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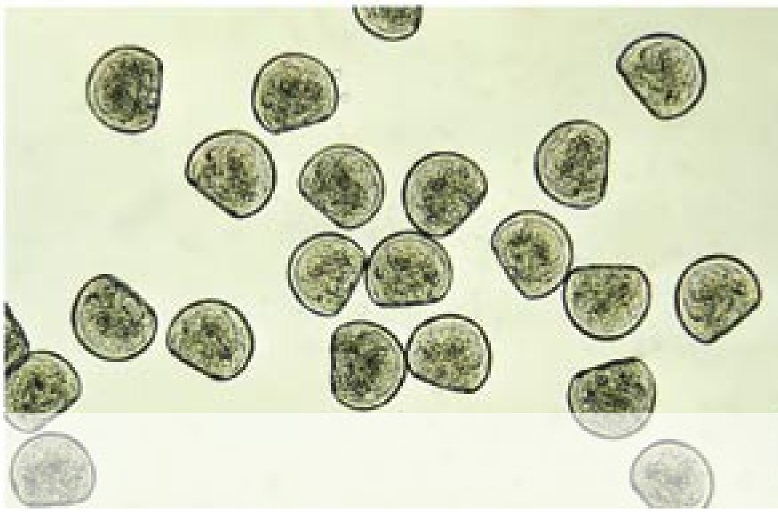
Hatchery culture of bivalves

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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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.

Unless otherwise acknowledged, all photographs were taken by the authors.

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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
Dioecious	organisms in which male and females 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 ctendia)
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
Polyploid	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
ft^2	square foot
yd^2	square yard
mi^2	square mile
m^2	square metre
ha	hectare
km^2	square kilometre
cc	cubic centimetre (= ml)
m^3	cubic metre

ft³	cubic foot
yd³	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 µl	0.001 ml = 0.000001 l
1 ml	0.001 l = 1 000 µl = 1 cc
1 L	1 000 000 µl = 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 µg/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 µl/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:

°F	(9 ÷ 5 x °C) + 32
°C	(°F - 32) x 5 ÷ 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 µg/kg would be written as 95 µg kg^{-1}. A stocking density of 11 kg/m^3 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.