RESEARCH ARTICLE Indian Journal of Animal Research, Volume 55 Issue 12: 1515-1520 (December 2021)

Population Viability Analysis of Yangtze Finless Porpoise in the Yangtze Main Steam Suggesting that a Total Ban on Productive Fishing could be Decisive

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10.18805/IJAR.B-1353

ABSTRACT

Background: China is paying more attention to ecological systems within the Yangtze River has provided great opportunities to the conservation of the Yangtze finless porpoise (YFP). The rapid population decline of YFP in the main steam appears to have slowed, but the infrequent movement of porpoises represents a considerable threat to the long-term viability of this species in this region. We studied the population viability of YFP in the Yangtze main steam, based on published ecological and genetic information.

Methods: Vortex model was used to analyze the population viability of the YFP. The simulations were started from the year 2017 when the initial population size was 445 animals in baseline scenario. We examined the population viability for the species under demographic fluctuations and conservation scenarios.

Result: Baseline model showed the probability of extinction was 0.245; deterministic growth rate was -0.023; stochastic growth rate was -0.036. Sensitivity analysis showed differences in population trends between the baseline and each alternative scenario and the most sensitive parameters were the percentage of females breeding and mortality rates. Under different conservation scenarios, the population of the YFP in the main stream will increase by 11.0%-181.2% in 100 years.

Key words: Conservation strategies, Dispersal, Extinction, *Neophocaena asiaeorientalis*, Vortex model.

INTRODUCTION

In recent years, the species extinction rate has accelerated worldwide and is a thousand times higher than through natural processes alone (IUCN, 2010). Population dynamic models have been successfully applied in aquatic animal protection and resource assessment (Zhang and Wang 1999; Hacer, 2018; Wu *et al.*, 2018, 2020a; Huang *et al.*, 2020). Population viability analysis (PVA) is a tool for endangered species management and conservation due to the focus on species limitation factors (Brook *et al.*, 2000).

The use of PVA results in conservation decision making has been recommended partly because they are thought to be objective and repeatable (Doak *et al.*, 2015). PVA has been a core methodology, a lot has been learned about the factors determining the dynamics of wildlife populations and about techniques for assessing viability (Lacy, 2018). Furthermore, many PVA studies may not have sufficient data to perform model validation or test predictive accuracy. Well-conducted PVA studies guided by specific questions have intrinsic values, even if they lack long-term data or do not test for predictive accuracy (Vratika and Madan 2020).

The Yangtze finless porpoise (YFP, Neophocaena asiaeorientalis) is a small, freshwater toothed porpoises that occurs only in the middle and lower reaches of the Yangtze River (from Yichang to Shanghai) and its adjoining lakes (Poyang and Dongting lake) (Gao *et al.*, 1995) it is genetically isolated from other porpoise populations and reveal the genomic signatures of adaptation to the freshwater environment of this incipient species (Zhou *et al.*, 2018). As the baiji (*Lipotes vexillifer*) is probably extinct (Turvey *et al.*, 2007, Wu *et al.*, 2020a), the YFP is the only cetacean to inhabit the Yangtze River catchment area. The immigration and emigration of the YFP between the main stream and the lakes (Poyang Lake and Dongting Lake) has basically disappeared (Zhao *et al.*, 2008; Huang *et al.*, 2020).

This is particularly true for species occurring in multiple populations, each of which may require a separate PVA (Helen *et al.*, 2019). In this study Vortex 10.3.7.0) was used to analyze the population viability of YFP in the Yangtze

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How to cite this article: Bin, W., Jingen, X., Jianmin, W., Lie, C., Weiping, W. and Song, Z. (2021). Population Viability Analysis of Yangtze Finless Porpoise in the Yangtze Main Steam Suggesting that a Total Ban on Productive Fishing could be Decisive. Indian Journal of Animal Research. 55(12): 1515-1520. DOI: 10.18805/IJAR.B-1353.

Submitted: 01-03-2021 **Accepted:** 12-05-2021 **Online:** 10-06-2021

main steam the best way to improve population vulnerability (Lacy *et al*., 2017). The program is chosen because it is powerful, easily available, tried and tested and continuously updated.

MATERIALS AND METHODS

In Yangtze River main stream waters, the mean annual growth rate from 2012 to 2017 was λ=0.975 the estimated abundance of YFP were 445 animals (CV=17.19%, 95% CI: 295-595), of which 106 were in the upper region, 103 were in the middle region 236 were in the lower region (Huang *et al*. 2020). The population of YFP in Yangtze River is disjunct and isolated (Zhang, 2011; Huang *et al*., 2020); Hence we assumed that immigration and emigration were unlikely to occur between the Yangtze River and the lakes that connect it (Poyang Lake and Dongting lake). The simulations were started from the year 2017, due to lack of available data for the subsequent years when the initial population size was 445 animals in baseline scenario.

Mating system and mortality rate

YFP is polygynous specie that reproduce between 4 year (age of first offspring females) and up to 18 years of age (maximum age of female reproduction), the babies have a birth ratio of 1: 1 and 1 litter per litter (Hao *et al*. 2006, Chen *et al*., 2016, Li 2017). The YFP breeding cycle is generally 2 years (Zhang *et al*., 1992). However, some YFP have overlapping lactation and pregnancy periods (Shirakihara *et al*., 1993), so the annual reproductive rate of the YFP is 50%, but it can reach 70% (Zhang *et al*., 1992, Yang *et al*. 1998).

The mortality rate of the YFP is 25% in the first year of life, 20% in the second year of life and 10% there after (Yang *et al*., 1998, Zhang and Wang, 1999, Li, 2017).

Disasters

VORTEX model recommendation sets natural disasters as the probability of a severe die-off for a particular population is approximately 14% per generation they define a catastrophe as any 1-year decrease in population size of 50% or greater (Reed *et al*., 2003). VORTEX model calculation of the YFP generation was 8-9 years, thus natural disaster scenario was set as the probability 1.75%, which simulated the population dynamics at 50% survival and reproduction rate, respectively. The number of registered dead YFP fluctuates periodically from peak to valley, possibly with a cycle of 6 years (Wu *et al*., 2020b). Therefore, human catastrophe scenario was set as the probability 16.7%, which simulated the population dynamics at 99% survival and reproduction rates, respectively.

Environmental capacity and in breeding

The environmental capacity of YFP is 5,000 animals in the Yangtze River (Zhang *et al*., 1999). Therefore, we estimate that the environmental capacity of YFP in the main stream of the Yangtze River was 3000 animals. And the near-bank area (km^2) of the upper region, middle region lower region Yangtze main steam are 401, 256 707, so the environmental capacity was 1000, 800 1200 animals, respectively.

Ralls *et al*. (1988) studied the lethal equivalence coefficient of 40 mammalian populations and concluded that each diploid had 3.14 lethal gene equivalents. So, set 3.14 as the lethality equivalence coefficient of the YFP.

We defined that extinction occurs only when one sex remained in the population. Each simulation was performed with 10000 iterations in 100 years, the calculation times were 10 times of the usual, so it was more stable and reliable.

RESULTS AND DISCUSSION

Population dynamics in baseline model

The probability of extinction was 0.245 for metapopulation, 0.566 for upper region population, 0.450 for middle region population 0.447 for lower region population, but there was almost no extinction probability within 30 years. The genetic diversity was on a continuous downward trend and the simulations presented here predict severe declines YFP population in the Yangtze main steam by 94.0% in 100 years, as shown in Fig 1.

In Europe, vulture population declines began in the mid-19th century leading to local extinctions of some species (Ogada *et al*., 2012). In the early 21st century, vulture populations showed a more stable and slightly increasing trend due to changes in European legislation (Margalida *et al*., 2010) and intensive management and conservation (Margalida *et al*., 2010; Donázar *et al*., 2009). The newly revised List of Key State Protected Wild Animals in 2021 confirmes that the YFP is officially promoted to the first class of protected wild animals in China. The major threats to the YFP include overfishing and illegal fishing, pollution, vessel traffic and construction over the last four decades, to a point where this species is classified as Critically Endangered on the IUCN Red List of Threatened Species (Wang *et al*., 2005). Therefore, we believe that a total ban on productive fishing, intensive management and conservation would have a decisive positive effect on the protection of the YFP in the main stream.

Sensitivity analysis and conservation scenarios

Our analysis also examined the sensitivity of dispersal, the maximum reproductive age, breeding rate, mortality rate, initial population size, carrying capacity, Model 2-14 were formed respectively. Models 2 and 4 predict a 92.4-92.2% population decline, Models 5 and 6 predict a 99.2-87.8% population decline, Model 7 predict a 100% population decline, Model 8 predict a 218.3% population rise, Models 9 and 10 predict a 99.2-69.4% population decline, Models 11 and 12 predict a 97.2-90.7% population decline, Models 13 and 14 predict a 94.1-94.0% population decline, in 100 years. Compare the deterministic growth rate (Det-r) and stochastic annual population growth rate (Stoch-r), it was not difficult to find that breeding rate mortality rate that would be more sensitive to maintain population stability.

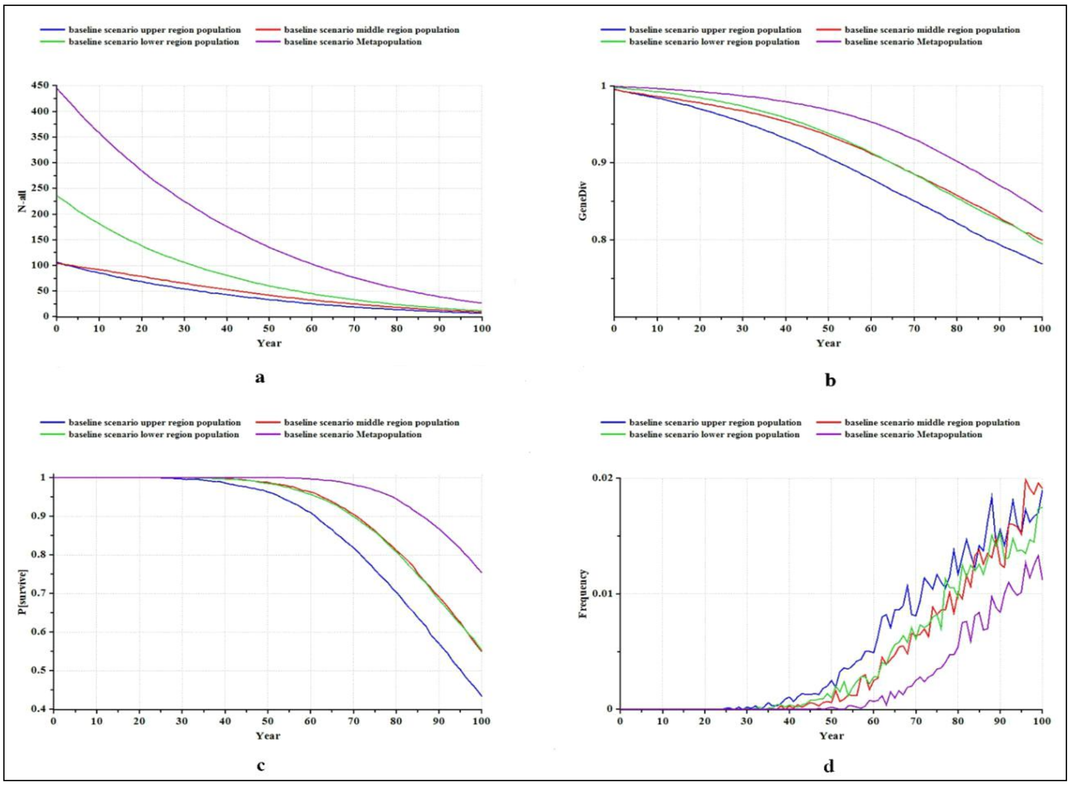

Fig 1: Population viability dynamics of YFP in the Yangtze main steam in baseline model (a, Population size; b, Genetic diversity; c, Survival probability; d, Extinction time frequency).

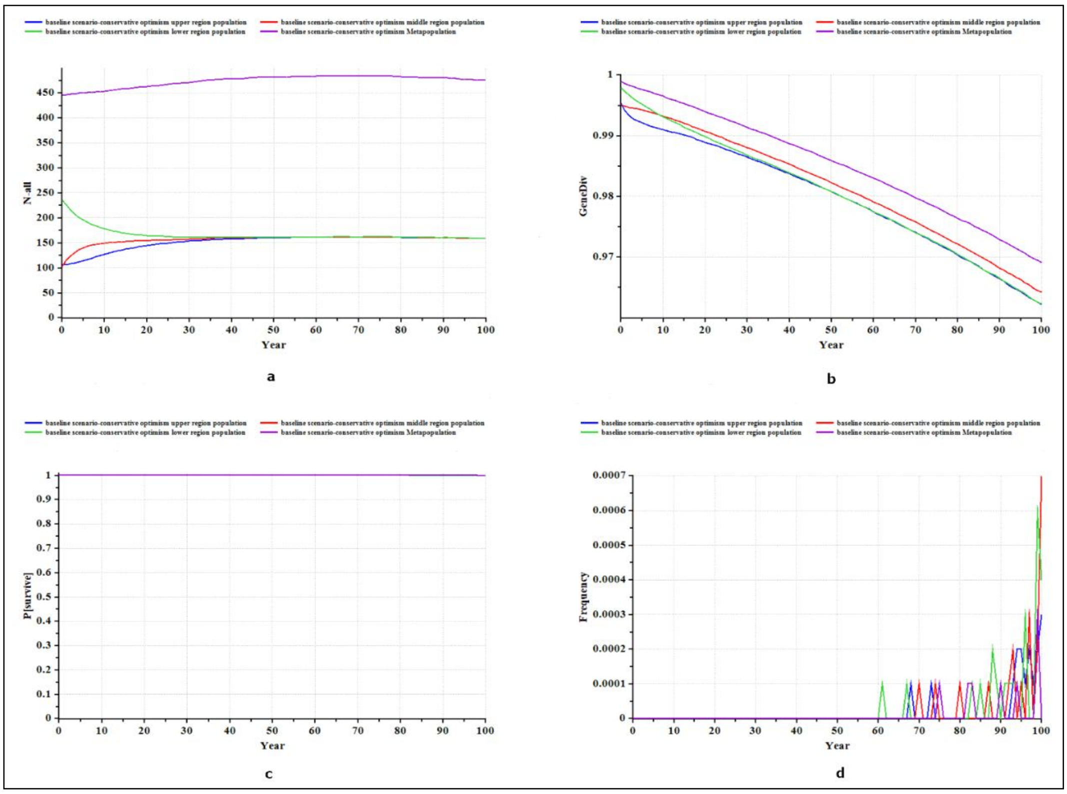

Fig 2: Population viability dynamics of YFP in the Yangtze main steam in mitigation conservation scenario (a, Population size; b, Genetic diversity; c, Survival probability; d, Extinction time frequency).

Population projections to 2025 and 2050 predicted continued population declines of Hector's and Maui dolphins under the current protection measures. But all risk analyses to date showed that without fisheries mortality, were predicted to recover, potentially up to half of their original population size by 2050 (Slooten and Dawson 2010, Slooten and Davies 2011). If there is enough food, the breeding interval will be relatively short (He *et al*., 2020). A total ban on productive fishing reinforces natural food availability and increases pre-adult survival, thus constitutes an important management practice for the conservation of YFP in the main stream. In addition, we speculate that the immigration

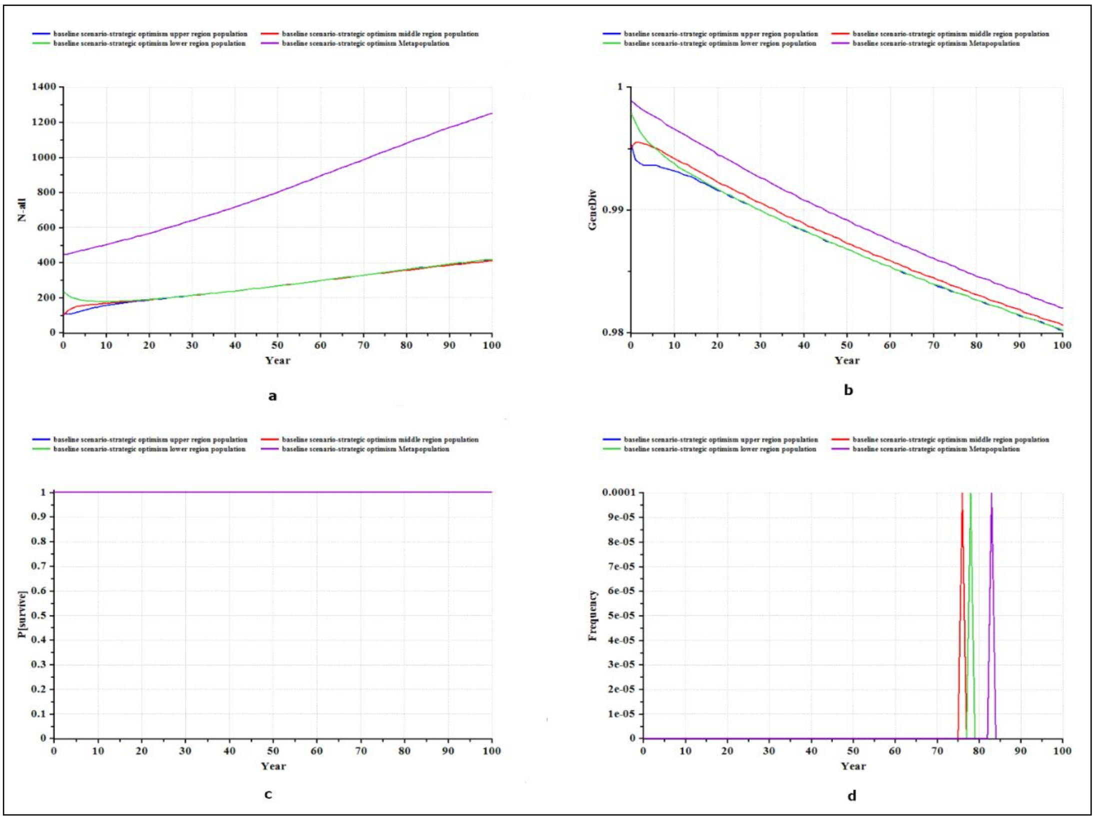

Fig 3: Population viability dynamics of YFP in the Yangtze main steam in comprehensive improved conservation scenario (a, Population size; b, Genetic diversity; c, Survival probability; d, Extinction time frequency).

Table 1: The deterministic growth rate (Det-r), stochastic growth rate (Stoch-r) and population size change (%) in 100 years under different scenarios.

Projects	Det-r	Stoch-r	Decrease
Model 1 (Baseline model)	-0.0230	-0.0356	94.0%
Model 2 (Model 1 + dispersal 10%)	-0.0230	-0.0325	92.4%
Model 3 (Model 1 + dispersal 20%)	-0.0230	-0.0321	92.3%
Model 4 (Model 1 + dispersal 30%)	-0.0230	-0.0319	92.2%
Model 5 (Model 1 + maximum reproductive age 15 years)	-0.0356	-0.0544	99.2%
Model 6 (Model 1 + maximum reproductive age 20 years)	-0.0177	-0.0270	87.8%
Model 7 (Model 1 + breeding rate 30%)	-0.0758	-0.0893	100.0%
Model 8 (Model 1 + breeding rate 70%)	0.0149	0.0111	-218.3%
Model 9 (Model 1 + mortality rate of 0-1 age 30%, 1-2 age group 25%)	-0.0373	-0.0539	99.2%
Model 10 (Model 1 + mortality rate of 0-1 age 20%, 1-2 age group 15%)	-0.0092	-0.0167	69.4%
Model 11 (Model 1 + initial population size 295 heads)	-0.0230	-0.0396	97.2%
Model 12 (Model 1 + initial population size 595 heads)	-0.0230	-0.0330	90.7%
Model 13 (Model 1 + carrying capacity, 6000 heads)	-0.0230	-0.0356	94.1%
Model 14 (Model 1 + carrying capacity, 1500 heads)	-0.0230	-0.0356	94.0%
Model 15 (Model 10 + breeding rate 55% + dispersal 10%)	0.0015	-0.0018	-11.0%
Model 16 (Model 10 + breeding rate 60% + dispersal 20%)	-0.0028	-0.0111	-181.2%

and emigration of YFP in different sections of the main stream will gradually recover. Therefore, we construct two protection scenarios, mitigation conservation scenario (Model 15) and comprehensive improved conservation scenario (Model 16). Models 15 and 16 predict a 11.0%-181.2% population rise in 100 years, but even under Model 16, it would take about 60 years for the population to double, results were shown in Fig 2 and 3. Models 1-16 and their output are summarized in Table 1. Our models suggested that juvenile mortality, habitat restoration, connectivity dispersal were far more pertinent and should be among the highest priorities for future conservation management and planning.

CONCLUSION

We provided a YFP baseline population viability model using multi-data source. Baseline scenario showed that this population was in a relatively vulnerability state in 100 years. This work highlights the importance of understanding how demographic fluctuations and conservation scenarios parameters affect long-term persistence of the threatened YFP and may provide knowledge fundamental to the understanding of other similar species. We have highlighted parameters critical for YFP persistence and discussed how variation in conservation scenarios may alter YFP population outcomes. From our models, we can infer that the long-term viability of YFP heavily relies on habitat restoration and diffusion connectivity.

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