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Patterns of use and exchange of genetic resources of the striped catfish *Pangasianodon hypophthalmus* (Sauvage 1878)

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Abstract

The present paper reviews the use and exchange of genetic resources of the migratory freshwater fish *Pangasianodon hypophthalmus* (Sauvage 1878) (the striped or sutchi catfish). This species is naturally distributed in the Mekong River and Chao Phraya River basins, and is cultured in several countries, but current production occurs predominantly in the Mekong Delta, Vietnam. Catfish aquaculture in Vietnam has evolved from extensive systems using wild-caught seed to an intensified farming system that is entirely dependent on hatchery-produced seed. Genetic improvement programmes on catfish have started in Vietnam, but are still in their infancy. Genetic studies have revealed several subpopulations of the species. Apart from selective breeding and the production of hybrids with closely related species, no other technologies have been applied to improve the performance of catfish. The use and exchange of *P. hypophthalmus* genetic resources have brought benefits to rural communities. Aquaculture development of catfish has evolved from being seen as an exploitation of natural resources to an activity that can reduce pressure on wild fish populations. Management of aquaculture stocks need to be rationalised to minimise the potential impacts it might cause to wild populations.

Key words: aquaculture, Mekong River, *Pangasianodon hypopthalmus*, population structure, striped catfish, translocation.

Introduction

Pangasianodon hypophthalmus (Sauvage 1878), often referred to as striped or sutchi catfish, is a freshwater species belonging to the family Pangasidae, and it is the only congener of the critically endangered Mekong giant catfish, *Pangasianodon gigas* (Chevey 1931) (Pouyaud *et al.* 2000; Na-Nakorn *et al.* 2006a). Striped catfish is a migratory species that is found naturally in the Mekong River and the Chao Phraya River basins (Rainboth 1996), but recently it has been translocated to other areas, primarily for aquaculture purposes (Fig. 1).

Pangasianodon hypophthalmus is an important species to the Mekong riparian countries. It is considered a valued food fish of great economic significance to many countries. Aquaculture of *P. hypophthalmus* has developed rather rapidly in recent years, generating significant employment opportunities and income to rural communities, as well as becoming a significant foreign exchange earner for Vietnam. However, reports have shown that wild stocks have greatly declined (Van Zalinge *et al.* 2002) because all stages of development, including fry to spawners, have been heavily exploited, particularly prior to the development of artificial propagation techniques in Vietnam (Cacot *et al.* 2002).

In Vietnam, the culture systems and practices have evolved over a period of four to five decades. Traditionally, wild-caught seed of striped catfish were stocked in latrine ponds and the produce was consumed domestically. However, current culture practices are much more intensified, using hatchery-produced seed and almost all catfish production in Vietnam currently is for export

Figure 1 Map showing the natural distribution of *Pangasianodon hypophthalmus* and the main locations on the Mekong and Bassac rivers where fry and fingerlings were collected for aquaculture before 1994. 1, Kampong Cham; 2, Kandal and Prey Vieng; 3, An Giang and Dong Thap.

(Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009).

Aquaculture of *P. hypophthalmus* in Vietnam is one of the most successful primary food production sectors in the world (Phuong & Oanh 2009). It achieved a production level of 835 000 t in the first 7 months of 2008 (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009), recording the fastest growth of a single species in any aquaculture sector; average production was approximately 400 t ha^{-1} per crop, superseding the production per unit area in other primary production sectors (Lam *et al.* 2009).

Over 90% of cultured catfish is processed and exported to more than 100 countries globally (Nguyen 2007; Wilkinson 2008; Phuong & Oanh 2009). In the first 7 months of 2008 the catfish export income from Vietnam topped US$740 000 (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009); third to global food export from shrimp and salmonid culture. The catfish farming sector provides jobs for 105 535 people (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009), the bulk of which are in the processing sector, mostly for rural women.

It is apparent that *P. hypophthalmus* plays a very important role in socioeconomic development in Vietnam, and in other countries where aquaculture of striped catfish is practised. Genetic resources of *P. hypophthalmus* have also been developed, mainly through selective breeding and hybridisation, with the latter only practised in Thailand (Naruepon Sukumasavin, pers. comm., 2005) and Indonesia (Maskur, pers. comm., 2009). It has been suggested that it is desirable to have rules and regulations in place for access to aquatic genetic resources early in the development of a new species for culture, in particular to avoid the movement of these resources and use in a variety of ways making later 'protection and control of access' much more difficult (see Olesen *et al.* 2007). As such it is important that any available genetic resources of the species and their uses are documented.

Genetic resources covered

The development and understanding of the genetic resources of *P. hypophthalmus* are currently very limited. Compared to other cultured commodities, such as tilapia, shrimp and salmon, domestication of striped catfish for aquaculture is still in its infancy. Apart from wild stocks, domesticated stocks are also available in several countries, such as Thailand and Vietnam. In addition, hybrids *P. hypophthalmus* × *Pangasius bocourti* Sauvage, 1880 are available in some private farms in Thailand (Naruepon Sukumasavin, pers. comm., 2006), and *P. hypophthalmus* × *Pangasius djambal* Bleeker, 1846 are used for cage culture in large reservoirs in Indonesia, such as Cirata and Jatiluhur, West Java, using seed from private hatcheries (Maskur, pers. comm., 2009).

Users and uses of *P. hypophthalmus* genetic resources

The production of *P. hypophthalmus* is solely for human consumption, although offal discarded from processing plants is used to extract oil and produce meal for animal feeds. The production chain of *P. hypophthalmus* can be divided into four separate sectors (Fig. 2): hatchery, nursery, grow-out and processing (Phuong & Oanh 2009).

Broodstocks used by the hatcheries originate from two different sources. Before 2000, broodstock, fry and fingerlings were collected from the wild and grown in ponds

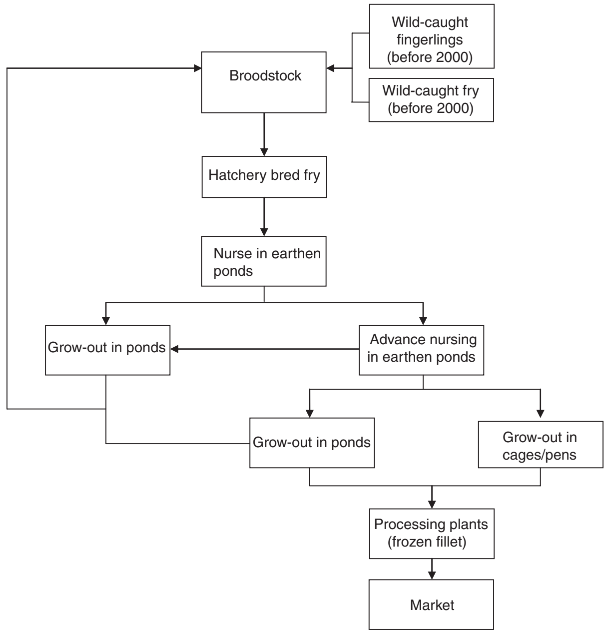

Figure 2 Production chain of striped catfish farming in Vietnam (modified from Phuong & Oanh 2009).

to maturity. After 2000, broodstocks have mainly come from hatchery-produced stocks, although attempts have been made to recruit and replenish hatchery-reared broodstocks with new wild stocks. Hatcheries often keep a small proportion of progeny for future usage (Ha *et al.* 2008).

Fingerling production is conducted in two stages, that is, primary grow-out from larvae to fry (1–1.5 months) and advanced grow-out from fry to fingerlings (1–1.5 months). Grow-out in cages and pens (7–8 months) often uses only advanced fingerlings, whereas in ponds both fry (6–7 months) and fingerlings (5–6 months) are used (Phuong & Oanh 2009). Cultured fish of approximately 1 kg are harvested and processed to produce frozen fillet for export. Currently there are over 100 processing plants in the Mekong Delta that use striped catfish as the primary raw material and processed catfish products are exported (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009).

All farming sectors in the production chain are separate entities and there is limited inter-linkage between the sectors. Several large processors are attempting to develop fully integrated systems, but to date none are in operation. Catfish farming is conducted on a wide variety of farm sizes, ranging from very small (0.2 ha), family owned and operated, to medium and very large size (i.e. up to 150 ha). However, most farms are small in size (approximately 4 ha) with 2.7 ha of water surface area (Lam *et al.* 2009).

Patterns of use and exchange of aquatic genetic resources

Use of *P. hypophthalmus* genetic resources

In Thailand, artificial propagation of *P. hypophthalmus* has been successful since 1967 (Sidthimonk & Pinyoying 1968); however, aquaculture of this species did not develop to the extent that is currently seen in Vietnam until recently. In the early stages of culture of this species, fry and fingerlings of *P. hypophthalmus* and other species were caught using small bag nets or 'dai' to procure seed for cage culture in Vietnam and to a lesser extent in Cambodia (Van Zalinge *et al.* 2002). In Cambodia, these fisheries were undertaken in the Kampong Cham, Prey Veng and Kandal provinces, in the Mekong River; in Vietnam fry fishing occurred in the An Giang and Dong Thap provinces in both the Mekong and Bassac Rivers (Fig. 1; Van Zalinge *et al.* 2002). It has been estimated that in 1977 the number of fry of *P. hypophthalmus* caught in Vietnam was approximately 800 billion (Khanh 1996), and the number caught in Cambodia in 1981 was 165 billion (Touch 2000). Fish were transferred to Vietnam in boats with tanks in the hull or in net cages with a bamboo frame.

It is noteworthy that in Vietnam from the early 1960s to 1996, aquaculture of *P. bocourti* was more dominant than *P. hypophthalmus*. In 1994 the Government of Cambodia banned the collection of wild seed of all species, including *P. bocourti*, and this led to research on artificial propagation of this species (Cacot 1999; Cacot *et al.* 2002). This technology was then applied to *P. hypophthalmus* and since a subsequent ban on bag-net fisheries by the Vietnam government in 2000, the sector has had to depend entirely on hatchery-produced seed (Fig. 3), providing impetus for the sector to grow rapidly.

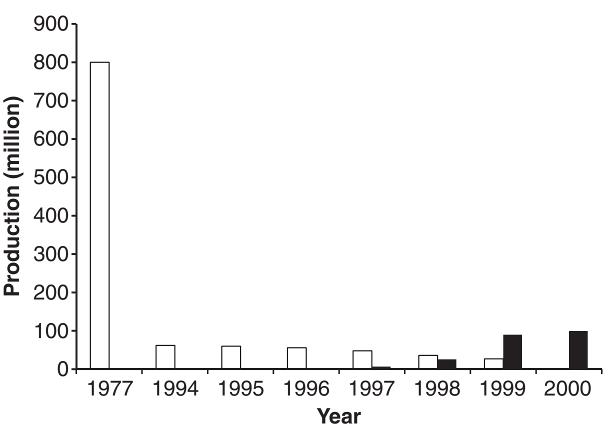

Figure 3 Production of fry of *Pangasianodon hypophthalmus* used for aquaculture in Vietnam from 1977 to 2000. Data from Khanh (1996) and Tung *et al.* (2001). All wild-caught fry were collected from Vietnam only. □, Wild-caught; ■, hatchery-produced.

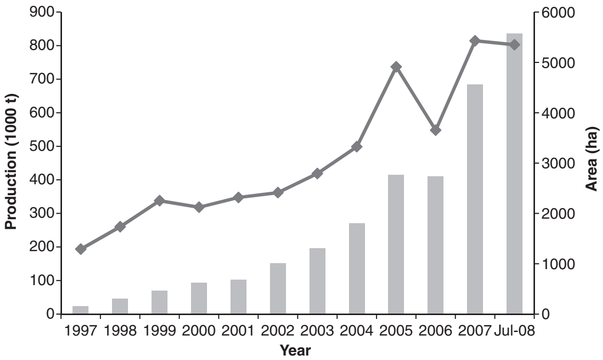

Figure 4 Increase in the culture area and production of catfish over the past decade. Data compiled from reports of provincial aquaculture departments. ■, Production; -◆-, area.

Consequently, the sector has become one of the fastest growing primary food production sectors in the world (Phuong & Oanh 2009). Within a decade of development, the production and farming area of catfish in Vietnam increased significantly (Fig. 4). Currently (for the first 7 months of 2008), Vietnam catfish production is estimated to be 835 000 t, valued at approximately US$745 million (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam 2009), making it the largest single species based farming system in a single nation in a small geographic area in the world.

In the context of rapid aquaculture development of catfish in Vietnam, it is advantageous on many fronts to have genetically improved strains with desirable traits, such as faster growth rate, higher fillet yield and higher levels of disease resistance. However, such approaches have started only recently in Vietnam. The 'Support to Freshwater Aquaculture' (SUFA) programme under the auspices of the Danish International Development Agency (DANIDA) (2001–2005) supports a selective breeding programme for *P. hypophthalmus* for economically important traits; this programme was carried out by the Research Institute for Aquaculture No. 2 (Sang *et al.* 2007). The programme initially aimed at selection for faster growth rate; the trait of higher fillet yield was included later. Selection for growth rate was undertaken using populations from 2 year classes (2001 and 2002) and individual selection, whereas fillet yield was selected using the 2003 class with a combination of individual and family selection (Sang *et al.* 2007).

Base populations for the selection programmes were collected as fry from different stocks from hatcheries in the Mekong Delta in Vietnam that are thought to be highly diverse (Sang *et al.* 2007). These fry were collected between 1999 and 2001, and at different times of the year, from hatcheries in the An Giang, Vinh Long, Dong Thap, Tien Giang and Binh Duong provinces. Results after one generation of selection were encouraging with the selected strain growing 13% faster; this strain has been named 'PanGi' (Sang *et al.* 2007).

Selected fish were disseminated for field trials and showed better performance in terms of growth rate and survival rate. Multiplier hatcheries have also been established together with dissemination networks to assist rapid dissemination of the selected fish to the aquaculture industry (Sang *et al.* 2007). The programme is continuing with funding support from the Ministry of Agriculture and Rural Development of Vietnam for 2006–2008.

In a general context, there is a need to achieve a degree of consensus and conformity with respect to the naming and continuance of the lines of various selectively bred strains, so that in the long run recognition of such strains can be maintained by avoiding confusion and undesired and/or unplanned mixing of genetic resources. Well-defined identification of improved strains will enable a much more considered transfer of genetic resources and access to these resources. It is somewhat surprising that the genetic origins of the cultured stocks in Vietnam are not well defined and/or understood. Therefore, there is a need for well-planned research to define the origin of individual broodstocks, enabling development of strategies for the introduction of a proper broodstock management plan(s) for this species.

Genetic diversity of *P. hypophthalmus*

According to Roberts and Vidthayanon (1991), the natural distribution range of *P. hypophthalmus* is limited to the Chao Phraya River of Thailand, the Mekong River, which runs from north to south along the borders of China, Myanmar, Lao, Thailand, and Cambodia, and the Mekong basin as it moves through Cambodia, Lao, Thailand and Vietnam. Stocks from Thailand have been translocated to Bangladesh for aquaculture purposes (Banglapedia 2006 cited by Ahmed & Hasan 2007). Myanmar also introduced *P. hypophthalmus* for aquaculture in 1982 (Myat Khine, pers. comm., 2009), and the original stock was likely to have originated from the Chao Phraya River (Wongpathorn Kamonrat, pers. comm., 2009).

In the Lower Mekong, *P. hypophthalmus* migrates annually between several upstream sites (upper stretches of the Cambodian section of the Mekong River between the Khone Falls on the Cambodian/Lao border and the town of Kratie; Fig. 2) and feeding grounds on the floodplain of the Mekong and the Tonle Sap. This species spawns from May to August (Poulsen & Valbo-Jørgensen 2001) and then migrates back to the feeding grounds and larvae drift to the nursery floodplains that are located near the feeding grounds.

There is limited knowledge on the present status of the genetic diversity of *P. hypophthalmus* as a whole.

Several studies have been undertaken to address questions relating to its population genetic structure. However, there is a lack of coordination and integration among the studies. Efforts have been made to have a better understanding of the biology of the species, but thus far have been confined to small geographic areas of interest.

Poulsen and Valbo-Jørgensen (2001) suggested that there might be two populations of *P. hypophthalmus* in the Mekong, one below and one above the Khone Falls. The former population includes stocks from Cambodia and Vietnam, which are thought to belong to the 'southern' population, whereas the latter, called the 'northern' population, comprises stocks from Lao and Thailand. Several attempts have been made to characterise the population genetic structure of *P. hypophthalmus* and the main findings are summarised in Table 1. Unfortunately, the genetic markers used in the different studies are not homogenous and as such do not permit direct comparisons between the studies nor do they permit a combined, comprehensive analysis.

So *et al.* (2006) used five microsatellite markers developed by Volckaert *et al.* (1999) and Hogan and May (2002) found that samples collected from 10 geographic locations of the 'southern' population belong to three distinct sympatric populations. Surprisingly, there was no evidence from microsatellite data of a recent reduction in effective population size, despite the extensive exploitation of fry and fingerlings in the past. Ha *et al.* (2009) did not find any significant genetic differentiation between captive and wild stocks in Vietnam based on five microsatellite markers developed by Na-Nakorn *et al.* (2006a).

In a recent study, based on microsatellite markers, Na-Nakorn and Moeikum (2009) suggested that populations from the Chao Phraya River and the Mekong River are genetically distinct. Furthermore, introductions of Mekong stocks into hatcheries in Thailand and subsequent stockings might have also led to the introgression

Table 1 Studies on genetic characterisation of *Pangasianodon hypophthalmus*

Sample origin	Marker	Major findings	Authors
Cambodia: Treng; Kratie and Sambo, Kratie; Kg, Chnang; Tonlesap; Prey Veng; Bassac Vietnam: Da Phuoc and Vinh Xuong in An Giang Province	Microsatellite loci *Phy01-KUL, Phy03-KUL, Phy05-KUL* of Volckaert *et al.* (1999) and *PSP-G505* and *PSP-G579* of Hogan and May (2002)	These samples belong to three cryptic populations No evidence of recent bottleneck	So *et al.* (2006)
Vietnam hatchery samples Sa Dec, Cao Lanh of Dong Thap province, Vietnam Chau Phu, Vinh Hoa, An Giang province Wild-caught fry samples Vinh Xuong, Phu Huu, Con Tien of An Giang province	Microsatellite loci that are *Pg1*, Pg2*, Pg3*, Pg13** and *Pg14** of Na-Nakorn *et al.* (2006a)	No significant genetic differentiation between captive and wild stocks	Ha *et al.* (2009)
Wild-caught samples from the Mekong and the Chao Phraya Rivers	Mitochondrial DNA sequences of partial 16S rRNA gene	No genetic differentiation of populations in the Mekong and Chao Phraya systems Private haplotypes were found in both populations	Na-Nakorn *et al.* (2006b)†
Wild caught and hatchery samples from Thailand	Microsatellite loci that are *Pg1*, Pg2*, Pg3*, Pg13**, and *Pg14** of Na-Nakorn *et al.* (2006a)	Natural stocks of the Chao Phraya and the Mekong are genetically distinct Genetic introgression of the Mekong population to hatchery that has origin from Chao Phraya stock Introgression of the Mekong stock into the Chao Phraya stock as a result of stock enhancement	Na-Nakorn and Moeikum (2009)†

†These findings appear contradictory, but because of the low power of the markers used in Na-Nakorn *et al.* (2006b) to detect population structure, the consensus is that natural populations of the Chao Phraya and Mekong are genetically different.

of Mekong stocks into the Chao Phraya gene pool (Na-Nakorn & Moeikum 2009). The finding that the stocks from the Chao Phraya and the Mekong Rivers are genetically different appears to contradict the observation made by Na-Nakorn *et al.* (2006a). However, because of the low power to detect population differentiation as a result of the markers (16S rRNA sequences) and small sample size used in the latter study, the accepted view is that the natural populations in the Chao Phraya and Mekong Rivers are different.

Exchange of genetic resources and benefits

During the early stage of development of aquaculture of *P. hypophthalmus*, the sector depended entirely on wild-seed stocks, which were procured from different sectors of the Mekong River (Fig. 1). Captive stocks based on seed that originated from Cambodian waters have become a valuable source of broodstock for aquaculture development in Vietnam.

Success in the artificial propagation and domestication of *P. hypophthalmus* has changed the aquaculture of this species from being seen as an activity that overexploited natural resources to one that reduces pressure on wild populations. Genetic management measures need to be in place as soon as possible to minimise potential adverse effects that genetic changes in hatcheries might bring to the wild populations.

Several countries in the Asian region have viewed the success of the Vietnam catfish farming sector favourably and have embarked on aquaculture of this species. As *P. hypophthalmus* is a shared resource among Mekong riparian countries, an increasing number of countries desire to introduce this species for aquaculture. However, there is no systematic guidance in place governing the movement of this shared genetic resource among the riparian countries of the Mekong. Haphazard seed procurements in the long term could impact negatively on all users of these resources, not only from a commercial viewpoint, but also from a genetic viewpoint. Mixing of distinct stocks may lead to outbreeding depression and its associated effects (Hallerman 2003). As such, translocations of shared genetic resources are best done through more systematic approaches involving consortia of countries that own the resources.

Recent attempts from several government and private hatcheries to conduct genetic improvement programs have led to further recruitment of broodstock from Cambodia. Public access to genetic resources of *P. hypophthalmus* for aquaculture is currently available from several provincial governmental hatcheries in Vietnam and the only provider of genetically improved seed is the National Breeding Center for Southern Freshwater Aquaculture of the Research Institute for Aquaculture No. 2 in Southern Vietnam.

Current practices in the exchange of genetic resources of *P. hypophthalmus*

The exchange of genetic resources of *P. hypophthalmus* is confined to Asia based on currently available information. Movements of *P. hypophthalmus* are mainly carried out by private sector groups from Cambodia to Vietnam, and from Thailand to other countries, such as Bangladesh, Myanmar and Indonesia (Thuy T. T. Nguyen, pers. obs., 2009). In the case of Cambodia and Vietnam, translocations of seed in the past were undertaken based on a contractual basis between buyers and sellers and there were no regulations to control such movements. Since 1994, when the Cambodian Government banned the use of bag nets or 'dai' for collecting fry and fingerling, such movements have ceased. Currently, there is a growing need for new genetic materials for genetic improvement programs in Vietnam and private sector agreements have been made to have young female catfish transferred to Vietnam.

Translation between Thailand and other countries are not known to the author. Recently, the Bangladesh Government requested that the Department of Fisheries of the Royal Thai Government obtain live fry and broodstock of *P. hypophthalmus* because it is believed that the current stock of *P. hypophthalmus* in Bangladesh has deteriorated (Sena S. De Silva, pers. comm., 2009). However, the request is still under consideration.

The question arises as to whether regular procurement of broodstock from Cambodia can be sustained, particularly in view of the fact that Cambodia itself is planning to develop its catfish aquaculture. A more international and/or regional approach with regard to access to genetic resources would be beneficial if developed and implemented. The situation is further exacerbated by the fact that individual hatcheries are attempting to produce their own strains without a clear understanding and/or definition of access and sharing of key stocks. It is in this context that it would be timely to introduce agreed guidelines on the access and sharing of genetic resources, preferably within the framework of the Code of Conduct for Responsible Fisheries (FAO 1995), as well as promoting more awareness of these issues among the relevant stakeholders.

In the wake of climate change impacts, primarily sealevel rise and reduced water flow in the Mekong River, De Silva and Soto (2009) have pointed out that the current catfish strains may no longer be usable in some areas because of salinity increases in the current areas of farming. It has been proposed (Sena S. De Silva, pers. comm., 2009) that selective breeding to produce a more salinity-resistant strain of catfish would be appropriate as an adaptive measure.

Conclusion

The genetic resources of *P. hypophthalmus* play a very important role in aquaculture development in many Asian countries. The production chain of *P. hypophthalmus* encompasses a wide spectrum of stakeholders, including seed collection, hatchery production to nurseries, grow-out farmers to processors and wholesalers/retailers. The aquaculture sector has dramatically grown since the success of artificial propagation in 1996, and this has significantly reduced the exploitation and translocations of wild stocks. There is still limited understanding on the genetic diversity of this species and development and improvement of this important resource still needs further investment. As stock from the Mekong River is shared among the riparian countries, translocations of shared genetic resources will be best achieved through consortia of countries that own the resources and with the agreement of all involved.

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