Agro-climatic Division of *Rana chensinensis* in Fushun

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Abstract　Based on data collected by 3 basic weather stations in Fushun City and 47 automatic weather stations in the whole region，we selected indexes suitable for agro-climatic division of *Rana chensinensis*，and carried out a study on agro-climatic division of *Rana chensinensis* in this region. Annual active accumulated temperature ≥10 ℃ and precipitation during April and September are used as basic calculation factors，and we use climatic aridity to make climatic division of *Rana chensinensis* in Fushun City. According to relevant indexes，we divide Fushun City into 3 regions，namely most appropriate，appropriate and general regions. Finally，countermeasures and suggestions are put forward for providing reference for agricultural production.

Key words　Fushun，*Rana chensinensis*，Agro-climatic division

Fushun City lies in northeast of Liaoning Province and belongs to East Asian continental monsoon climatic zone. It is characterized by frequent rain in summer，long winter，great temperature difference，and distinct division of four seasons. The annual mean temperature of the region is 3. 8 to 8. 4 ℃；the annual rainfall range is 718 to 880 mm；the mean annual hours of sunshine is 1 860 to 2 750 hours；so there are rich climatic resources. Fushun is source region of Hunhe River，Chaihe River，Qinghe River and Liuhe River in eastern part of Liaoning Province. It is also the drinking water protection zone of many cities，including Shenyang City and Fushun City. Fushun region has moist climate，the soil is fertile，water resource is sufficient，and so the whole area is " eight mountains，one water and one field" . The forest coverage reaches 68. 9% in Fushun City，so the forest resource is rich. This structure provides favorable condition for development of agriculture，forestry，animal husbandry，and fishery.

The Asiatic Grass Frog or Chinese Brown Frog is also called *Rana chensinensis* or hasma. It belongs to Amphibia，Order Anura，and Ranidae Family，is amphibian that has extremely high economic value[1-2]. The hasma fat is reputed as soft gold and deemed as nourishing product[3]. *Rana chensinensis* is always natural species in Fushun，and it is distributed in all regions of Fushun City. With moist climate，dense forest，many great and small rivers，Fushun City is a good natural habitat for *Rana chensinensis*.

1　Data source and methods

1.1　Source of data　Data is selected from ground meteorological observational data during 1961 to 2008 in 3 basic weather stations in Fushun and 47 automatic weather stations in the

whole region.

1.2　Biological and metrological indicator of *Rana chensinensis*　*Rana chensinensis* moves to water source region in forest from late September，enters shallow water region in the end of September to the beginning of October，swims to deep water region from late October and early November，and lives through the winter in deep water region from late November to the next middle March. In the end of March to the beginning of April，*Rana chensinensis* starts to come out of hibernation. After coming out of hibernation，*Rana chensinensis* stays in hallow water for breeding at temperature about 10 ℃，and water depth should be 20 to 30 cm. During the growth of tadpoles，water temperature should be 20 to 25 ℃. If the temperature is lower than 10 ℃ or higher 28 ℃，*Rana chensinensis* may die.

Till early and middle April，when water temperature is above 2 ℃ and air temperature is above 5 ℃，*Rana chensinensis* revives from hibernation. Thus，it is required to put *Rana chensinensis* into spawning pond at this time. When water temperature and air temperature rise to 8 ℃ or so，*Rana chensinensis* starts ovulating. The ovulation has three periods：when water temperature in the pond reaches 2. 5 ℃ and air temperature reaches 7. 8 ℃，the ovulation begins；when water temperature in the pond reaches 4 ℃ and air temperature reaches 9. 7 ℃，the ovulation reaches peak period；when water temperature in the pond reaches 6 ℃ and air temperature reaches 10 ℃，the ovulation stops. It shows the temperature requirement is different in stages of ovulation. From cleavage to blastula period，it is highly adaptive to low temperature，and it can develop in water temperature about 2 ℃，but develops slowly. In this period，the appropriate temperature is 5 to 7 ℃. From blastula period to gastrula period，the appropriate temperature is about 8 to 10 ℃. From gastrula period to neurula period，the appropriate period is 10 to 12 ℃. This stage is also the period when egg embryo is most sensitive to external temperature，especially to low temperature，embryo is likely to die，which is one of

the major reasons of low incubation rate. Therefore, from the embryo to complete tadpole, the appropriate air temperature is 9 to 11 ℃, the suitable water temperature is 10 to 14 ℃, and incubation time is about 15 days.

When air temperature drops to −5 to 10 ℃, *Rana chensinensis* starts hibernating. Therefore, it is preferred to grasp trend of climatic changes before winter has set in, to ensure their safety during hibernation.

2   Results and analyses

2.1   Index for zoning of *Rana chensinensis*

2.1.1   Climatic aridity. Compared with other natural conditions, *Rana chensinensis* prefers to cool and moist climate environment. In this situation, we take the aridity as the index for zoning of *Rana chensinensis* in Fushun City.

2.1.2   Calculation method and formula of aridity. We use annual active accumulated temperature ≥10 ℃ and precipitation during April and September as basic calculation factor, and calculate the aridity with following formula:

$$k = 0.1 \sum_{i=1}^{n} X_{\geqslant 10 ℃} / R_{4-9} \tag{1}$$

where, k is aridity; $\sum T \geqslant 10$ ℃ means the active accumulated temperature ≥10 ℃; and R_{4-9} refers to the precipitation during April and September. The calculation results of the aridity in all areas of Fushun City are listed in Table 1.

2.1.3   Designation of climate type. Method of index determination: since there is only slight difference in growth conditions of *Rana chensinensis* in regions of Fushun City, we only divide growth conditions of *Rana chensinensis* in regions of Fushun City into three grades, namely, moist, general and arid.

2.1.4   Calculation method, formula and results of zoning index. We take standard deviation (STD) as limit index to calculate the mean aridity ±STD. The STD is indicated by σ. When $k \geqslant -\bar{k} - \sigma$, it is determined as arid; when $-\bar{k}$ is between ± σ, it is determined as general; and when $k \leqslant -\bar{k} - \sigma$, it is determined as moist. The STD σ is calculated by the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}} \tag{2}$$

Through calculation, the average aridity of Fushun regions $\bar{x}(k) = 0.43$, $n = 50$. We use v_1 to stand for arid, v_2 to refer to general, and v_3 to indicate moist. The calculation results: $v_1 \geqslant 0.46$; $0.4 < v_2 < 0.46$; $v_3 \leqslant 0.40$.

Table 1   Climatic aridity and zoning of Fushun City

Township	Aridity k	Ranking of aridity analytical data			Climate type	Evaluation of growth condition of *Rana chensinensis*
		Deviation ∥ $\triangle k$	Square sum	Grade		
Xiangshuihezi	0.400	−0.030 1	0.000 9	3	Moist	Most appropriate
Muqi	0.394	−0.035 7	0.001 3	3	Moist	Most appropriate
Dasiping	0.379	−0.050 8	0.002 6	3	Moist	Most appropriate
Wangqingmen	0.396	−0.034 1	0.001 2	3	Moist	Most appropriate
Dasuhe	0.373	−0.057 4	0.003 3	3	Moist	Most appropriate
Beisiping	0.391	−0.038 7	0.001 5	3	Moist	Most appropriate
Hongsheng	0.390	−0.040 4	0.001 6	3	Moist	Most appropriate
Wandianzi	0.373	−0.056 6	0.003 2	3	Moist	Most appropriate
Yongling	0.372	−0.057 8	0.003 3	3	Moist	Most appropriate
Pingdingshan	0.392	−0.037 7	0.001 4	3	Moist	Most appropriate
Xiajiabao	0.369	−0.061 1	0.003 7	3	Moist	Most appropriate
Majuanzi	0.388	−0.042 5	0.001 8	3	Moist	Most appropriate
Hongtoushan	0.398	−0.032 3	0.001 0	3	Moist	Most appropriate
Tangtu	0.379	−0.050 8	0.002 6	3	Moist	Most appropriate
Yushu	0.426	−0.003 8	0.000 0	2	General	Appropriate
Xiajiahe	0.421	−0.009 2	0.000 1	2	General	Appropriate
Nanzamu	0.410	−0.020 3	0.000 4	2	General	Appropriate
Shangjiahe	0.400	−0.029 8	0.000 9	2	General	Appropriate
Beisanjia	0.437	0.007 3	0.000 1	2	General	Appropriate
Nankouqian	0.415	−0.014 7	0.000 2	2	General	Appropriate
Aojiabao	0.406	−0.023 8	0.000 6	2	General	Appropriate
Ying'emen	0.455	0.025 3	0.000 6	2	General	Appropriate
Gounaidian	0.401	−0.029 2	0.000 8	2	General	Appropriate
Caoshi	0.437	0.006 8	0.000 0	2	General	Appropriate
Dagujia	0.425	−0.004 6	0.000 0	2	General	Appropriate
Tukouzi	0.438	0.008 1	0.000 1	2	General	Appropriate
Nanshancheng	0.430	0.000 0	0.000 0	2	General	Appropriate
Shangma	0.450	0.020 4	0.000 4	2	General	Appropriate
Lanshan	0.141	0.011 4	0.000 1	2	General	Appropriate
Weiziyu	0.406	−0.023 8	0.000 6	2	General	Appropriate
Hada	0.426	−0.003 8	0.000 0	2	General	Appropriate
Houan	0.445	0.014 8	0.000 2	2	General	Appropriate

To be continued

Continued（Table 1）

| Township | Aridity *k* | Ranking of aridity analytical data | | | Climate type | Evaluation of growth condition of *Rana chensinensis* |
		Deviation △*k*	Square sum	Grade		
Hailang	0.452	0.022 4	0.000 5	2	General	Appropriate
Xinbin	0.444	0.013 7	0.000 2	2	General	Appropriate
Zhangdang	0.441	0.011 5	0.000 1	2	General	Appropriate
Qingyuan	0.456	0.026 2	0.000 7	2	General	Appropriate
Huiyuan	0.475	0.045 3	0.002 0	1	Arid	General
Development zone	0.55l	0.120 0	0.014 4	1	Arid	General
Hongmiaozi	0.474	0.044 1	0.001 9	1	Arid	General
Jiubing	0.462	0.032 2	0.001 0	1	Arid	General
Xiahe	0.471	0.040 7	0.001 7	1	Arid	General
Houyaolinchang	0.477	0.047 2	0.002 2	1	Arid	General
Shiwen	0.474	0.044 0	0.001 9	1	Arid	General
Lagu	0.475	0.044 7	0.002 2	1	Arid	General
Henanshuichang	0.502	0.072 4	0.005 2	1	Arid	General
Tayu	0.489	0.058 8	0.003 5	1	Arid	General
Municipal government	0.480	0.049 8	0.002 5	1	Arid	General
Gaowan	0.472	0.042 4	0.001 8	1	Arid	General
Qiandian	0.477	0.047 0	0.002 2	1	Arid	General
Nianpan	0.461	0.031 3	0.001 0	1	Arid	General

2.2 Regions appropriate for *Rana chensinensis* Based on the above index, appropriate regions of *Rana chensinensis* in Fushun City are classified into three types：zone I is moist region, which is most appropriate region；zone II is relatively moist region, which is appropriate region；and zone III is arid region, which is general region. Zone I includes Xiangshuihezi, Muqi, Dasiping, Wangqingmen, Dasuhe, Beisiping, Hongsheng, Wandianzi, Yongling, Pingdingshan, Xiajiabao, Majuanzi, Hongtoushan, and Tangtu townships；zone II includes Yushu, Xiajiahe, Nanzamu, Shangjiahe, Beisanjia, Nankouqian, Aojiabao, Ying'emen, Gounaidian, Caoshi, Dagujia, Tukouzi, Nanshancheng, Shangma, Lanshan, Weiziyu, Hada, Houan, Hailang, Xinbin, Zhangdang, and Qingyuan townships；and zone III includes Huiyuan Township, Development Zone, Hongmiaozi, Jiubing, Xiahe, Houyaolinchang, Shiwen, Lagu, Henanshuichang, Tayu, Municipal Government, Gaowan, Qiandian, and Nianpan townships.

3 Conclusions and discussions

According to living habits of *Rana chensinensis*, and in combination with actual climatic situations of Fushun City, we can divide climatic regions of *Rana chensinensis* in Fushun City into three zones. Zone I is the most appropriate region for growth of *Rana chensinensis*. This zone mainly includes southeastern areas of Fushun County, southern areas of Qingyuan County and middle areas of Xinbin County, most of which are river basins at higher land areas, or shady slope of source region or upstream areas. This zone features low temperature, much precipitation, high air humidity, much fog, dense forest and high mountains, many rivers, and favorable ecological conditions. All of these conditions are favorable for growth of *Rana chensinensis*. Zone II is appropriate region for growth of *Rana chensinensis*. Some areas of this region is as good as Zone I. However, due to most townships are located in mid-stream and downstream, the basin area decreases, farmland area increases, population increases and natural ecological conditions are not so good as Zone I. There is no big difference in precipitation between Zone I and II, but the temperature of Zone II is obviously higher than Zone I, so the probability and intensity of aridity of Zone II is greater than Zone I. As a result, Zone II is appropriate region for growth of *Rana chensinensis*. Zone III has general conditions for growth of *Rana chensinensis*. Most townships in this zone are situated in downstream or separated from mountainous areas, so the basin area is much smaller. Farmland and town become major part. The precipitation is still appropriate, but the temperature becomes higher, and the higher probability and intensity of aridity become unfavorable factors. Consequently, Zone III is not favorable for natural growth of *Rana chensinensis*. Nevertheless, artificial propagation is completely worth trying.

In line with agro-climatic division of *Rana chensinensis* in Fushun, it is proposed to：（i）strengthen natural propagation from west to east, and strengthen artificial propagation from east to west；（ii）strengthen small basin protection to improve ecological environment；（iii）formulate strict policy and management method for catching *Rana chensinensis*；and（iv）strengthen technical guidance of scientific development.

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