The Pearl Oyster

Paul C. Southgate
John S. Lucas
INDEX

A
Absorption
of dissolved organic matter (DOM), 104, 107
efficiency, 114, 117, 119–121
Adductor muscle see also Musculature
in gametogenesis, 152, 153, 154
Aerial exposure
tolerance, 213–214, 544
Akoya pearl oyster
distribution, 51, 52–54
exploitation history, 304
genetic structuring, 52–54, 442–444
habitat, 52, 105–106
shell morphology, 42, 43–45
soft anatomy, 45–51
taxonomic status, 52–54
Akoya pearl oyster farming
China, 307–308, 310–311, 313
India, 308–309
Japan, 310, 312–313
Vietnam, 309
Akoya pearl oyster fisheries
Central America, 31
Indian Ocean, 12–13, 19, 20
Indian/Pacific Ocean, 22–23
Pacific Ocean, 27
Anaerobic metabolism
in low dissolved oxygen, 209
Antibiotics
accumulation, 512
use during nucleation, 229, 513
use in hatcheries, 513
Anoxia
recovery from, 214
tolerance of, 207–209
Bead insertion see Nucleation
Biodeposition and sedimentation
environmental impacts, 508–510, 516–517
rates, 112, 510
Biofouling
adverse effects, 209, 265–266, 489, 535–539
and shell size, 535
by other bivalves, 529, 536
organisms involved, 529, 530
Biofouling control
biocide coatings, 545–547
biological, 545
cleaning frequency, 543
manual methods, 266, 511, 516, 539–545
natural defences, 539
Biofouling effects
biological competition for resources, 530, 537
environmental modification, 537–538
increased friction and drag on equipment, 538–539
mechanical interference with shell function, 530,
535–537
physical damage, 530–535
Black-lip pearl oyster see Pinctada margaritifera
Blister pearls
cultured (mabe), 280, 298, 325
Blistering
as adverse condition, 533–534
formation, 276, 277, 533
Blood vessels see Circulatory system
Boring organisms
adverse impacts, 530–535
micro-organisms, 530
mudworm (Polychaeta spp.), 211–212, 312, 531, 532–533
sponges (Clionidae spp., etc.), 531–532, 534
mudworms, 202, 544
Broodstock
conditioning, 160–161, 235–236, 286
spawning, 503
spawning induction, 236–238
strip spawning, 239
Byssus and byssal gland
anatomy, 39, 40, 47, 86, 87
bacterial infection, 387
C
Chaplets
  farming method, 262, 263
Ciona spp. see boring organisms
Circulatory system
  anatomy, 49, 88
  functioning, 49
  pathology, 384–385, 402
Clearance rate (CR), effects of
  food quality, 190–193
  and particle concentration, 113, 114
  pearl oyster size, 110, 124–126
  temperature, 193–196
Clearance rates (CRs)
  compared with other bivalves, 109, 126
Conchiolin
  and shell disease, 369–370, 374, 419
  composition, 91–92
  in blister formation, 533
  in pearl formation, 274, 276, 388
  in pearl structure, 277–279
  in periostracum, 91–92
Ctenidia see Gills
Culture methods see Farming methods and Nursery culture
Currents
  effects, 210–211
D
Depth
  and spatfall, 213
  related effects on growth and survival, 211–213
Diatoms
  as food, 115, 189–190, 217
  blooms, 104, 190, 217
  for culturing larvæ, 244, 245, 246
  nanoplankton component, 103, 105
Digestive gland (diverticula) see also Digestive system
role in gametogenesis, 136, 137, 153–156
  pathology, 380–384
Digestive system
  anatomy, 48–49, 82–85, 117–119
  functioning, 114, 117–121
  pathology, 380–384, 397, 406, 415
Dinoflagellate blooms see Mass mortalities
Diseases
  clinical signs, 368–370
  bacterial, 400–405
  cestode, 377, 379, 412–415
  crustacean, 415–416
  ‘double-back’ shell, 369
  nematode, 411
  of uncertain cause, 417–423
  protozoal, 405–411
  red adductor muscle, 200
  trematode, 411–412
  tumours, 417
  viral, 394–400
Dissolved organic matter (DOM)
  as food source, 104, 107
Diving
  free, 13–14, 340–341
  ‘hard hat’, 316–318, 341
DNA (anDNA, cDNA, mtDNA, rDNA) and microsatellites
  in population genetic studies, 438–448, 558–559
E
Ear-hanging
  farming method, 262, 263
Ecological modelling
  of farm environments, 218–221
Economic modelling
  for Pacific islands, 481–484
Economics of scale
  bipolar nature of industry, 488, 493
  farm size, 477–478, 479–480, 482, 490
  large producers, 488–489, 489
  small producers, 492, 493–494
Egg
  incubation, 240–241
Electroma
  current standing of genus, 38–39
  habitats of species, 41, 63
  phylogeny, 63, 65
Embryos
  development, 161–163
Excretory system
  anatomy, 49–50, 89
  functioning, 122–124
Extrapallial space
  mantle-shell morphology, 90, 92
F
Farming intensity see Stocking density
Farming methods
  ear-hanging, 262, 263
  for juveniles, 262–264, 310
  longlines, 258–260, 311, 511, 515
  nets, box, panel (pocket) and pearl, 260–262
  racks, trestles, fence-lines, 260, 517
  rafts (pontoons), 257–258, 259
Fecal pollution see also Biodeposition and sedimentation
  effects of, 216, 508–510
Feces
  defecation rate, 114, 120–121
  expulsion, 109
Index

Feeding mechanisms
- morphology and functioning, 106–117
- capture efficiency, 111–112
Filter feeding see Clearance rate and Feeding mechanisms
Fisheries
- Central America, 31–35
- Indian Ocean, 11–21
- Indian/Pacific Ocean, 21–24, 313–321
- Pacific Ocean, 27–31
- Southeast Asia, 22, 24–27
Flagellates
- in nanoplankton, 103
- food for larval culture, 174, 245
- nutritional value, 119, 190–192
Food sources
- field, 103–106, 188–189, 218
- in culture see Micro-algae
Foot
- anatomy, 47, 86, 87
- pathology, 387–388
Fossil record
- outline, 64–65
Fouling see Biofouling
Freshwater pearls
- market impacts, 555–557
- production data, 360–361, 485, 486, 494, 556
- production methods, 283, 361, 556
G
Gametogenesis
- energetics of, 149–150, 157–158
- non-germinal (auxiliary) cells, 139, 140
- nourishment, 139, 151–156
- oogenesis, 145–146
- sex reversal, 139, 141–142
- spermatogenesis, 146–147
- stages, 137–138, 147–149
Gametes
- cryopreservation, 240
- fertilisation, 239
Genetic diversity see also Selective breeding
- impact of culture, 446–448, 502–504
- impact of translocations, 448
Geneic structuring see topic within each species
Genome mapping
- potential, 462–463
Gilis (ctenidia)
- anatomy, 47–48, 81–82, 108
- particle capture, 109, 111–112
- pathology, 375–376
- symbionts, 376
- ventilation rate, 207–208
Gold-lip pearl oyster see P. maxima
Gonads see also Reproductive system
- pathology, 388
Gonoducts
- anatomy and functioning, 85, 136, 145, 146
Grading see Pearl quality
Grafting see Nucleation
Growth
- measurement, 167–169
- modelling, 169–172
- morphometrics, 173
- von Bertalanffy parameters, 171
Growth rate, effects of
- farm site, 175–176
- food, 173–174, 188–193
- temperature, 188, 197–198
- salinity, 175, 205–206
H
Habits
- of pearl oysters, 41
Handicrafts see Pearl handicrafts
Hatchery rearing technology see also Larval culture
- embryos and larvae, 239–254, 310–311
- hygiene, 372, 513
- settlement, 249–254
- spat, 254–256
Heart see Circulatory system
Heavy metals
- affecting growth, 215
- biosequestration, 215, 512, 559–560
- in anti-fouling, 540, 546–547
- monitoring, 512, 560
Heritability
- of commercial traits, 449–451
Hermaphroditism
- occurrence, 139, 141–142
Heterocapsa circulariasquama see also Mass mortalities
- toxicity, 392–393
I
Immunity
- cellular, 371
- humoral, 371
- wound healing, 370–371
In vitro culture of pearls
- preliminary studies, 557–559
Indigenous communities see also Pearl handicrafts
- involvement, 478, 514–515
Inbreeding see Selective breeding
Ingestion
- pre-ingestive sorting, 113, 105
- process, 107, 117
- rate, 108, 114–115, 120
Interstitial tissue
inflammation, 388

Intestine see also Digestive system
anatomy, 48, 79, 83–84
pathology, 384
typhlosole, 56, 83

J
Jewelry
historic, 5–7, 8–10, 15
value adding to local pearl production, 479, 480, 481
world markets, 485

K
Kidney see Excretory system

L
Labial palps see also Digestive system
anatomy, 47, 114–116
pathology, 376–377, 398

Larvae see also Embryos and Hatchery rearing technology
development and growth, 163, 165–167, 250, 251
diseases, 372, 400
energetics, 167, 177
food and nutrition, 243–248
mortality, 372
salinity ranges, 203
temperature ranges, 199
Life-cycle
generalised scheme, 250

Longlines
technology, 258–260, 311
and marine mammals, 506–508

M
Mabe (composite) pearls
production, 281–283

Management of industries
Pinctada margaritifera, 476–478, 488–489
Pinctada maxima, 319–321

Mantle
anatomy, 45–46, 80–81, 90–91
natural pearl formation, 273–277
pathology, 372–375
shell secretion, 90–93, 97

Marine mammals see Longlines

Marketing:
Akoya pearls, 359–360
black South Sea pearls, 334–335, 358–359
brand recognition, 361, 487
consumer market, 361–362
international organisation, 362, 363, 554
white/gold South Sea pearls, 326–328, 359

Markets for pearls
current, 355–356, 485, 553–554
future developments, 362–363
global share, 485
late entrants into, 488, 554

Mass mortalities of Akoya pearl oysters in Japan
cyanobacterium blooms, 394
diatom blooms, 190, 217
dinoflagellate blooms (red tides), 391–392
occurrences, 187–188, 211–212, 216–217, 312–313,
417–418
viral disease, 394–396, 417–418

Mass mortalities of Pinctada margaritifera
Cook Islands, 333, 422, 489
French Polynesia, 406, 418–419, 489
Red Sea, 419–420

Mass mortalities of Pinctada maxima
northern Australia, 420–423

Metabolic rate
and Scope for Growth, 121–124

Metamorphosis
energetics, 167, 177

Microalgae
culture, 244
nutritional value, 189–190, 243–246, 254–257
substitutes, 248
toxic, 216–217, 312, 380, 392

Mikimoto, Kokichi
cultured pearl industry pioneer, 284–286

Mother-of-Pearl (MOP)
fisheries see within Species
structure see Nacre

Mouth see also Digestive system
anatomy, 46, 48, 79, 82, 83, 85
pathology, 378–379

Mud worm see Boring organisms

Muscle scars
on inner shell surface, 55

Musculature
accessory pedo-bysal retractors, 47
adductor, 39, 40, 45, 78, 86
general, 86
gill, 81
levators, 79, 86
pathology, 385–386, 396
pedo-bysal retractors, 39, 40, 47, 85, 86, 87
radial pallial retractors, 47, 80, 90

Nacre
biomedical applications, 560–561
fine structure, 92–95, 279
formation, 95–98, 277–279, 558–559
Index

matrix proteins, 558–559
thickness in mabe, 282
thickness in spherical pearls, 308, 327, 336
Natural pearls
final era of dominance, 9–10
formation, 273–277
Nervous system
anatomy, 50, 89
Nucleation operation
origins of technique, 284–286
pearl nucleus (head) source and manufacture, 286–288
pearl nucleus implantation, 288–291, 513–514
post-operation survival and care, 266–267, 291–292, 369–390, 402
pre-operation conditioning, 286–287
saibo (mantle) donor, 288–290, 452–454
Nursery (spat/small juvenile) culture
in field, 262–264, 310
in hatchery, 254–257
Nutritional requirements
adults, 188–189
larvae, 243–245, 248
O
Oil spills
adverse effects, 215–216, 421
Oogenesis see also Gametogenesis
process, 145–146
Osmoconforming condition, 201
Oxygen consumption see Respiration rate
Over-exploitation, 13, 26, 30–31, 32, 303, 329, 339, 340, 349
Over-fishing see Over-exploitation
Oxygen partial pressure (PO2) and dissolved oxygen (DO)
influencing ventilation rate, 207–208
influencing % oxygen uptake, 206–208
P
Pallial organ
structure and function, 107–108, 113
Pallial zone
of mantle, 45, 80, 90–91
Panamanian or Calafia pearl oyster see Pinctada maxima
Panel (pocket) nets
farming method, 261, 262
Parasites see also Diseases
various, 412–415, 418–419, 422–423
Pearl
chemical composition, 279–280
formation, 273–277
in vitro culture, 557–559
layers, 277–279
nacre see Nacre
physical properties, 280
Pearl handicrafts
income generation, 479, 484
Pearl harvest
techniques, 293
Pearl nets
farming method, 261
'Pearl pocket' see Pearl sac
Pearl production and trade
country share of exports, 486
country share of pearl jewelry market, 485
country share of production, 485, 554–555
Global statistics, 484–487
Pearl quality
control of, 335–336, 357, 488
criteria, 293–295
enhancement, 296–297
grading, 293–294, 309
Pearl quality, factors effecting
environment, 175, 220–221
genetics, 449
growth rate, 296
husbandry, 296
infections, 388–389, 396, 412
saibo donor, 295
surgical technique, 295, 388–389
Pearl value
grading, 293–294, 309
unit value of Australian exports, 323
vs demand, 476–477, 491–492
vs supply, 323, 477, 491
Pearl yield
effects of boring organisms, 527, 529, 531
Pearl sac
pathology, 388–390
Pearls in history
Antiquity, 1–3, 11
Medieval times, 3–5
the early modern ages, 5–6
the modern ages, 8–10
Pediveliger larvae see also Larvae
anatomy and behaviour, 164, 177, 465
Perlostracan
formation and composition, 90–92
role in fouling protection, 539
Phylogeny
Pterioidea, 63–65
species-level, 53, 63–64
Phytoplankton see Food sources and Micro-algae
Pinctada
generic description, 40, 46
soft anatomy, 46
species-level relationships, 53, 64
Pinctada albina
Neighbour-joining tree, 53
proposed evolution, 64
Pinctada cumingii
status, 57
Pinctada fucata see Akoya pearl oyster
Pinctada galissofi
status, 57
Pinctada imbricata see Akoya pearl oyster
Pinctada maculata
as a pest, 111, 427
'Pipi pearls', 31
Neighbour-joining tree, 53
trial culture, 332
Pinctada margaritifera
distribution, 56
exports, 477
genetic structuring, 439-442
habitat, 56-57, 105-106
industry structure in French Polynesia, 477-478
shell morphology, 42, 54-55
soft anatomy, 55-56, 78-89
translocations, 442, 501-502
Pinctada margaritifera pearl production
French Polynesia, 328-332
Japan, 328
production trends, 328-338, 358-359, 476-477
Pinctada margaritifera fisheries
French Polynesia, 328-329
Indian Ocean, 13, 15, 16
Southeast Asia, 26
Pacific Ocean, 27, 30
Pinctada martensii see Akoya pearl oyster
Pinctada maxima
distribution, 56-59
habitat, 59, 105-106
shell morphology, 42, 57-58
soft anatomy, 58
Pinctada maxima fisheries
Australia, 23-24, 314-321
Indonesia, 25-26
Myanmar, 24-25
Philippines, 25
Pinctada maxima pearl production
Australia, 321-324, 474-476
general, 314, 326
Indonesia, 324-325
Philippines, 325-326
Pinctada mazatlallica
distribution, 56, 60-61
genetic structuring, 444-446
historical farming, 34-35, 342-344
pearls, 31
shell morphology, 42, 60
soft anatomy, 60
Pinctada mazatlallica fisheries
Colombia and Venezuela, 32-33
Mexico, 34, 338-342
Panama, 33-34
Pinctada nigra see Pinctada albina
Pinctada radiata see Akoya pearl oyster
Pinctada sugillata see Pinctada albina sugillata
Plantigrade see also Larvae
anatomy, 164, 165, 250
Pollution
and morbidity, 417, 418, 421
sources and effects, 215-216, 559
from pearl oyster farms, 516
Prismatic (ostracum) layer
formation, 92-93
structure, 90, 91
Polyculture of pearl oysters
with red alga, 538
with sea urchin, 545
Polydora spp. see Boring organisms
Predation
on spat and juveniles, 257, 423
protective measures, 423
Predators
crustaceans, 426, 427, 428
fishes, sharks, rays, 424, 426
flatworms, 426, 427
gastropods, 425-427
octopus, 427
Pseudoaeces
production, 108-109, 114-115, 116-117
Pterelectroma
habitat of Pt. zebra, 41
taxonomic status, 38
Pteria
generic description, 39-40, 46
Pteria colymbus
potential for pearl culture, 345, 349
Pteria penguin
culture, 347-348, 517
distribution, 60-61, 62
habitat, 62
pearl production trends, 345-347, 347-348
shell morphology, 42, 61-62
soft anatomy, 46 (c.f. Fig. 2.3B)
Index

Pteria sterna
   culture and pearl production trends, 346, 348–349
distribution, 62–63
Pteriidae
   genera, 38
   habitats of species, 41
   species and distribution, 37–38
   taxonomic studies, 37–38, 39, 63
   unnatural taxon, 63
Pterioidae
crown-group, 63
phylogeny, 65
taxonomic position, 38

Q
QIO
   of metabolic functions, 195–197
Quotas
   Australia, 475–476
   French Polynesia, 477

R
Rafts
   farming methods, 257–259
‘Red arse’ see Boring organisms, sponges
Red tides see Mass mortalities of Akoya pearl oysters
Reproduction
   energetics, 149–156, 157–158
   gonad stages, 137–138, 147–149
   neuroendocrine control, 158, 160
   strategies, 156–157
Reproductive system see also Gametogenesis and Sex
   acini, 135
   gonads, 50–51, 84–85, 135–140
   gonoducts, 85, 136
   pathology, 388
   sexual maturity, 132–134
   Respiration rate
   and metabolic rate, 121–122
   and QIO, 196
Rickettsia
   infections, 403–405
Risk Assessment
   modelling, 482–484
RNA (rRNA)
   in population genetic studies, 52–53, 444, 559

S
Saibo see also Nucleation
   selection studies, 452–453
   tissue, 288–290
Salinity
   effects, 205–206, 212
tolerances, 202–205
Saville-Kent, W.
   pioneer pearl production, 285
Scope for Growth (SPG)
calculation, 124–126, 149, 219–220
   negative, 125, 197
   relative to size, 125
Sedimentation see Biodeposition and Sedimentation
Seeding operation see Nucleation
Selective breeding
   and pearl weight, 453–454
   for shell traits, 450–453
   inbreeding from, 454–456
   pedigree identification, 460–461
Sensory receptors
   anatomy, 50
Seston see Suspended particulate matter
Settlement and metamorphosis
   processes, 165–167, 213, 249–254
Sex
   differentiation and reversal, 139–142
   ratios, 142–143
Shell see also Genus and Species
descriptions
   general morphology, 42, 44
Shell layers
   morphology, 90
   secretion, 91–92, 95–98
Shell abnormalities
   disease, 374–375
   disrupted secretion of layers, 369, 370, 375, 419
   fouling and boring organisms, 529–535
Silver-lip pearl oyster see Pinctada maxima
Socio-economics
   benefits for rural communities, 478–484, 517–518
Soft anatomy
   general figures, 46
see also Genus and Species
descriptions
South Sea cultured pearls
   Black see Pinctada margaritifera pearl production
   White/Golden see Pinctada maxima pearl production
Spat
   collectors, 232–235, 310
   morphology, 165–166
   spatfall and depth, 213
   genetic impact, 448
Spawning see also Broodstock
   process, 143–144, 161
Spermatogenesis see also Gametogenesis
   process, 145–146
Sponges see Boring organisms
Starvation
effects of, 193

Stomach see also Digestive system
anatomy, 48, 83
pathology, 379

Stock for farms
sources, 231–234
Stocking density
and biodeposition, 509
comparative, 509
high-density (intensive), 489, 518, 519

Suspended particulate matter (SPM)
and feeding, 114
and food uptake, 190–193
composition, 103–106, 190

T
Tahitian pearls see Pinctada margaritifera pearl production
Temperature optima
and metabolic rate, 193–196
Temperature affects on
broodstock conditioning, 236
clearance rate, 194
growth rate, 188, 197–198
health, 390–391
metabolic rate, 194–197
reproductive periodicity, 160–161
survival, 189, 198–200

Tetraploids
induction, 457

Translocations
 genetic effects, 442, 500–502
history, 501
spreading disease, parasites and pests, 504–505

Triploids
growth, 458–459
maturation, 458
production, 456–457

Tochophore larvae see Larvae

Turbidity
effects of, 214–215
from cleaning biofouling, 516–517

V
Vascular system see Circulatory system
Veliger larvae see Larvae
Vibrio spp. see also Diseases
infections, 400–402
Vives, Gaston
pioneer culturist, 342–343
von Bertalanffy Growth Functions
fitted, 169–171

Water currents
effects, 210–211
Winged pearl oyster see Pteria spp.
Index

Pteria sterna
  culture and pearl production trends, 346, 348–349
distribution, 62–63
Pterididae
  genera, 38
  habitats of species, 41
  species and distribution, 37–38
  taxonomic studies, 37–38, 39, 63
  unnatural taxon, 63
Pteriodoea
  crown-group, 63
  phylogeny, 65
  taxonomic position, 38
Pterioidea
  crown-group, 63
  phylogeny, 65
  taxonomic position, 38
Q
  Q_{10} of metabolic functions, 195–197
Quotas
  Australia, 475–476
  French Polynesia, 477
R
  Rafts
    farming methods, 257–259
  ‘Red arse’ see Boring organisms, sponges
Red tides see Mass mortalities of Akoya pearl oysters
Reproduction
  energetics, 149–156, 157–158
  gonad stages, 137–138, 147–149
  neuroendocrine control, 158, 160
  strategies, 156–157
Reproductive system see also Gametogenesis and Sex
  acini, 135
  gonads, 50–51, 84–85, 135–140
  gonoducts, 85, 136
  pathology, 388
  sexual maturity, 132–134
  Respiration rate
    and metabolic rate, 121–122
    and Q_{10}, 196
Rickettsia
  infections, 403–405
Risk Assessment
  modelling, 482–484
RNA (rRNA)
  in population genetic studies, 52–53, 444, 559
S
  Saibo see also Nucleation
    selection studies, 452–453
    tissue, 288–290
  Salinity
    effects, 205–206, 212
    tolerances, 202–205
  Saville-Kent, W.
    pioneer pearl production, 285
Scope for Growth (SPG)
  calculation, 124–126, 149, 219–220
  negative, 125, 197
  relative to size, 125
Sedimentation see Biodeposition and Sedimentation
Seeding operation see Nucleation
Selective breeding
  and pearl weight, 453–454
  for shell traits, 450–453
  inbreeding from, 454–456
  pedigree identification, 460–461
Sensory receptors
  anatomy, 50
  Seston see Suspended particulate matter
Settlement and metamorphosis processes, 165–167, 213, 249–254
Sex
  differentiation and reversal, 139–142
  ratios, 142–143
  Shell see also Genus and Species descriptions
    general morphology, 42, 44
Shell layers
  morphology, 90
  secretion, 91–92, 95–98
Shell abnormalities
  disease, 374–375
  disrupted secretion of layers, 369, 370, 375, 419
  fouling and boring organisms, 529–535
Silver-lip pearl oyster see Pinctada maxima
Socio-economics
  benefits for rural communities, 478–484, 517–518
Soft anatomy
  general figures, 46
  see also Genus and Species descriptions
South Sea cultured pearls
  Black see Pinctada margaritifera pearl production
  White/Golden see Pinctada maxima pearl production
Spat
  collectors, 232–235, 310
  morphology, 165–166
  spatfall and depth, 213
  genetic impact, 448
Spawning see also Broodstock
  process, 143–144, 161
Spermatogenesis see also Gametogenesis
  process, 145–146
Sponges see Boring organisms