How this researcher is transforming the goose industry one 'artificial day' at a time

Professor Zhendan Shi of Jiangsu Academy of Agricultural Sciences and his team are working to revolutionise the goose industry by inducing continuous, year-round production in domestic geese. The economically important waterfowl are utilised to supply meat, eggs and feathers in China and the annual production totals more than 600 million birds. However, seasonal breeding behaviours limit gosling and commercial meat goose production to a certain time of year. By understanding the regulatory mechanisms behind seasonal breeding and designing complex lighting programmes, Shi and his team not only realised out-of-season breeding, but also improved egg-laying performance over conventional production. Their research greatly improves the economic efficiency, sustainability and expansion of the goose industry.

Domestic geese are economically important waterfowl that supply eggs, meat and feathers to many parts of the world. The goose industry is particularly lucrative for China which, as of 2015, supplies over 90% of the world's geese.

However, seasonal breeding behaviours restrict the production of goslings and commercial meat geese to a certain time of year. This causes large price fluctuations for the birds throughout the year and discourages goose consumption. Through their research, Professor Shi and his team hope to induce continuous, year-round breeding in geese, leading to improved economic efficiency, sustainability, growth and modernisation of the goose industry.

Over the last 15 years, Professor Zhendan Shi of Jiangsu Academy of Agricultural Sciences and his team have sought to turn the goose industry on its head by changing breeding seasons in domestic geese by artificially changing their day length or 'photoperiods'.

Domestic geese are economically important waterfowl that supply eggs, meat and feathers to many parts of the world.

Their approach is based on the theory that light signals detected by photoreceptors in birds' brains can either stimulate (photostimulation) or inhibit (photorefractoriness) reproductive activities. In this theory, photostimulation occurs when photoreceptors in the brain set off a chain reaction of enzyme activities and nervous impulses that trigger hormone creation and secretion in the pituitary gland underneath the brain (as explained in Figure 1). These hormones, called gonadotrophins, stimulate gonad growth and development and sexual behaviour. Likewise, the photoreceptors can trigger the production of another set of hormones that lead to gonad regression and end the breeding season.

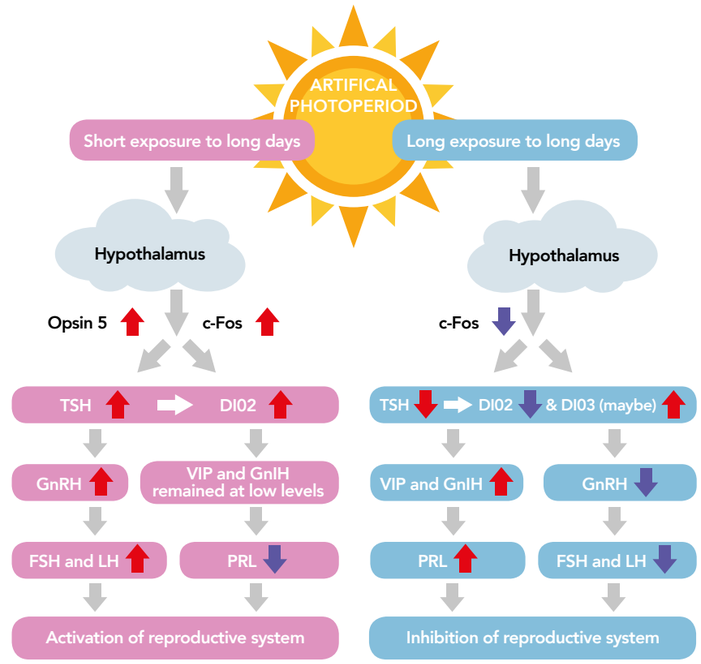
NATURE OF SEASONAL BREEDING

Seasonal breeding is a physiological mechanism that helps animals living in the wild to cope with the seasonal fluctuations in climate and food availability.

Wild birds living in cold or temperate regions rely on seasonal breeding to ensure their young have maximal chances of survival. The timing and duration of their breeding season is based on seasonal changes in environmental conditions. In the case of geese, this is based on the daily photoperiod, where longer photoperiods signal the arrival of spring or summer, and with them, abundant food and – for those living in colder regions – optimal temperatures for survival.

As a result, most birds are long-day breeders, reproducing in the spring, hatching their young in late spring or early summer and finishing their breeding season in early-to-mid summer. This ensures chicks have enough time to grow and prepare for the harsh winter or long migration ahead.

Figure 1: Diagram of photoperiodic regulation pathways that regulate reproductive systems in geese. Light can penetrate the bird's skull and activate photoreceptors such as opsin proteins that reside in the deep brain. Through a series of enzymatic reactions and hormone syntheses and regulations, GnRH is secreted by the hypothalamus. This drives secretion of gonadotrophins, FSH and LH, by the pituitary gland, which activates the reproductive system. On the other hand, inhibitive photo-signals lead to the production and secretion of different hormones: VIP and GnIH. GnIH inhibits gonadotrophin secretion by the pituitary gland, while VIP stimulates secretion of another reproductive hormone called prolactin.



While domestic geese don't have to worry about harsh winters or long migrations, they continue to display seasonal breeding behaviours. This is also true of domestic geese living in warmer regions which have contrasting breeding seasons.

Based on studies conducted by Professor Shi and his colleagues, that surveyed year-round egg-laying data from eight geese breeds, from north to south, throughout the vast area of China, geese can be categorised into one of three types based on their habitat locations and subsequent breeding seasonality:

1 Northern long day breeders – breeding occurs during the long days in spring and early summer,
2 Middle latitude long day breeders – breeding occurs in late autumn and ends in spring or early summer, and
3 Southern short day breeders – breeding starts in late summer and ends in spring.

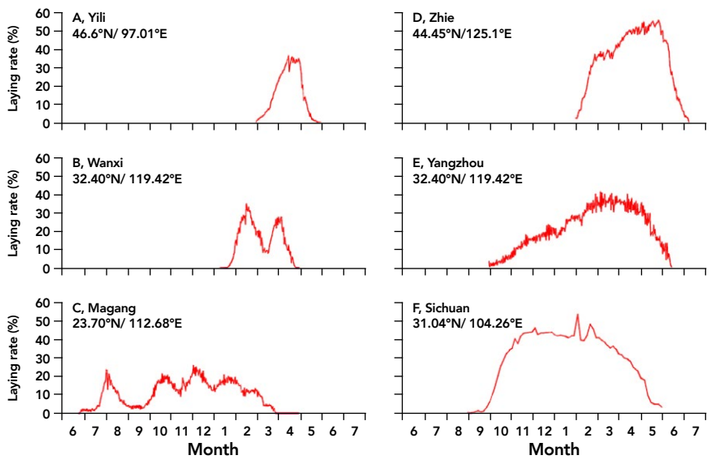
The extended breeding season of type 2 geese (Yangzhou geese) is attributed to milder temperatures experienced in the temperate zones and less extreme changes in daily photoperiods. Meanwhile, the milder winters experienced by type 3 geese (such as Magang geese) living in subtropical zones allow them to continue their breeding season for most of the year. However, unlike the long day breeders, these geese do not fare well in summer.

A MATTER OF TIME

In practical production of the goose industry, the lack of eggs laid in summer interrupts gosling hatching and commercial goose production. This sends the prices of meat geese and goslings skyrocketing. Farmers therefore wish to be able to breed goslings out-of-season in the summer months. Professor Shi first started to help farmers solve this seasonal breeding problem in the short-day breeding Magang goose in Guangdong Province. Treating birds with a very long photoperiod of 18 hours of light per day in winter months allowed them to stop egg laying. After the geese rested for two and a half months, and were ready for laying eggs again, a shortening of the daily photoperiod to 11 hours from early summer induced the geese to lay eggs again. This short 11-hour photoperiod helped to maintain good secretion of the pro-reproductive hormones, gonadotrophins, but depressed secretion of the reproduction-inhibiting hormone prolactin. Geese were able to manifest full egg laying activity. With this photoperiodic system, the egg laying capacity of Magang geese could be increased from the norm of 35–40 by 30% to 50–55.

The story on the long day breeding Yangzhou geese is more complicated. In opposition to that used for the Magang geese, a simple photoperiod program

Figure 2: Egg laying curves of six indigenous geese breeds at different locations throughout China.



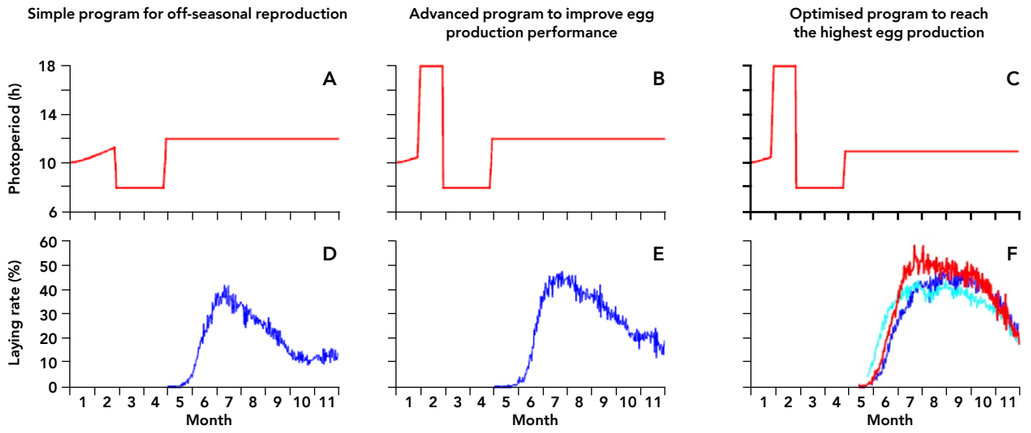


Figure 3: Diagram of increasing egg production in out-of-season breeding Yangzhou geese by improvement of photoperiod programs. Left panel, a simple program produces 45 eggs per bird. Middle panel, an additional 18 hour long photoperiod treatment increased egg production to 55. Right panel, shortening of daily photoperiod during out-of-season breeding in summer months further brought the egg laying performance to 70-75 per bird.

(8 hours per day in winter, and 12 hours per day from spring to summer) was used to induce egg laying in summer months. However, the egg production performance following this regime is not very long, only yielding 45 eggs per bird. An additional treatment of a very long photoperiod of 18 hours for one month prior to the 8-hour short days, can prime the geese to synthesise higher amounts of pro-reproductive hormones or gonadotrophins FSH and LH, and enhance the egg-laying capacity to 55 eggs per bird. If the daily photoperiod is further shortened from the previous 12 hours to 11 hours, secretion of prolactin is depressed for much longer periods, and the reproductive system remains fully active accordingly, so egg production is further increased to 70–75 per bird.

While this may not sound important, it has huge implications for goose productivity when applied to industry. An increase in goose productivity translates to an increase in income for geese farmers which can have wider ranging economic benefits. As a result, Professor Shi suggested that the industry adopt a regime where geese are exposed to a cycle of relatively long photoperiods of 11 hours followed by shorter photoperiods of around 8 hours. However, this may vary slightly depending on goose breeding type.

That said, Professor Shi's photoperiod programs can be used to synchronise sexual activities of long or short day breeding geese, allowing farmers to cross-breed geese with high efficiency, which was previously very difficult.

Apart from using the photoperiod, timing of gosling stocking is also important. By stocking goslings from January to May, farmers can ensure they'll start laying as soon as they reach sexual maturity (7 or 8 months old). Conversely, goslings stocked from October to December would be inhibited from reproducing until at least September the following year, as the prevailing photoperiod would prevent reproductive activity.

IMPACT ON INDUSTRY

The ability to produce geese out-of-season using artificial photoperiods has significantly improved productivity and profit margins within the Chinese goose industry and caused farms to grow exponentially.

In fact, annual production of commercial geese has increased at a rate of three to four percent per year since the technique was developed in 2000. Currently, there are 87 million commercial geese produced each year in Guangdong Province alone, compared to 41 million in 2000.

The goose industry's rapid growth has helped foster year-round consumption and encouraged enterprises to invest in goose production in anticipation of increasing market demands – particularly in north and east China.

As a result, farmers using the out-of-season lay technique have achieved net profits four to six times higher than those using natural reproduction of goslings and almost double those naturally producing commercial meat geese.

This has helped change farmers' lives considerably. Where goose raising used to be a small-scale family side practice, it has now become a specialised, lucrative business. High earnings have helped farmers to not only improve their living standard, but also to educate themselves, as well as their younger generations.

The latter are now more attracted to farming and developing agri-business, which adds new impetus to rural development. Professor Shi expects this trend to continue with widening adoption of his out-of-season breeding technique and modernisation of the goose industry.

While domestic geese don't have to worry about harsh winters or long migrations, they continue to display seasonal breeding behaviours.

Behind the Research

Professor Zhendan Shi

E: zdshi@jaas.ac.cn **T:** +86 25 84390683 **W:** www.jaas.ac.cn

Research Objectives

Professor Zhendan Shi's work aims to better understand the breeding behaviour of geese in order to strengthen and modernise the goose industry in China.

Detail

Institute of Animal Science
Jiangsu Academy of Agricultural Sciences
50 Zhongling Street
Nanjing, 210014
China

Bio

Dr Shi studied in New Zealand in his youth before returning to China. He first taught at South China Agricultural University, and now is Deputy director of Institute of animal science. His main area of research is on regulation of animal reproductive activities, both in poultry and farm animals.

Collaborators

- Huanxi Zhu
- Yunmao Huang
- Aidong Sun

References

Shi, Z., Tian, Y., Wu, W. and Wang, Z. (2008). Controlling reproductive seasonality in the geese: a review. *World's Poultry Science Journal*, 64, 343-355.

Sun, A., Shi, Z., Huang, Y. and Liang, S. (2007). Development of out-of-season laying in geese and its impact on the goose industry in Guangdong Province, China. *World's Poultry Science Journal*, 63, 481-490

Zhu, H., Chen, Z., Shao, X., Yu, J., et al. (2017). Reproductive axis gene regulation during photostimulation and photorefractoriness in Yangzhou goose ganders. *Frontiers in Zoology*, 14 (11), 1-15.

Zhu, H., Liu X, Hu, M., Lei, M., et al. (2019). Endocrine and molecular regulation mechanisms of the reproductive system of Hungarian White geese investigated under two artificial photoperiodic programs. *Theriogenology*, 123, 167-176.

Pingel, H. (2011). Waterfowl production for food security. Lohmann Information [online] 46 (2), 32-42. Available at: www.lohmann-information.de/content/l_i_46_artikel13.pdf [Accessed 20.11.18]

Personal Response

What ethical challenges, if any, have you faced when conducting these experiments and how do you approach them?

"Changing geese breeding seasonality may damage their welfare as the public may consider. However, regulation of geese reproductive activity using artificial photoperiod does not differentiate from that by the natural photoperiod. In addition, geese were in practice given better housing to protect them from cold in winter, and cool ventilation in summer to avoid heat stress. Better nutritional and zootechnic measures were adopted in order to provide geese with better welfare and hygiene that guarantee their health and production performances."