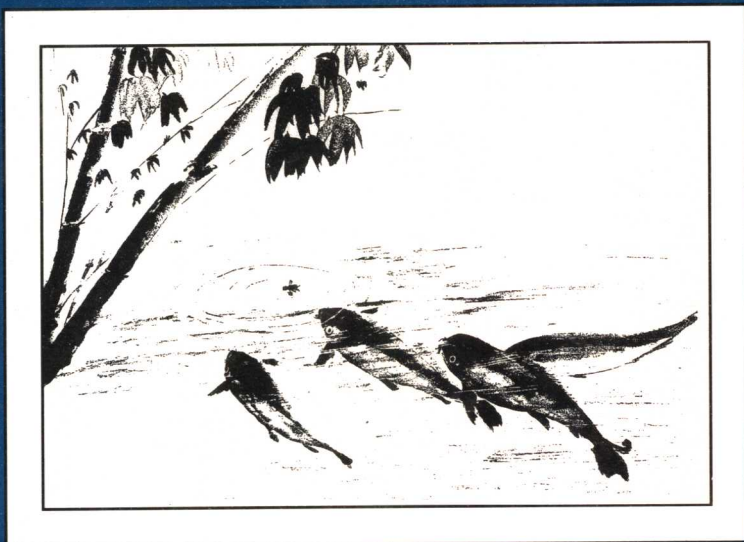


**DEVELOPMENTS IN AQUACULTURE
AND FISHERIES SCIENCE, VOLUME 28**

**FRESHWATER FISH CULTURE
IN CHINA:
PRINCIPLES AND PRACTICE**



**SIFA LI and
JACK MATHIAS/EDITORS**

ELSEVIER

Developments in Aquaculture and Fisheries Science, 28

**FRESHWATER FISH CULTURE
IN CHINA:
PRINCIPLES AND PRACTICE**

FRESHWATER FISH CULTURE IN CHINA: PRINCIPLES AND PRACTICE

Edited by

SIFA LI

*Department of Aquaculture, Shanghai Fisheries University, 334 Jun Gong Road,
Shanghai 200090, China*

JACK MATHIAS

Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada



1994

ELSEVIER

Amsterdam - Lausanne - New York - Oxford - Shannon - Tokyo

DEVELOPMENTS IN AQUACULTURE AND FISHERIES SCIENCE

The following volumes are not available anymore: 5, 6, 10-12 and 14

1. **FARMING MARINE ORGANISMS LOW IN THE FOOD CHAIN**
A Multidisciplinary Approach to Edible Seaweed, Mussel and Clam Production
by P. KORRINGA 1976 xvi + 264 pages
2. **FARMING CUPPED OYSTERS OF THE GENUS *CRASSOSTREA***
A Multidisciplinary Treatise
by P. KORRINGA 1976 x + 224 pages
3. **FARMING THE FLAT OYSTERS OF THE GENUS *OSTREA***
A Multidisciplinary Treatise
by P. KORRINGA 1976 xiv + 238 pages
4. **FARMING MARINE FISHES AND SHRIMPS**
A Multidisciplinary Treatise
by P. KORRINGA 1976 xii + 209 pages
7. **MUSSEL CULTURE AND HARVEST: A NORTH AMERICAN PERSPECTIVE**
edited by R.A. LUTZ 1980 xiii + 350 pages
8. **CHEMORECEPTION IN FISHES**
edited by T.J. HARA 1982 x + 434 pages
9. **WATER QUALITY MANAGEMENT FOR POND FISH CULTURE**
by C.E. BOYD 1982 xii + 318 pages
13. **BIOECONOMICS OF AQUACULTURE**
by P.G. ALLEN, L.W. BOTSFORD, A.M. SCHUUR and W.E. JOHNSTON
1984 xvi + 351 pages
15. **CHANNEL CATFISH CULTURE**
edited by C.S. TUCKER 1985 xvi + 657 pages
16. **SEAWEED CULTIVATION FOR RENEWABLE RESOURCES**
edited by K.T. BIRD and P.H. BENSON 1987 xiv + 382 pages
17. **DISEASE DIAGNOSIS AND CONTROL IN NORTH AMERICAN MARINE AQUACULTURE**
edited by C.J. SINDERMAN and D.V. LIGHTNER 1988 xv + 412 pages
18. **BASIC FISHERY SCIENCE PROGRAMS: A COMPENDIUM OF MICROCOMPUTER PROGRAMS AND MANUAL OF OPERATIONS**
by S.B. SAILA, C.W. RECKSIEK and M.H. PRAGER 1988 iv + 230 pages
19. **CLAM MARICULTURE IN NORTH AMERICA**
edited by J.J. MANZI AND M. CASTAGNA 1989 x + 462 pages
20. **DESIGN AND OPERATING GUIDE FOR AQUACULTURE SEAWATER SYSTEMS**
by J.E. HUGUENIN and J. COLT 1989 iv + 264 pages
21. **SCALLOPS: BIOLOGY, ECOLOGY AND AQUACULTURE**
edited by S.E. SHUMWAY 1991 xx + 1095 pages
22. **FRONTIERS OF SHRIMP RESEARCH**
edited by P.F. DeLOACH, W.J. DOUGHERTY, and M.A. DAVIDSON 1991 viii + 294 pages
23. **MARINE SHRIMP CULTURE: PRINCIPLES AND PRACTICES**
by A.W. FAST and L.J. LESTER 1992 xvi + 862 pages
24. **THE MUSSEL *MYTILUS*: ECOLOGY, PHYSIOLOGY, GENETICS AND CULTURE**
by E. GOSLING 1992 xiv + 589 pages
25. **MODERN METHODS OF AQUACULTURE IN JAPAN (2ND REV. ED.)**
edited by H. IKENOUE and T. KAFUKU 1992 xiv + 274 pages
26. **PROTOZOAN PARASITES OF FISHES**
by J. LOM and I. DYKOVÁ 1992 xii + 316 pages
27. **AQUACULTURE WATER REUSE SYSTEMS: ENGINEERING DESIGN AND MANAGEMENT**
edited by M.B. TIMMONS and T. M. LOSORDO
28. **FRESHWATER FISH CULTURE IN CHINA: PRINCIPLES AND PRACTICE**
edited by S. LI and J. MATHIAS 1994 xvi + 446 pages

PREFACE

Since 1991, China's fisheries production has continued to exceed 10 million tons each year. It has increased tremendously from a mere one million metric tons in 1951 to over 15 million metric tons in 1992.

Rapid aquaculture development has been identified as the key factor contributing to the remarkable growth of the Chinese fishery. Freshwater aquaculture accounts for about 36 percent of total fisheries production. Its growth can be attributed to scientific advances, adoption of new technologies, and expanded use of existing bodies of water and aquatic resources, all set in the context of economic reform and an open-door foreign policy.

The novel techniques of Chinese pond fish-farming have made China the world leader in freshwater aquaculture. The production from freshwater fish culture had increased from 0.81 million tons in 1979 to 5.3 million tons in 1992 (Qian, 1994). Chinese farmers with little land have recognized aquaculture as an effective avenue to wealth. This is particularly true in rural areas where aquaculture plays an active role in the continuing transformation towards a market economy. Aquaculture now takes its place as a significant segment of the "vegetable blanket", covering 1.2 billion Chinese, as it contributes more and more to increasing living standards. Aquaculture products also comprise a growing portion of the international market, in which China is becoming more competitive. In China, with its rich resources in water, fish and labour, aquaculture is a central life-force with its own vigorous social-economic-ecological vitality. It is a thriving industry.

The statistics of FAO (1991) clearly signal that world fish production from inland waters and most seas and oceans is reaching its biological peak of about 100 million tons, and that there are few new fisheries resources which can contribute to any substantial increase. On the other hand, the demand for aquatic products is increasing, for three main reasons: (1) population growth, (2) increase in disposable incomes and (3) increase in the relative preference for fish over other foods. Thus the continued development of aquaculture is assured. It is becoming widely believed that aquaculture will develop best in the context of agriculture, as a new crop within existing farming systems. China's fishery success follows from its advanced fishery techniques and the technology of freshwater fish culture. We believe that this technology is important not only for the Chinese, but can be of great benefit for the advancement of world aquaculture, particularly in the context of rural economic development in developing nations.

Although there are three thousand years of history to Chinese freshwater fish culture, and a rich literature on aquaculture has been produced in China, most of this is inaccessible to those unversed in the language. This situation affects the exchange of information and advancement of fisheries science and technology between China and other countries.

Aquaculture in China is noted for its diversification. It is difficult to master the profusion of Chinese aquaculture activity without deep investigation and study. Through this book, we wish to introduce the theory and practice of Chinese freshwater fish culture to the world. Fish resources, reproduction, feeding and nutrition, genetics and breeding, fry and fingerling nursing, integrated fish farming, fish culture in lakes, reservoirs, pens and cages, luxury species culture, as well as disease control are described. A representative collection of the Chinese literature is cited, much of it exposed to the world for the first time.

The authors would like to express their thanks to the International Development Research Centre (IDRC), Canada, for its support, and to Dr. Brian Davy and Mr. Andrew McNaughton for their encouragement to write this book. They also express their appreciation to the Department of Fisheries & Oceans, Government of Canada, for supporting this endeavour, and to Mr. Zhou Enhua for his translation of the first draft of the manuscript from Chinese to English. Special appreciation also goes to:

Dr. Neil Billington, Southern Illinois University at Carbondale, Carbondale, USA.

Dr. Edward Donaldson, West Vancouver Laboratory, Canada Department of Fisheries & Oceans, West Vancouver, Canada.

Dr. Brian Harvey, International Fisheries Gene Bank, Vancouver, Canada.

Dr. Richard Heckmann, Brigham Young University, Provo, USA.

Dr. Russell Kelly, Freshwater Institute, Canada Department of Fisheries & Oceans, Winnipeg, Canada.

Dr. Monty Little, Syndel Laboratories, Vancouver, Canada.

Prof. Zhou, Y.Q., Shanghai Fisheries University, Shanghai, China.

for their reviews during preparation of the manuscript.

Sifa Li
Professor
Shanghai Fisheries University
China

Dr. Jack Mathias
Research scientist
Department of Fisheries & Oceans
Freshwater Institute
Canada

References:

- FAO. 1991. Living marine resources. Research paper 5. Commissioned by the United Nations Conference on Environment and Development (UNCED). 41 p. Rome.
- Qian, Z.L. (ed.). 1994. The development of Chinese Fisheries and Manpower in Aquaculture. China Agricultural Press. Beijing. 212 p.

- | | | |
|----|-----------------|--|
| 1. | Wanqi Cai | Shanghai Fisheries University
Shanghai |
| 2. | Sifa Li | Shanghai Fisheries University
Shanghai |
| 3. | Tianfu Song | Shanghai Fisheries University
Shanghai |
| 4. | Ansheng Yan | Huazhong Agriculture University
Wuhan, Hubei Province |
| 5. | Huazhu Yang | Freshwater Fisheries Research Centre
Wuxi, Jiangsu Province |
| 6. | Xingzhong Zhang | Changjiang Fisheries Research Institute
Shasi, Hubei Province |
| 7. | Wenbiao Zheng | Huanan Normal University
Guangzhou, Guangdong Province |
| 8. | Lingen Zhu | Freshwater Fisheries Research Centre
Wuxi, Jiangsu Province |

TABLE OF CONTENTS

INTRODUCTION: FRESHWATER FISH CULTURE 1

Sifa Li

1. NATURAL RESOURCES	1
1.1 Geography and Climate	1
1.2 Water resources	3
1.3 Fishery resource	7
1.4 Aquatic productivity	9
2. HISTORY AND EVOLUTION	11
3. RECENT ACHIEVEMENTS	13
3.1 Rapid Increase in Fish Production	13
3.2 Expansion of Water Area Used for Aquaculture	14
3.3 Fish Culture in Ponds	14
3.4 Fishery Enhancement in Open Waters	15
4. THE TWO TRADITIONAL FISH CULTURE CENTRES	18
4.1 Changjiang River Delta	18
4.2 Zhujiang River Delta	20
5. FISHERIES EDUCATION AND RESEARCH	22
5.1 Fisheries Education Institutes	22
5.2 Fisheries Research Institutes	23
REFERENCES	24

Chapter 1. FISH SPECIES CULTURED 27

Sifa Li

1. CHARACTERISTICS OF FRESHWATER FISH RESOURCES	27
1.1 Species Richness	27
1.2 Habitat Diversity	27
1.3 Cyprinid Diversity	31
1.4 Highly Productive Species	31

2. MAJOR CULTURED FISH SPECIES	32
2.1 Silver Carp	32
2.2 Bighead Carp	35
2.3 Grass Carp	36
2.4 Black Carp	37
2.5 Common Carp	38
2.6 Crucian Carp	39
2.7 Blunt Snout Bream	40
2.8 Small Scale Fish	41
2.9 Mud Carp	42
2.10 Tilapia	43
2.11 Mandarin Fish	43
2.12 Eel	44
2.13 Rohu	45
2.14 Leather Catfish	45
2.15 Channel Catfish	46
2.16 Largemouth Bass	46
2.17 Freshwater Pompano	47
3. OTHER CULTURED AQUATIC ANIMALS	47
3.1 River Crab	47
3.2 Prawn	48
3.3 Soft-shell Turtle	50
REFERENCES	50
 Chapter 2. REPRODUCTION	51
Ansheng Yan	
1. NATURAL REPRODUCTION OF CHINESE CARPS	51
1.1 Reproductive Cycles	51
1.2 Ecological Conditions for Spawning	51
2. ENDOCRINOLOGY	56
2.1 Pituitary Extracts	57
2.2 Synthetic Hormones	58
2.3 Dompamine Antagonists	61
2.4 Sex Steroids	62
2.5 Antiestrogen Therapy	63
3. OOCYTE DEVELOPMENT AND GONADAL GROWTH	64
3.1 Oocyte Development	64
3.2 Classification of Ovarian Development	68

3.3 Classification of Testes Development	69
--	----

REFERENCES	70
-------------------	-----------

Chapter 3. FEEDING AND NUTRITION	79
---	-----------

Tianfu Song

1. FEEDING BIOLOGY	79
1.1 Morphology	79
1.2 Ecology	83
1.3 Nutrient Digestibility	88
2. NUTRIENT REQUIREMENTS	90
2.1 Proteins	90
2.2 Amino Acids	94
2.3 Lipids	95
2.4 Carbohydrates	96
2.5 Vitamins	97
2.6 Minerals	97
2.7 Energy Budget	101
3. NATURAL AND COMMERCIAL FOOD	104
3.1 Natural Foods	105
3.2 Commercial Feeds	108
3.3 Compound Feeds	115
3.4 Additives	116
REFERENCES	120

Chapter 4. GENETICS AND BREEDING	129
---	------------

Xingzhong Zhang

1. GENETIC CHARACTER OF CULTURED FISH	129
1.1 Cytogenetics	129
1.2 Nuclear DNA Content	131
1.3 Biochemical Genetics	132
2. SELECTIVE BREEDING	132
2.1 Red Purse Carp	132
2.2 Xinguo Red Carp	137
2.3 Wanan Glass-red Carp	138

2.4 Songpu Crucian Carp	138
2.5 Pengze Crucian Carp	139
3. HYBRIDS AND HETEROSIS	139
3.1 Useful Hybrids in Chinese Aquaculture	139
3.2 Cross Breeding and Selection	143
4. ALL-MALE TILAPIA PRODUCTION	145
4.1 Supermale Tilapia	146
4.2 Tilapia Hybridization	148
5. BIOENGINEERING	148
5.1 Cell Engineering	148
5.2 Cell Fusion	149
5.3 Development Potential of Cell Lines	150
5.4 Chromosome Engineering	151
5.5 Gene Engineering	153
6. GENETIC MANAGEMENT OF BROODSTOCK POPULATIONS	154
REFERENCES	156
 Chapter 5. ARTIFICIAL PROPAGATION	 163
 Lingen Zhu	
1. HATCHERY DESIGN	164
1.1 Brood Fish Ponds	164
1.2 Spawning Tanks	165
1.3 Hatching Incubators	167
2. CULTURE OF BROOD FISH	170
2.1 Basic Requirements	170
2.2 Source of Brood Fish	173
2.3 Stocking of Brood Fish	174
2.4 Silver and Bighead Carp	175
2.5 Grass Carp	176
2.6 Black Carp	177
2.7 Mud Carp	177
3. SPAWNING INDUCTION	177
3.1 Basic Principles of Induced Spawning	177
3.2 Inducing Agents	177

3.3 Injection	179
3.4 Selection of Spawners	181
4. SPAWNING	182
4.1 Response Time	182
4.2 Natural Spawning	183
4.3 Artificial Insemination	184
4.4 Egg Quality	184
5. HATCHING	185
5.1 Water Velocity and Quality	185
5.2 Water Temperature	185
5.3 Dissolved Oxygen	186
5.4 Calculations	187
REFERENCES	187
 Chapter 6. FRY AND FINGERLING PRODUCTION	189
Lingen Zhu	
1. FEEDING ORGANS AND HABITS	189
2. REARING OF FRY	193
2.1 Pond Management	193
2.2 Food and Nutrition	195
2.3 Stocking	200
3. REARING OF FINGERLINGS	202
3.1 Pond Conditions	202
3.2 Food and Nutrition	203
3.3 Nursing	208
4. REARING OF 2-YEAR-OLD FINGERLINGS	208
4.1 Grass Carp	209
4.2 Black Carp	210
5. NEW MEASURES FOR INCREASED PRODUCTION	212
5.1 Non-filtering Fish	212
5.2 Staggered Stocking	214
5.3 Rotary Stocking	214
5.4 Oxygenation	216
REFERENCES	217

Chapter 7. INTEGRATED FISH FARMING 219

Huazhu Yang

1. INTEGRATED FISH FARMING ECOSYSTEMS	219
1.1 Integration with Agriculture	219
1.2 Integration with Animal Husbandry	225
1.3 Integration with Agriculture and Animal Husbandry	229
1.4 Vertical, Multi-level Integration	233
1.5 Industrial Integration	235
2. POLYCULTURE	236
2.1 Biological Basis of Polyculture	236
2.2 Stocking Models and Ratios	239
3. FINGERLING STOCKING	247
3.1 Stocking Season	247
3.2 Stocking Density	247
3.3 Stocking Sizes of Fingerlings	248
4. ROTATION HARVESTING	250
4.1 Principles of Rotation Harvesting	251
4.2 Method of Rotary Harvesting	253
4.3 Mixed-age Culture in Grow-out Ponds	256
5. ENERGY CONVERSION	256
5.1 Filtering Fish Model	257
5.2 Grass Carp Model	257
5.3 Commercial Feed Model	258
5.4 Comparison of Efficiencies	258
6. MANAGEMENT OF GROW-OUT PONDS	261
6.1 Dissolved Oxygen	261
6.2 Manuring	263
6.3 Feeding	265
REFERENCES	265

Chapter 8. FISH CULTURE IN OPEN WATERS 271

Sifa Li

1. TYPES OF LAKES AND RESERVOIRS FOR FISH CULTURE	271
1.1 Lakes Used for Fish Culture	271
1.2 Reservoirs Used for Fish Culture	274

2. TROPHIC CLASSIFICATION OF LAKES AND RESERVOIRS	276
2.1 Oligotrophic Lakes and Reservoirs	277
2.2 Eutrophic Lakes and Reservoirs	277
2.3 Mesotrophic Lakes and Reservoirs	277
2.4 Fish Productivity and Trophic Classification	277
3. PREDICTION OF FISH PRODUCTIVITY	281
3.1 Prediction Using Prey Biomass	281
3.2 Prediction Using Primary Productivity	285
4. STOCKING IN LAKES AND RESERVOIRS	287
4.1 Species Selection	287
4.2 Stocking Density and Ratio	289
5. ENHANCEMENT OF FISHERIES RESOURCES	294
5.1 Fishery Closure	294
5.2 Size Limits	294
5.3 Species Introductions	294
REFERENCES	301
 Chapter 9. FISH CULTURE IN CAGES AND PENS	 305
Sifa Li	
1. FISH CULTURE IN CAGES	305
1.1 Operational Principles	306
1.2 Cage Design	308
1.3 Non-feeding Cage Model	316
1.4 Feeding Cage Model	320
1.5 Energy Efficiency	326
1.6 Eco-physiology of Caged Fish	327
2. FISH CULTURE IN PENS	330
2.1 Operational Principles	330
2.2 Pen Design	331
2.3 Technical Preparations	335
2.4 Stocking Models	336
3. ENVIRONMENTAL IMPACTS	340
3.1 Cage Carrying Capacity	340
3.2 Case Studies	341
REFERENCES	344

Chapter 10. SPECIAL TYPES OF AQUACULTURE 347**Wenbiao Zheng**

1. CULTURE OF LUXURY SPECIES	347
1.1 Eel Culture	347
1.2 Culture of Mandarin Fish	352
1.3 Catfish Culture	358
1.4 Culture of Bass, Snakehead, Perch and Other Species	363
2. INTEGRATED RICE-FISH CULTURE	368
2.1 History	368
2.2 Biological Principles	369
2.3 Techniques of Fish Culture	376
2.4 Economics	381
REFERENCES	382

Chapter 11. FISH DISEASES 387**Wanqi Cai**

1. OVERVIEW	387
1.1 A Brief History	387
1.2 Prophylaxis of Fish Disease	389
1.3 Treatment of Fish Diseases	392
2. SPECIFIC DISEASES	393
2.1 Microbial Disease	393
2.2 Parasitic Diseases	407
3. ENVIRONMENTAL DISEASES	419
3.1 Water Quality Diseases	419
3.2 Food Deficiency Diseases	420
REFERENCES	420

INDEX 425

INTRODUCTION: FRESHWATER FISH CULTURE

Sifa Li

1. NATURAL RESOURCES

1.1 Geography and Climate

The People's Republic of China lies in Eastern Asia and covers an area of 9,600,000 km². It spans about 5000 km from east to west and 5500 km from south to north. China consists of 23 provinces, 5 autonomous regions and 3 municipalities directly under the Central Government (Figure 1).

China is situated in the temperate, subtropical and tropical zones. The temperature increases from north to south (Figures 2, 3) and the minimum air temperature difference between the south and north is over 30°C during the winter and 4.5°C in the summer. There are 12 growing months in a year in the Zhujiang (Pearl) River basin, 10 months in the Changjiang (Yangtze) River basin, 8 months in the Huanghe (Yellow) River basin, 6 months in the Heilongjiang (Amur) River basin and about 7 months in the northwest plateau area when the average monthly air temperature is above 10°C. In the above four river basin areas, the average monthly water temperature is over 18°C for 10, 7, 6, and 5 months, respectively. Most parts of China have a mild climate with four distinct seasons thus providing favourable ecological conditions for growth and reproduction of various aquatic organisms.

The average annual precipitation is 450 mm. Eastern China borders on the Pacific Ocean, has a higher annual rainfall of 400-2000 mm and has ample water resources for fishery production. Monsoons from the Pacific and Indian Oceans affect locations south of the Huaihe River and Qingling mountain (Figure 4), such as the mid and lower reaches of the Changjiang River, Zhujiang River, Yunnan-Guizhou plateaux and Sichuan basin where the average annual precipitation is 800-2400 mm. These locations belong to the 'wet areas' which are considered to be most suitable for the development of freshwater aquaculture. Monsoons also affect the area north of the Huaihe River to the outer Xing'anling Mountain (near the Great Wall, Figure 4) where the annual precipitation is 400-800 mm. These places are called 'semi-wet', and are considered to be of secondary importance for freshwater aquaculture. Northwest China, as well as the Qinghai and Tibet areas are comparatively dry with less rainfall.

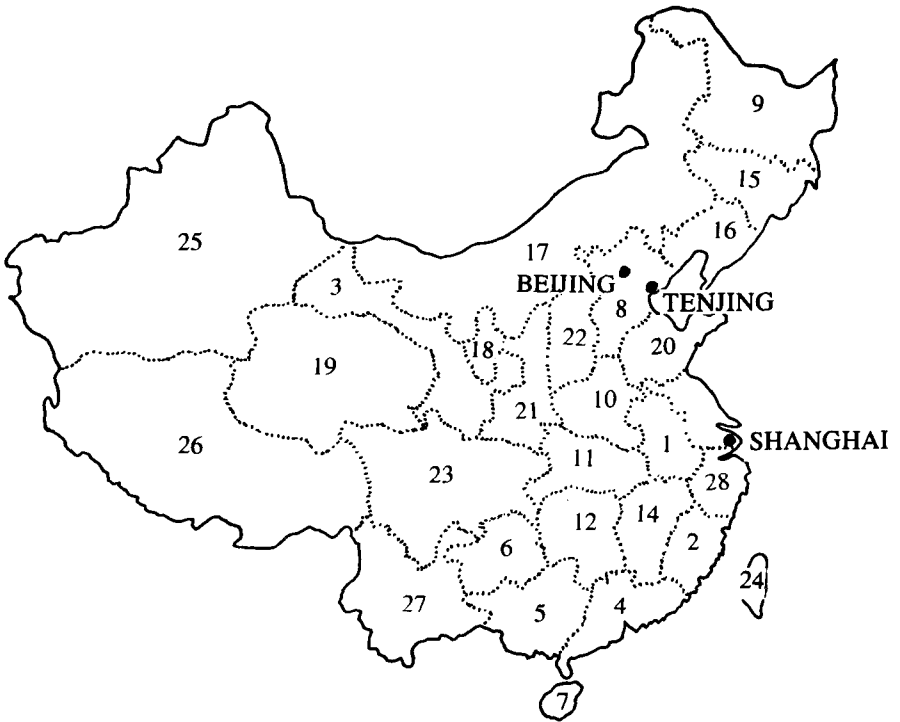


Figure 1. Administrative division of the People's Republic of China

Provinces and Autonomous Regions

1. Anhui	2. Fujian	3. Gansu	4. Guangdong
5. Guangxi	6. Guizhou	7. Hainan	8. Hebei
9. Heilongjiang	10. Henan	11. Hubei	12. Hunan
13. Jiangsu	14. Jiangxi	15. Jilin	16. Liaoning
17. Neimeng	18. Ningxia	19. Qinghai	20. Shandong
21. Shaanxi	22. Shanxi	23. Sichuan	24. Taiwan
25. Xinjiang	26. Xizang	27. Yunnan	28. Zhejiang

Municipalities

1. Beijing	2. Tianjin	3. Shanghai
------------	------------	-------------