Subject Index

Note: Page numbers in italics denote tables and figures (when outside page ranges).

abbreviations and acronyms xxi–xxiv
age at maturity
  fisheries impact 365–8, 372
  life-history variables 325
  population dynamics 362–3
aggression
  appeasement of male aggression 220
  territoriality 175–6, 181, 183, 184–7
aloparental care 270–4
  brood parasitism 271–3
  cooperative care 273–4
  egg dumping 270–1
  egg stealing 271
  kidnapping 271
  misdirected care 274
  nest takeovers 271
  sneaky mating 267, 270–1
alternative life-history strategies 240–5, 267, 272, 346, 354–6
alternative mating tactics 240–5, 267, 270–1, 346, 354–6
anal gland 255, 256
  androgen receptors (ARs) 88, 95, 108, 118, 121
androgenesis 385
  antagonistic genes model of mate choice 209–10
  appeasement of male aggression in courtship 220
appetite
  growth interactions 115–16
  reproductive cycle 115–16
aquaculture and the control of reproduction 373–88
  facilitating reproduction 374–9
  suppressing reproduction 379–88
arbitrary mate choice in sexual selection 210–12
atresia 60–2, 116, 144, 152, 153, 156, 326, 364, 377
auditory signals in courtship 226–7
Balbiani body 50, 54
Beverton-Holt stock-recruitment relationship 359–60
bower nest 190, 206
brain–pituitary–gonad (BPG) reproductive axis 83–5
  feedback control 106–9
  growth interactions 113–16
  levels of analysis 85–6
  brain–pituitary relationship 98
breeding system see mating system
breeding tubercles 216, 217, 223
brood parasitism 243, 245, 271–3, 274
brood pouch evolution in syngnathids 295–8
bubble nests 194–5, 196
capital breeders 151–3
capture fisheries 373–4
  chase-away selection 209
chemical sterilisation in aquaculture 386
chorion 55, 63, 64, 78, 328, 332
compatible genes model of mate choice 207–9
concentric territories 174
cooperative care 273–4
  cost of meiosis 304
  costs of reproduction 334–8
    evidence 336–8
    life-history theory 334–8
    measuring 335–6
courtship 219–29
  *see also* mating system; sexual selection; sexual signals
appeasement of male aggression 220
auditory signals 226–7
body size 222–3
colour 224
display behaviour 225–6
electrical cues 228
functions 219–21
gustation 227–8
mate attraction 219–20
mate identification 219–20
mate stimulation 220
mating synchrony 220
morphological trait size 223
multiple cues 228–9
nuptial colouration 224
olfaction 227–8
ornaments/signals 212–14, 215, 221–9
pair bond maintenance 221
tactile cues 228
UV reflectance 224–5
visual signals 222
cryptic female mate choice 63, 203, 205, 239

Darwinian demon 334, 353
Darwin's 'double process' of sexual selection 214–16
demographic models of life-history evolution 339–47
diel reproductive cycles 136
dimensionless life-history variables 350–1
direct intersexual selection 205–6, 218
diversity of teleosts 1–2
  *see also* reproductive diversity
dopamine
  inhibition of GTH release 104–5, 125
  receptors 105

EDCs *see* endocrine-disrupting chemicals
egg and offspring size 327–31, 332
egg dumping 270–1
egg stealing 271
ejaculate size 236–7
ejaculation frequency 236–7
electrical cues in courtship 228
embryoparity *see* zygoparity
endocrine control
  hormones, modes of action 82–3
  male viviparity 297–8
  oogenesis 88–93
  secondary sexual characteristics 117, 120–1
  social interactions 121–2
  spermatogenesis 93–7
  viviparity 292, 297–8
endocrine-disrupting chemicals (EDCs) 123–5
waste water treatment plants (WWTPs) 124–5
endocrine manipulation in aquaculture
  facilitating reproduction 375–8
  monosex production 380–1
  sexual dysfunction 376
  sexual dysfunction in females 376–8
  sexual dysfunction in males 378
devolution of sex-determining mechanisms 26–30
  genomic architecture 28
  heterogamety 26–30
  phylogenetic analysis 28–30
  sex determination 26–30
  sex ratio 26–7
evolutionary history of teleosts 8–11
evolutionary stable strategy (ESS) 174–5
  external bearing 257–61
  external fertilisation 237–8

facilitating reproduction in aquaculture 374–9
endocrine manipulation 375–8
environmental manipulation 374–5, 376
gamete preservation 378–9
fecundity
determinate 4–5, 92–3, 113, 152–3, 156, 326, 364
indeterminate 4–5, 92–3, 113, 115, 154, 326, 329, 364
population dynamics 363–4
spawning dynamics 66
fecundity and clutch size, life-history variables 325–7
female mating polymorphisms 245–6
female monosex lines in aquaculture
  direct feminisation 381
  indirect feminisation 381–2
female ornaments 212–14, 215
fertilisation 62–4, 231
  external 237–8
  fertilisation cone 63
  internal 238–9, 283–6
  micropyle 62–4, 78, 231, 240
  modes 3, 5
  polyspermy 63, 64, 231
  quasi-internal 239–40
  success 237
filial cannibalism 274–6
Fisherman selection 210–11
fisheries impact on reproductive traits
  age and size structure 365–8
  age at maturity 372
  Allee effect see depensation
depensation 371–2
  evolution 372–3
gamete quality 368
  mortality 365
  population sex ratio 368–70
  population size and density 370–2
  sex ratio 368–70
  size selectivity 368
  stock-recruitment relationships 368
fisheries-induced evolution 372–3
Fisher’s runaway process see Fisherman selection
follicle-stimulating hormone (FSH)
gonadotrophs 99
  oogenesis 84, 89–90
food/feeding
  capital breeders 151–3
  income breeders 154–5
  reproductive cycles 150–7
  skipped spawnings 155–6
  spawning patterns 150–7
frequency-dependent selection 26, 175, 230, 240, 355
frozen niche variation (FNV) model 304–5
FSH see follicle-stimulating hormone
game theory 175
gamete preservation 378–9
gamete quality and fisheries 368
gender systems 2–4
  genetic control
    gonadal differentiation 40–2
    oogenesis 64–5
    spermatogenesis 79
genotypic sex determination (GSD) 14–21, 25–6
  monofactorial GSD 14–20
  multifactorial GSD 20
  polyfactorial (polygenic) GSD 20–1
germinal epithelium arrangement of
  testes 67, 68
gestation
  embryonic nutrition 290–1
  intra-follicular 283, 289, 290, 292
  intra-luminal 283, 287, 289, 292
  intra-ovarian 283
  sequence 289–90
  superfetation 291–2
  viviparity 289–92
global seasonal patterns of reproduction 128–9
GnRH see gonadotrophin-releasing hormone
gonad embryology 32–40
gonadal anlagen 35–6
gonadal initial differentiation 36–7
  ovaries, initial differentiation 38
  primordia see gonadal anlagen
  primordial germ cells (PGCs) 33–5
  sex differentiation 32–40
testes, initial differentiation 38–40
gonad genetic control, sex
differentiation 40–2
gonadal anlagen, sex differentiation 35–6
gonadal initial differentiation 36–7
  commonalities 42–3
  inhibitory relationships 42
gonadal steroids 86–8
  receptors 87–8
  synthesis 86–7
gonadosomatic index (GSI) 46–8, 339
gonadotrophin receptors, pituitary 100–1
gonadotrophin-releasing hormone (GnRH) 101–9
dopamine 104–5, 125
  functions 102
  neurons distribution 103–6
  pituitary 101–3
  receptors 102–3
gonadotrophs
  developmental control model 109
gonadotrophin-stimulating hormone (FSH) 99
  kisspeptin 105, 106
  luteinising hormone (LH) 99
  pituitary 99
gonochorist 2, 4, 13, 20, 24, 26, 28, 31, 32, 36, 37, 40, 42, 46, 70, 121, 124, 282, 306, 308, 309, 310–12, 314, 316, 319, 369, 374
gonoduct development
  female 51–2
  male 69–70
gonopodium 247, 284–6
good genes model of mate choice 207, 208
growth
  axial 113
  compensatory 107
  gonadal 113–14, 145, 153
  indeterminate 113, 242
  ponderal 113
  stored 113
  structural 113, 114, 115
Subject Index

growth interactions
  appetite change 115–16
  brain–pituitary–gonad (BPG)
    reproductive axis 113–16
  hypothalamus–pituitary–gonad (HPG)
    reproductive axis 113–16
GSD see genotypic sex determination
GSI see gonadosomatic index
guarders/non-guarders mating
  polymorphisms 243–5

GSD
  see genotypic sex determination

GSI
  see gonadosomatic index

Gynogenesis
  monofactorial GSD 14–15
  monosex production 383–5
  parthenogenesis 298, 299, 301

habitat templet model of life-history
  theory 347–9

Handicap principle 207

Hermaphroditism 305–21
  adaptive significance 316–19
  bidirectional sex change 315–16
  cross-fertilisation 313
  deep-sea anglerfish 320–1
  distribution 306–8
  endocrine control 309–12
  gonadal organisation 308–9
  modes 306–8
  phylogenetic distribution 306–8
  protandry 315
  protogyne 314–15
  quasi-hermaphroditism 320–1
  self-fertilisation 312–13
  sequential hermaphroditism 306–8, 313–16
  serial sex change 315–16
  simultaneous hermaphroditism 306–8, 312–13
  size-advantage hypothesis 317–18
  synchronous hermaphroditism 306–8, 312–13
  heterogamety 14, 16, 17–19, 20, 26–30, 36, 383, 385

Homing mechanisms 168–71

Hormones see endocrine control

HPG see hypothalamus–pituitary–gonad

human impacts on migration 172–3

hybridisation
  monosex production 385–6
  sterilisation 387
  unisexual teleosts 298–303

hybridogenesis, parthenogenesis 298–9, 301

hypophysis see pituitary gland

hypothalamus–pituitary–gonad (HPG)
  reproductive axis 83–5
  growth interactions 113–16
  levels of analysis 85–6
  hypoxia 253–5

immunological sterilisation 386

imprinting 170–1

income breeders
  food/feeding 152, 154–5
  reproductive cycles 154–5
  indirect intersexual selection 206–10, 218
  internal bearing 238, 261
  internal fertilisation 238–9
  viviparity 283–6
  intertidal spawners 135, 137
  intrasexual selection 216–18
  iteroparity 4, 5, 90, 112, 163, 166, 341, 342, 343

kidnapping offspring 271

Kisspeptin
  gonadotrophs 105, 106
  puberty 105, 106, 108, 109, 110, 125, 150

landmarks used in migration 170–1

lecithotrophy-matrotrophy 286–7, 288

LH see luteinising hormone

life-history evolution 339–47
  alternative life-history strategies 354–6
  constraints 353–4
  Darwinian demon 334, 353
  empirical studies 342–4, 346–7
  environmental gradients 346–7
  fitness measures 340–1
  habitat invasion 344–6
  iteroparity 4, 5, 90, 112, 163, 166, 341, 342, 343
  plasticity of life-history traits 351–3
  predictions of demographic models 341–2

semelparity 4

life-history theory 334–9
  costs of reproduction 334–8
  demographic models 339–47
  habitat templet models 347–9
  life-history invariants 350–1
  reproductive diversity 9–11
  reproductive effort 338–9
  reproductive value 340
  residual reproductive value (RRV) 340
  trade-offs 334, 335, 338, 342–3
  Winemiller’s model 348–9

life-history variables 324–33
  age and size at maturity 325
  egg size and offspring size 327–31, 332
  fecundity and clutch size 325–7
  incubation time 331–3
  offspring size and egg size 327–31, 332
  parental care 333
  plasticity 351–3
  reaction norms 352–3
  reproductive lifespan 333
  size and age at maturity 325

lunar-related reproductive cycles 134–6, 143

coral reef spawners 135

freshwater spawners 136

intertidal spawners 135

luteinising hormone (LH)
<table>
<thead>
<tr>
<th>Subject Index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>gonadotrophs</strong> 99</td>
</tr>
<tr>
<td><strong>oogenesis</strong> 84, 89</td>
</tr>
<tr>
<td><strong>major histocompatibility complex (MHC)</strong> 209</td>
</tr>
<tr>
<td><strong>male mate choice</strong> 212–14</td>
</tr>
<tr>
<td><strong>male mating polymorphisms</strong> 240–5</td>
</tr>
<tr>
<td><strong>causal factors</strong> 242</td>
</tr>
<tr>
<td><strong>female mimics</strong> 243</td>
</tr>
<tr>
<td><strong>female responses</strong> 244–5</td>
</tr>
<tr>
<td><strong>guarders/non-guarders</strong> 243–5</td>
</tr>
<tr>
<td><strong>sperm competition</strong> 244</td>
</tr>
<tr>
<td><strong>terminology</strong> 243–4</td>
</tr>
<tr>
<td><strong>male monosex lines in aquaculture</strong></td>
</tr>
<tr>
<td><strong>direct protocol</strong> 382</td>
</tr>
<tr>
<td><strong>indirect protocol</strong> 382</td>
</tr>
<tr>
<td><strong>monosex production</strong> 382</td>
</tr>
<tr>
<td><strong>male viviparity</strong></td>
</tr>
<tr>
<td><strong>endocrine control</strong> 297–8</td>
</tr>
<tr>
<td><strong>Gastrophori</strong> 295–6</td>
</tr>
<tr>
<td><strong>Syngnathidae</strong> 295–8</td>
</tr>
<tr>
<td><strong>Urophori</strong> 295–6</td>
</tr>
<tr>
<td><strong>mate attraction during courtship</strong> 219–20</td>
</tr>
<tr>
<td><strong>mate choice</strong></td>
</tr>
<tr>
<td><strong>cryptic mate choice</strong> 78, 203, 205, 239, 240</td>
</tr>
<tr>
<td><strong>cues</strong> 229</td>
</tr>
<tr>
<td><strong>direct benefits</strong> 189, 206, 220, 223, 226, 244, 245</td>
</tr>
<tr>
<td><strong>indirect benefits</strong> 206, 223, 229</td>
</tr>
<tr>
<td><strong>male mate choice</strong> 212–14</td>
</tr>
<tr>
<td><strong>matting bias</strong> 205</td>
</tr>
<tr>
<td><strong>theory</strong> 204–5</td>
</tr>
<tr>
<td><strong>mate choice copying</strong> 216</td>
</tr>
<tr>
<td><strong>mate choice theory</strong> 204–5</td>
</tr>
<tr>
<td><strong>mating system</strong> 3, 5, 202</td>
</tr>
<tr>
<td>see also courtship; sexual selection; sexual signals; classification 3, 203–4</td>
</tr>
<tr>
<td><strong>evolution</strong> 202, 249</td>
</tr>
<tr>
<td><strong>external fertilisation</strong> 237–8</td>
</tr>
<tr>
<td><strong>genetic monogamy</strong> 3, 5, 203, 204</td>
</tr>
<tr>
<td><strong>internal fertilisation</strong> 238–9, 283–6</td>
</tr>
<tr>
<td><strong>lek</strong> 164, 182, 187, 190, 206, 213, 369, 375, 376</td>
</tr>
<tr>
<td><strong>monogamy</strong> 3, 5, 203, 204, 217, 221, 313, 316, 318, 324, 337</td>
</tr>
<tr>
<td><strong>phylogenetic history</strong> 249</td>
</tr>
<tr>
<td><strong>polyandry</strong> 3, 204</td>
</tr>
<tr>
<td><strong>polygamy</strong> 3, 5</td>
</tr>
<tr>
<td><strong>polygynandry</strong> 3, 5, 203</td>
</tr>
<tr>
<td><strong>polygyny</strong> 3, 180, 185, 283</td>
</tr>
<tr>
<td><strong>promiscuity</strong> 3, 5, 203</td>
</tr>
<tr>
<td><strong>quasi-internal fertilisation</strong> 239–40</td>
</tr>
<tr>
<td><strong>social monogamy</strong> 5</td>
</tr>
<tr>
<td><strong>susceptibility to overexploitation</strong> 364–5</td>
</tr>
<tr>
<td><strong>matrotrophy evolution</strong> 292–4</td>
</tr>
<tr>
<td><strong>matrotrophy-lecithotrophy</strong> 286–7, 288</td>
</tr>
<tr>
<td><strong>maturation-inducing hormone (MIH), oogenesis</strong> 90–1</td>
</tr>
<tr>
<td><strong>maturation staging</strong> 46, 47</td>
</tr>
<tr>
<td><strong>mechanical sterilisation in aquaculture</strong> 386</td>
</tr>
<tr>
<td><strong>melatonin production</strong></td>
</tr>
<tr>
<td><strong>photoperiodic response</strong> 147–50</td>
</tr>
<tr>
<td><strong>pineal gland</strong> 147–50</td>
</tr>
<tr>
<td><strong>reproductive cycles</strong> 147–50</td>
</tr>
<tr>
<td><strong>MHC</strong> see major histocompatibility complex</td>
</tr>
<tr>
<td><strong>micropyle</strong> 62–4, 78, 231, 240</td>
</tr>
<tr>
<td><strong>migration</strong> 160–73</td>
</tr>
<tr>
<td><strong>adaptations</strong> 167–8</td>
</tr>
<tr>
<td><strong>adaptive significance</strong> 164–6</td>
</tr>
<tr>
<td><strong>chemical stimuli</strong> 169–70</td>
</tr>
<tr>
<td><strong>energetic costs</strong> 166</td>
</tr>
<tr>
<td><strong>homing mechanisms</strong> 168–71</td>
</tr>
<tr>
<td><strong>human impacts</strong> 172–3</td>
</tr>
<tr>
<td><strong>imprinting</strong> 170–1</td>
</tr>
<tr>
<td><strong>landmarks</strong> 170–1</td>
</tr>
<tr>
<td><strong>magnetic sensing</strong> 169</td>
</tr>
<tr>
<td><strong>orientation mechanisms</strong> 168–71</td>
</tr>
<tr>
<td><strong>partial</strong> 165–6</td>
</tr>
<tr>
<td><strong>periodicity</strong> 161</td>
</tr>
<tr>
<td><strong>pheromones</strong> 170</td>
</tr>
<tr>
<td><strong>physiological adaptations</strong> 167–8</td>
</tr>
<tr>
<td><strong>sex differences</strong> 172</td>
</tr>
<tr>
<td><strong>spatial scale</strong> 160–1</td>
</tr>
<tr>
<td><strong>sun-compass orientation</strong> 168</td>
</tr>
<tr>
<td><strong>survival costs</strong> 167</td>
</tr>
<tr>
<td><strong>terms/definitions</strong> 161–2</td>
</tr>
<tr>
<td><strong>thyroxine</strong> 169, 171</td>
</tr>
<tr>
<td><strong>timing control</strong> 171–2</td>
</tr>
<tr>
<td><strong>water currents</strong> 169</td>
</tr>
<tr>
<td><strong>water temperature</strong> 171–2</td>
</tr>
<tr>
<td><strong>MIH</strong> see maturation-inducing hormone</td>
</tr>
<tr>
<td><strong>misdirected parental care</strong> 274</td>
</tr>
<tr>
<td><strong>mode of reproduction and overexploitation</strong> 364–5, 366, 367</td>
</tr>
<tr>
<td><strong>monofactorial GSD</strong> 14–20</td>
</tr>
<tr>
<td><strong>DNA technology</strong> 15</td>
</tr>
<tr>
<td><strong>gynogenesis</strong> 14–15</td>
</tr>
<tr>
<td><strong>SEX (male-determining gene)</strong> 19–20</td>
</tr>
<tr>
<td><strong>temperature-dependent sex determination (TSD)</strong> 25–6</td>
</tr>
<tr>
<td><strong>visible sex-linked morphological traits</strong> 15</td>
</tr>
<tr>
<td><strong>monosex production in aquaculture</strong> 379–86</td>
</tr>
<tr>
<td><strong>androgenesis</strong> 385</td>
</tr>
<tr>
<td><strong>endocrine manipulation</strong> 380–1</td>
</tr>
<tr>
<td><strong>female monosex lines</strong> 381–2</td>
</tr>
<tr>
<td><strong>gynogenesis</strong> 383–5</td>
</tr>
<tr>
<td><strong>hybridisation</strong> 385–6</td>
</tr>
<tr>
<td><strong>male monosex lines</strong> 382</td>
</tr>
<tr>
<td><strong>suppressing reproduction</strong> 379–86</td>
</tr>
<tr>
<td><strong>morphological trait size</strong> 223</td>
</tr>
<tr>
<td><strong>mouthbrooding</strong> 259–60, 264–5, 273, 337, 375</td>
</tr>
<tr>
<td><strong>mucins</strong> 70, 74, 235, 238, 241</td>
</tr>
<tr>
<td><strong>Müller’s ratchet</strong> 304</td>
</tr>
<tr>
<td><strong>multifactorial GSD</strong> 20</td>
</tr>
<tr>
<td><strong>mutual mate choice</strong> 214–16</td>
</tr>
</tbody>
</table>
nest construction 193–5, 196
nest takeovers 271
nutrition
  embryonic 290–1
  gestation 290–1
  parental care 256–7
oestrogen receptors (ERs) 88, 89, 90, 106, 108, 118
offspring size and egg size 327–31, 332
olfactory cues in courtship 118, 123, 227–8, 229, 244
ovary
  cystovarian 48, 49, 51
  developmental control model 109
  gonad development 51–2
  gross morphology 48–51
  gymnovarian 48, 49, 51, 58, 60
  initial differentiation 38
  Müllerian ducts 41, 51, 52, 283, 292
  structure 48–52
overexploitation and mode of reproduction 364–5, 366, 367
oviposition 70, 130, 180, 188–9, 197–200, 205, 234–6, 238, 240, 243, 245, 246, 253, 331, 360–1, 371
ovulation 60, 90–1
pair bond maintenance 221
paradox of the lek 206
parental care 3, 6, 251–79
  age of offspring 267
  age of parents 268, 269
  allopatal care 270–4
  biparental care 3, 6, 215, 221, 256, 268–9, 272, 276, 278, 278
  brood parasitism 271–3
  cannibalism 274–6
  cooperative care 273–4
  costs 262–5
  definition 252
  desiccation protection 253–5
  disturbance protection 253
  egg dumping 270–1
  egg stealing 271
  evolution 276–9
  external bearing 257–61
  internal bearing 257–61
  fanning behaviour 253–5, 254
  filial cannibalism 274–6
  flexibility 266–9
  food availability 268
  helper care systems 269–70
  hypoxia protection 253–5
  internal bearing 261
  kidnapping 271
  life-history variable 333
  male viviparity 295–8
  maternal care 3, 6, 182, 216, 276, 278, 278
  misdirected care 274
  modes of care 253–61, 276–9
  mouthbrooding 259–60, 264–5, 273, 337, 375
  nest takeovers 271
  number of offspring 264–5, 266–7
  nutrition 256–7, 268
  oral brooding see mouthbrooding
orientation mechanisms during migration 168–71
ornaments/signals
courtship 221–9
  female ornaments 212–14, 215
OSR see operational sex ratio
ovarian modifications for viviparity 287–9
ovaries
cystovarian 48, 49, 51
developmental control model 109
gonandoct development 51–2
gross morphology 48–51
gymnovarian 48, 49, 51, 58, 60
initial differentiation 38
Müllerian ducts 41, 51, 52, 283, 292
structure 48–52
overexploitation and mode of reproduction 364–5, 366, 367
oviposition 70, 130, 180, 188–9, 197–200, 205, 234–6, 238, 240, 243, 245, 246, 253, 331, 360–1, 371
ovulation 60, 90–1
pair bond maintenance 221
paradox of the lek 206
parental care 3, 6, 251–79
  age of offspring 267
  age of parents 268, 269
  allopatal care 270–4
  biparental care 3, 6, 215, 221, 256, 268–9, 272, 276, 278, 278
  brood parasitism 271–3
  cannibalism 274–6
  cooperative care 273–4
  costs 262–5
  definition 252
  desiccation protection 253–5
  disturbance protection 253
  egg dumping 270–1
  egg stealing 271
  evolution 276–9
  external bearing 257–61
  fanning behaviour 253–5, 254
  filial cannibalism 274–6
  flexibility 266–9
  food availability 268
  helper care systems 269–70
  hypoxia protection 253–5
  internal bearing 261
  kidnapping 271
  life-history variable 333
  male viviparity 295–8
  maternal care 3, 6, 182, 216, 276, 278, 278
  misdirected care 274
  modes of care 253–61, 276–9
  mouthbrooding 259–60, 264–5, 273, 337, 375
  nest takeovers 271
  number of offspring 264–5, 266–7
  nutrition 256–7, 268
  oral brooding see mouthbrooding

468  Subject Index
<table>
<thead>
<tr>
<th>Subject Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>parental investment 262</td>
</tr>
<tr>
<td>parental survival 262–4</td>
</tr>
<tr>
<td>parental care 3, 6, 181, 238, 240, 249, 267, 276–8, 295</td>
</tr>
<tr>
<td>phenotypic plasticity 266–9</td>
</tr>
<tr>
<td>phylogenetic distribution 252–3</td>
</tr>
<tr>
<td>protection from pathogens 255–6</td>
</tr>
<tr>
<td>protection from predators 253</td>
</tr>
<tr>
<td>quality of offspring 267</td>
</tr>
<tr>
<td>sex role reversal 265–6</td>
</tr>
<tr>
<td>skin brooding 260–1</td>
</tr>
<tr>
<td>viviparity 8, 278–9, 282–4, 286–7, 292–7</td>
</tr>
<tr>
<td>William’s principle 262, 263</td>
</tr>
<tr>
<td>parthenogenesis</td>
</tr>
<tr>
<td>gynogenesis 298, 299, 301</td>
</tr>
<tr>
<td>hybridogenesis 298–9, 301</td>
</tr>
<tr>
<td>unisexual teleosts 298–9</td>
</tr>
<tr>
<td>pearl organs see breeding tubercles</td>
</tr>
<tr>
<td>pebble nests 191–2</td>
</tr>
<tr>
<td>phenotypic plasticity in parental care 266–9</td>
</tr>
<tr>
<td>pheromones in reproduction 122–3, 170, 227–8</td>
</tr>
<tr>
<td>photoperiodic response</td>
</tr>
<tr>
<td>melatonin production 147–50</td>
</tr>
<tr>
<td>pineal gland 147–50</td>
</tr>
<tr>
<td>reproductive cycles 139–43, 147–50</td>
</tr>
<tr>
<td>phylogenetic analysis</td>
</tr>
<tr>
<td>male viviparity 295–8</td>
</tr>
<tr>
<td>mating system evolution 249</td>
</tr>
<tr>
<td>parental care evolution 276–9</td>
</tr>
<tr>
<td>sex-determining mechanisms 28–30</td>
</tr>
<tr>
<td>viviparity 292–4</td>
</tr>
<tr>
<td>pineal gland</td>
</tr>
<tr>
<td>melatonin production 147–50</td>
</tr>
<tr>
<td>photoperiodic response 147–50</td>
</tr>
<tr>
<td>reproductive cycles 147–50</td>
</tr>
<tr>
<td>pituitary gland 98–101</td>
</tr>
<tr>
<td>brain–pituitary–gonad (BPG)</td>
</tr>
<tr>
<td>reproductive axis 83–5</td>
</tr>
<tr>
<td>brain–pituitary relationship 98</td>
</tr>
<tr>
<td>gonadotropin receptors 100–1</td>
</tr>
<tr>
<td>gonadotrophin-releasing hormone (GnRH) 101–3</td>
</tr>
<tr>
<td>gonadotrophins 99</td>
</tr>
<tr>
<td>hypothalamic control 101–3</td>
</tr>
<tr>
<td>hypothalamus–pituitary–gonad (HPG)</td>
</tr>
<tr>
<td>reproductive axis 83–5</td>
</tr>
<tr>
<td>placenta evolution 294</td>
</tr>
<tr>
<td>poeciliid unisexuals 300–1, 304–5</td>
</tr>
<tr>
<td>polar body expulsion 52</td>
</tr>
<tr>
<td>polyfactorial (polygenic) GSD 20–1</td>
</tr>
<tr>
<td>polyploidy 387–8</td>
</tr>
<tr>
<td>polyspermy 63, 64, 231</td>
</tr>
<tr>
<td>population dynamics</td>
</tr>
<tr>
<td>age at maturity 362–3</td>
</tr>
<tr>
<td>fecundity 363–4</td>
</tr>
<tr>
<td>reproductive traits 362–4</td>
</tr>
<tr>
<td>territoriality 185–8</td>
</tr>
<tr>
<td>population sex ratio and fisheries 368–70</td>
</tr>
<tr>
<td>population size and density and fisheries 370–2</td>
</tr>
<tr>
<td>pre-oviposition ejaculation 234–5</td>
</tr>
<tr>
<td>primordial germ cells (PGCs)</td>
</tr>
<tr>
<td>origin and migration 33–5</td>
</tr>
<tr>
<td>sex differentiation 33–5</td>
</tr>
<tr>
<td>progestagen receptors (PgRs) 88, 90</td>
</tr>
<tr>
<td>puberty 109–13</td>
</tr>
<tr>
<td>kisspeptin 105, 106, 108, 109, 110, 125, 150</td>
</tr>
<tr>
<td>physiological control 104, 110–13, 137</td>
</tr>
<tr>
<td>quasi-hermaphroditism 320–1</td>
</tr>
<tr>
<td>quasi-internal fertilisation 239–40</td>
</tr>
<tr>
<td>rainfall/flooding and reproductive cycles 143–4</td>
</tr>
<tr>
<td>reproduction control in aquaculture 373–4</td>
</tr>
<tr>
<td>reproduction costs 334–8</td>
</tr>
<tr>
<td>evidence 336–8</td>
</tr>
<tr>
<td>life-history theory 334–8</td>
</tr>
<tr>
<td>measuring 335–6</td>
</tr>
<tr>
<td>reproduction sites see sites for reproduction</td>
</tr>
<tr>
<td>reproduction suppression see suppressing reproduction in aquaculture</td>
</tr>
<tr>
<td>reproductive cycles see also seasonal patterns of reproduction; spawning patterns</td>
</tr>
<tr>
<td>appetite change 115–16</td>
</tr>
<tr>
<td>capital breeders 151–3</td>
</tr>
<tr>
<td>diel reproductive cycles 136</td>
</tr>
<tr>
<td>endogenous cycles 137–8</td>
</tr>
<tr>
<td>food/feeding 150–7</td>
</tr>
<tr>
<td>income breeders 154–5</td>
</tr>
<tr>
<td>lunar-related reproductive cycles 134–6, 143</td>
</tr>
<tr>
<td>melatonin production 147–50</td>
</tr>
<tr>
<td>migratory patterns 162–4</td>
</tr>
<tr>
<td>multiple environmental cycles 136–7</td>
</tr>
<tr>
<td>neuroendocrine mechanisms mediating environmental effects 147–50</td>
</tr>
<tr>
<td>photoperiod/temperature 128, 139–43</td>
</tr>
<tr>
<td>photoperiodic response 128, 147–50</td>
</tr>
<tr>
<td>pineal gland 147–50</td>
</tr>
<tr>
<td>proximate factors 138–44</td>
</tr>
<tr>
<td>rainfall/flooding 143–4</td>
</tr>
<tr>
<td>social interactions 144, 145</td>
</tr>
<tr>
<td>spawning patterns 134–6</td>
</tr>
<tr>
<td>stress 144–7</td>
</tr>
<tr>
<td>temperature/photoperiod 139–43</td>
</tr>
<tr>
<td>tidal cycles 143</td>
</tr>
<tr>
<td>water quality 144–5</td>
</tr>
<tr>
<td>reproductive diversity 2–11, 389–90</td>
</tr>
<tr>
<td>evolutionary puzzle 389–90</td>
</tr>
<tr>
<td>life-history theory 9–11</td>
</tr>
<tr>
<td>phylogenetic relationships 8–9, 10</td>
</tr>
<tr>
<td>reproductive effort 338–9</td>
</tr>
<tr>
<td>reproductive guilds 6, 7</td>
</tr>
<tr>
<td>reproductive isolation</td>
</tr>
<tr>
<td>sexual signals 229–31</td>
</tr>
<tr>
<td>speciation 229–31</td>
</tr>
</tbody>
</table>
reproductive lifespan 333
Ricker stock-recruitment relationship 359, 360
seasonal patterns of reproduction 128–34
see also reproductive cycles
global seasonal patterns 128–9
proximate factors 130
spawning seasonality in freshwater species 130–2, 133
spawning seasonality in marine species 132–4
ultimate factors 129–30
secondary sexual characteristics 3, 6
endocrine control 117, 120–1
self-fertilisation, hermaphroditism 312–13
seminal fluid composition 235
sensory bias 211–12
sequential hermaphroditism 306–8, 312–13
evolution 317–19
proteandry 315
protophyny 314–15
serial sex change 315–16
serial hermaphroditism see sequential hermaphroditism
serial territories see concentric territories
Sertoli cells
sex chromosomes
heterogamety 14, 16, 17–19, 20, 36, 383, 385
homogamety 20
sex determination 3, 13–30
dmrt1bY 19, 20, 25, 26, 41
environmental sex determination (ESD) 21–6
evolution of sex-determining mechanisms 26–30
genotypic sex determination (GSD) 14–21, 25–6
GsdF 19, 20
sdY 16, 20
SEX (male-determining gene) 19–20
Sry 13, 15, 19, 40, 42
sex differences in migration 172
sex differentiation 31–43
anti-Müllerian hormone (AMH) 41, 79, 94, 95
gonad embryology 32–40
gonad genetic control 40–2
gonochorist 31, 32, 36, 37, 40, 42
secondary gonochorist 37
undifferentiated gonochorist 36, 42
sex-linked morphological traits 15
SEX (male-determining gene), monofactorial GSD 19–20
sex ratio
evolution of sex-determining mechanisms 26–7
fisheries impact 368–70
sex role reversal 212–13, 265–6, 297
sexual conflict 246–9
sexual dimorphism 3, 6, 41, 228, 314, 320
sexual dysfunction in aquaculture 376
in females 376–8
in males 378
sexual selection 201–31
see also courtship; mating system; sexual signals
antagonistic genes model 209–10
arbitrary mate choice 210–12
compatible genes models 207–9
courtship 219–29
Darwin’s ‘double process’ of sexual selection 214–16
direct intersexual selection 205–6, 218
female mating polymorphisms 245–6
female ornaments 212–14, 215
Fishierian selection 210–11
good genes models 207, 208
indirect intersexual selection 206–10, 218
intrasexual selection 216–18
major histocompatibility complex (MHC) 209
male mate choice 212–14
male mating polymorphisms 240–5
mate choice copying 216
mutual mate choice 214–16
operational sex ratio (OSR) 218–19
paradox of the lek 206
sensory bias 211–12
speciation 229–31
strength 218–19
sexual signals
see also courtship; mating system; sexual selection
reproductive isolation 229–31
speciation 229–31
shelter excavation 192–3
Shepherd stock-recruitment relationship 360
sialomucins see mucins
signals/ornaments
courtship 221–9
female ornaments 212–14, 215
sensory bias 211–12
simultaneous hermaphroditism 306–8, 312–13
cross-fertilisation 313
self-fertilisation 312–13
sites for reproduction 188–96
bubble nests 194–5, 196
nest construction 193–5
pebble nests 191–2
redds 163, 191, 197, 253, 360
terrestrial spawning sites 195
size-advantage hypothesis 317–18
size selectivity in fisheries 368
skin brooding 260–1
skipped spawnings 155–6
sneaky mating 240–5, 267, 270–1, 346, 354–6
social interactions
  endocrine control 121–2
  reproductive cycles 144, 145
  stress 145
spawning dynamics 4–5
  fecundity 66
spawning migration see migration
spawning patterns
  see also reproductive cycles
  batch spawners 91–3
  coral reef spawners 135
  determinate spawners 66
  diel reproductive cycles 136
  food/feeding 150–7
  freshwater spawners 136
  indeterminate spawners 66
  intertidal spawners 135
  lunar-related reproductive cycles 93, 134–6
  seasonality 130–4
  skipped spawnings, food/feeding 155–6
  spermatogenesis 96–7
  total spawners 4, 47, 65, 79, 96, 109, 113, 115, 130–1, 139, 141, 151, 364
spawning potential ratio (SPR) 361
spawning seasonality
  freshwater systems 130–2, 133
  marine systems 132–4
spawning site preparation see sites for reproduction
spawning site selection 188–200
  cues 197
  sites for reproduction 188–96
  spawning symbioses 197–200
speciation
  reproductive isolation 229–31
  sexual signals 229–31
sperm capacitation and motility 75–8, 235–6
sperm competition 231–7
  avoidance 234
  cost of sperm production 231–2, 233
  ejaculate size 236–7
  ejaculation frequency 236–7
  intensity 232–4
  male mating polymorphisms 244
  pre-oviposition ejaculation 234–5
  risk 232–4
  seminal fluid composition 235
  sperm capacitation and motility 75–8, 235–6
sperm depletion 232, 233
sperm production
  cost 231–2, 233
  quantitative analysis 80
sperm storage 238–9
spermatids 74–5
spermatocysts 71, 95–6
spermatogenesis 71–4, 75, 76
  capacitation 75–8, 235–6
  developmental control model 109
differentiated spermatogonia 73
  dynamics 79–80
  endocrine control 93–7
  genetic control 79
  primary spermatocysts 73
  secondary spermatocysts 73–4
  semi-cystic 74, 97, 100, 236
  Sertoli cells 71–3
  spawning patterns 96–7
  spermatids 74–5
  spermatocysts 71, 73–4, 95–6
  spermatogonial proliferation 95
  spermiation 75–6, 96
  spermatogonial proliferation 95
  spermatophore 246, 247, 286
  spermatozeugmata 18–19, 238, 284, 285, 289, 294
spermatozoa
  beat frequency 78
  capacitation 75–8, 235–6
  fertilisation 62–4
  motility 78
  movement 78
  phylogenetic distribution 76–7
  structure 76–7
  types 76–8
  velocities 77–8
  viability 77–8
  spermiation 75–6, 96, 235–6
  spiggin 83, 97, 117, 121, 124, 193
sterilisation in aquaculture 386–8
  chemical 386
  hybridisation 387
  immunological 386
  irradiation 386
  mechanical 386
  polyploidy 387–8
steroids 86–8
  receptors 87–8
  synthesis 86–7
stock-recruitment relationships 358–61
  Beverton-Holt model 359–60
  fisheries impact 368
  Ricker model 360
  Shepherd model 360
stress
  reproductive cycles 144–7
  responses 145–7
  social interactions 145
  water quality 144–5
sun-compass orientation during migration 168
super embryonation see superfetation
superfetation 291–2, 333
suppressing reproduction in aquaculture 379–88
  endocrine manipulation 380–1
  monosex production 379–86
sterilisation 386–8
symbioses in spawning 197–200
synchronous hermaphroditism see simultaneous hermaphroditism
tactile cues in courtship 228
temperature-dependent sex determination (TSD) 21–6
monofactorial GSD 25–6
 terrestrial spawning sites 195
territorial adaptiveness 173–88
adaptive significance 174–6
aggression 175–6, 181, 183, 184–7
body patterns 182–4
body size 181–2
buffer effect 187
competitor density 181
concept 174
cost–benefit analysis 174–5
definitions 174
energetic costs 184
establishment of territories 180–2
evolutionary stable strategy (ESS) 174–5
exclusion 186–7
floaters 186–7
game theory 175
geological basis 184–5
maintenance of territories 180–2
patterns of occurrence 176–80
physiological basis 182–4
population dynamics 185–8
predation impact 180–1
prior residence 181
subordination 186–7
testes
accessory structures 70–1
anastomising tubular 67, 68, 69
developmental control model 109
germinall epithelium arrangements 67, 68
gonaducts development 69–70
gross morphology 66–9
initial differentiation 38–40
Leydig cells 35, 67, 70, 72, 94–5, 100, 109, 111, 140, 297
mesorchial gland 67, 71
modification in viviparity 289
restricted lobular 67, 68, 69
Sertoli cells 71–3
spem duct gland 70, 71
spematoctysts 71
spematoctogenesis 71–4
structure 66–76
testicular gland 70, 74
unrestricted lobular 67, 68, 69
tidal reproductive cycles 143
TSD see temperature-dependent sex determination
cost of meiosis 304
Cypriniformes 301–3
Cyprinodontiformes 300–1
developmental problems 303
distribution 299–300
evolution 304–5
frozen niche variation (FNV) model 304–5
Müller’s ratchet 304
parthenogenesis 298–9
sperm parasites 304
UV reflectance 224–5
visual signals in courtship 222
vitellogenesis 55–8, 89–90
vitellogenin (VTG)
oogenesis 53, 55–8, 89
structure 57
viviparity 282–98
distribution 283, 284
embryonic nutrition 290–1
embryopathy 294
endocrine control 292, 297–8
evolution 292–4
gestation 289–92
internal fertilisation 283–6
intra-follicular gestation 283, 289, 290, 292
intra-luminal gestation 283, 287, 289, 292
intra-ovarian gestation 283
lecithotrophy-matrotrophy 286–7, 288
male viviparity 295–8
matrotrophy evolution 292–4
ovarian modifications 287–9
placenta 290–1, 294
sperm storage 283–9
superfetation 291–2, 333
testes modification 289
trophotaenia 290
zygoparity 294
VTG see vitellogenin
waste water treatment plants (WWTPs) 124–5
water quality
reproductive cycles 144–5
stress 144–5
whole genome duplication (WGD) 9, 26, 88, 101, 106
Winemiller’s triangular demographic life-history model 347–9
WWTPs see waste water treatment plants
zygoparity 294