppm = 0.001 ml/l |

Area:

| | |
|-------------------|--|
| 1 m ² | 10.764 ft ² = 1.196 yd ² |
| 1 ha | 10 000 m ² = 100 ares = 2.471 acres |
| 1 km ² | 100 ha = 0.386 mi ² |
| 1 ft ² | 0.0929 m ² |
| 1 yd ² | 9 ft ² = 0.836 m ² |
| 1 acre | 4 840 yd ² = 0.405 ha |
| 1 mi ² | 640 acres = 2.59 km ² |

Temperature:

| | |
|--------------|---|
| $^{\circ}$ F | $(9 \div 5 \times ^{\circ}\text{C}) + 32$ |
| $^{\circ}$ C | $(^{\circ}\text{F} - 32) \times 5 \div 9$ |

Pressure:

| | |
|-------|--------------------------|
| 1 psi | 70.307 g/cm ² |
|-------|--------------------------|

Scientific units

Scientists have a different way of writing some of the units described in this glossary. They use what is called the Système International (SI). The units are referred to as SI units. For example: 1 ppt, which can be written as 1 g/l (see concentration above) is written as 1 g l⁻¹ in scientific journals. 1 g/kg is written as 1 g kg⁻¹. 12 mg/kg would be written as 12 mg kg⁻¹. 95 μ g/kg would be written as 95 μ g kg⁻¹. A stocking density of 11 kg/m³ would be written as 11 kg m⁻³. This system of standardization is not normally used in commercial aquaculture hatcheries and growout units and has therefore not been used in this manual. More information about this topic can be found on the internet by searching for SI Units.

