

Practical Genetics *for* Aquaculture

C. GREG LUTZ



Contents

<i>Preface</i>	xiii
<i>Acknowledgments</i>	xv
1 Overview	1
1.1 Rationale	1
1.2 Content	2
1.3 References	3
2 Gene Action I: Qualitative Traits	4
2.1 Introduction	4
2.2 Theory	4
2.2.1 Chromosomes, loci, and alleles	4
2.2.2 Dominance	6
2.2.3 Formation of gametes	6
2.3 Practice	9
2.3.1 Ascertaining qualitative inheritance	9
2.4 Illustrative investigations and applications	16
2.4.1 Simple inheritance: a production-related trait	16
2.4.2 Inheritance of color and coloration patterns	17
2.4.3 Albinism	25
2.5 References	30
3 Gene Action II: Inheritance of Quantitative Traits	33
3.1 Introduction	33
3.2 Theory	34
3.2.1 Genetic effects and phenotypic variation	34
3.2.2 Average effects and dominance deviations	35
3.2.3 Attributing observed variation to genetic effects	36
3.2.4 Utility of estimates of genetic variation: heritability	43
3.3 Practice	44
3.3.1 Directed mating	44
3.3.2 Identifying or segregating family groups	45
3.3.3 Constraints: analysis and interpretation	50
3.4 Notable investigations and applications	52
3.4.1 Interpreting and applying heritability estimates	52
3.4.2 A case study: <i>Ictalurus punctatus</i>	54

3.4.3	A case study: <i>Macrobrachium rosenbergii</i>	56
3.4.4	A case study: <i>Procambarus clarkii</i>	57
3.4.5	A case study: <i>Sparus aurata</i>	59
3.4.6	Growth, survival, conformation and dressout traits	60
3.4.7	Disease resistance	63
3.5	References	64
4	Selection and Realized Heritability	66
4.1	Introduction	66
4.2	Theory	67
4.2.1	Estimating and predicting heritability	67
4.2.2	Applying selection	70
4.2.3	Correlated responses	72
4.2.4	Multi-trait approaches	73
4.2.5	Complicating and constraining factors	75
4.2.6	Improving selection efficiency	76
4.2.7	Using family data	77
4.3	Practice	78
4.3.1	Implementation difficulties	78
4.3.2	Identification options	79
4.3.3	Lack of response to selection	80
4.4	Illustrative investigations and applications	80
4.4.1	Evaluating available strains	80
4.4.2	Domestication selection	81
4.4.3	Conflicting results	82
4.4.4	Correlated responses	83
4.4.5	Indirect selection through production practices	84
4.4.6	Indirect measurement	84
4.4.7	Altering environmental tolerances	85
4.4.8	Adjusting data for environmental bias	86
4.4.9	Accounting for differences between sexes	86
4.4.10	Genotype by environment interactions	86
4.4.11	Miscellaneous results: finfish	87
4.4.12	Miscellaneous results: mollusks	88
4.4.13	Miscellaneous results: crustaceans	89
4.5	References	90
5	Inbreeding, Crossbreeding and Hybridization	93
5.1	Introduction	93
5.2	Theory	94
5.2.1	Dominance effects and multi-locus traits	94
5.2.2	Population genetics and dominance effects	95
5.2.3	Molecular genetics and dominance effects	99
5.2.4	Utilizing dominance effects for genetic improvement	99
5.2.5	Alternate goals in hybridization trials	100
5.3	Practice	100

	<i>Contents</i>	<i>ix</i>
5.3.1	Inbreeding impacts	100
5.3.2	Exploiting heterosis in a production environment	101
5.3.3	Maternal effects	102
5.4.3	Combining strain or species attributes	104
5.3.5	Monosex and sterile hybrids	104
5.3.6	Combining appropriate broodstock and gametes	104
5.3.7	Crossbreeding or hybridization in breed formation	105
5.4	Illustrative investigations and applications	107
5.4.1	A case study: carp and related species	108
5.4.2	A case study: dominance effects in salmonids	109
5.4.3	Monosex hybrid stocks	111
5.4.4	Unexpected results	111
5.4.5	Results: miscellaneous fish	112
5.4.6	Hybrid fish for stocking natural waters	115
5.4.7	Examples: invertebrates	115
5.5	References	116
6	Chromosomal Genetics I: Gynogenesis and Androgenesis	120
6.1	Introduction	120
6.2	Theory	120
6.2.1	Meiosis and polar bodies	120
6.2.2	Meiotic gynogenesis	122
6.2.3	Mitotic gynogenesis	123
6.2.4	Androgenesis	124
6.3	Practice	125
6.3.1	Heterozygous versus homozygous gynogenesis	125
6.3.2	Determining appropriate procedures	127
6.3.3	Evaluating success	129
6.3.4	Bivalves	130
6.3.5	Maternal influences	131
6.4	Illustrative investigations and applications	131
6.4.1	Gynogenesis	131
6.4.2	Androgenesis	136
6.5	References	137
7	Chromosomal Genetics II: Polyploidy	141
7.1	Introduction	141
7.2	Theory	142
7.2.1	Mechanics of inducing polyploidy	142
7.3	Practice	144
7.3.1	Shock-induced versus interploid triploidy	146
7.3.2	Bivalve polyploidy	148
7.4	Illustrative investigations and applications	149
7.4.1	Triploidy in tilapia	149
7.4.2	Cyprinid results	149

74.3	Salmonid polyploidy	150
74.4	Various other finfish findings	152
74.5	Bivalve studies	154
74.6	Evaluating polyploidy induction	157
7.5	References	158
8	Sex Determination and Control	162
8.1	Introduction	162
8.2	Theory	163
8.3	Practice	164
8.3.1	Homogametic monosex stocks	164
8.3.2	Heterogametic monosex stocks	165
8.3.3	Minor genetic and environmental influences	165
8.4	Illustrative investigations and applications	166
8.4.1	A case study: tilapias	166
8.4.2	Various other finfish	169
8.4.3	Crustacean sex control and determination	170
8.5	References	171
9	Control and Induction of Maturation and Spawning	174
9.1	Introduction	174
9.2	Theory	175
9.2.1	The role of external stimuli	175
9.2.2	Internal processes	176
9.2.3	Artificial induction	177
9.3	Practice	178
9.3.1	Photothermal conditioning and maturation	178
9.3.2	Hormone-induced spawning	179
9.3.3	Hormone preparation and injection practices	186
9.3.4	Injection protocols	189
9.3.5	Hormone implant technologies	189
9.3.6	Determining maturational status	192
9.3.7	Holding and handling broodstock	192
9.3.8	Obtaining gametes: finfish	193
9.4	Illustrative investigations and applications	198
9.4.1	Historical development	198
9.4.2	A case study: the red drum (<i>Sciaenops ocellatus</i>)	200
9.4.3	A case study: the striped bass (<i>Morone saxatilis</i>) and its hybrids	202
9.4.4	Induction with asynchronous ovarian development	206
9.4.5	Hormone injection of various fish	207
9.4.6	Crustaceans	211
9.4.7	Mollusks	212
9.5	References	213
10	Transgenic Aquatic Organisms	218
10.1	Introduction	218

10.2	Theory	219
10.3	Practice	219
10.3.1	Microinjection	219
10.3.2	Electroporation	220
10.3.3	Biolistics	220
10.3.4	Lipofection	220
10.3.5	Incorporation and integration	221
10.4	Illustrative investigations and applications	221
10.4.1	Transgenesis in Indian catfish	221
10.4.2	Transgenic tilapia	222
10.4.3	Atlantic salmon	222
10.4.4	Carp	223
10.5	References	224
11	Genetic Threats to Wild Stocks and Ecosystems	225
11.1	Introduction	225
11.2	Theory	225
11.3	Illustrative investigations	226
11.4	References	228
	<i>Index</i>	229