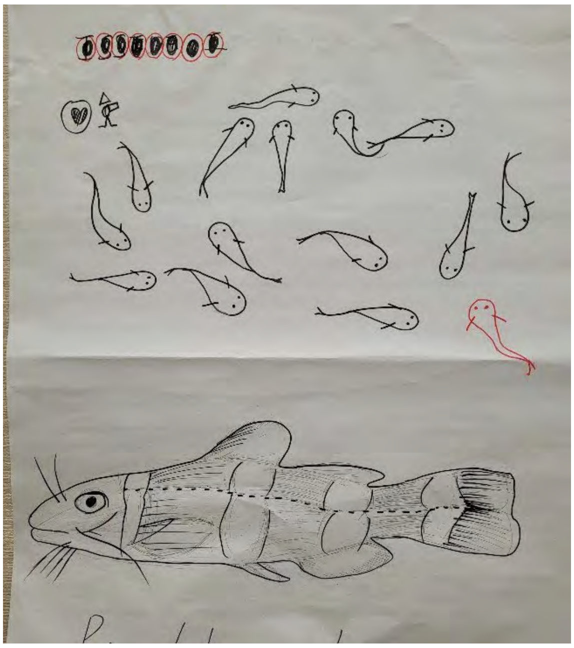
KOREAN STUMPY BULLHEAD (*Pseudobagrus brevicorpus*) SPECIES CONSERVATION PLANNING WORKSHOP (SCP|PVA)

14-17 February 2023, Seoul, South Korea

Final Report



국립생태원 2013-2023 anniversary

IUCN SSC Species Survival Commission

CONSERVATION PLANNING SPECIALIST GROUP

Acknowledgements

Many people contributed to the 2023 Korean Stumpy bullhead Species Conservation Planning | Population Viability Assessment Workshop and to the completion of this Korean Stumpy bullhead Conservation Action Plan. Their time and contributions are acknowledged here:

Workshop facilitator and PVA modeller: Caroline Lees (CPSG)
Working group facilitators: Moonhyun Shin (NIE), and Hakbong Lee (NIE)
PVA data collection: Ju-Duk Yoon & NIE Fish & Amphibian Team (see PVA report, page 27)
Translators and documenters: Seongeun Yang (Translator), Hakbong Lee (documenter)

A full list of workshop participants is provided in Appendix I of this document and all are thanked for their contributions. **This document was compiled and edited** with help from Moonhyun Shin, Onnie Byers and Caroline Lees.

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Contents

EXECUTIVE SUMMARY

INTRODUCTION

The Korean Stumpy Bullhead, *Pseudobagrus brevicorpus* (Mori, 1936) is a small (8cm), nocturnal, freshwater Bagrid catfish, endemic to South Korea. Known habitats are the upstream parts of Nakdonggang River in Yeongcheon, Daegu, Bonghwa, Yeongju, Seongju, Miryang, Changnyeong, Sancheong, and Hamyang. It is found in clean waters with large stones and pebble substrates. Due to riverside development, and river and flood management measures, it has become a rare species and in recent years has not been found at all, or found only in small numbers, in habitat where it was previously more common. It feeds on the larvae of aquatic insects and lays its eggs in June-July. The species' average migration distance and home range (minimum convex polygon) are about 140 m and 512 m^2, respectively. With the rapid destruction of its natural habitat, the Korean stumpy bullhead has been listed as an endangered species by the South Korean Ministry of Environment, for its protection and management. In 2021, the IUCN SSC Conservation Planning Specialist Group (CPSG) was invited to work with South Korean experts and stakeholders, to help to plan a future for this species. Due to covid 19 restrictions, the face-to-face workshop had to be postponed but the communications, logistical preparations, and initial planning process steps continued, including a population viability assessment held 29-30th of November 2021.

The Korean Stumpy Bullhead species planning project is part of a larger, three workshop collaboration between IUCN and the South Korean Ministry of Environment. In addition to this project, there is agreement to conduct planning workshops for the Korean gold-spotted pond frog and the Oriental stork. Importantly, this collaboration includes a capacity building element. Through an increasingly intensive series of training, mentoring and coaching sessions, the intent is to develop a South Korean team capable of conducting CPSG-style species conservation planning processes.

THE WORKSHOP

In February 2023, at the invitation of the National Institute of Ecology, more than 20 delegates gathered for four days in Seoul, South Korea to build a Korean Stumpy bullhead Conservation Action Plan. In attendance were representatives from # organizations including IUCN, Korea Water Resources Corporation, National Institute of Fisheries Science Inland Fisheries Research Institute, Gosu Ecological institute, Yesan Oriental Stork Park, and Jeongeup City.

The event was organised by Ministry of Environment, co-hosted by National Institute of Ecology, and facilitated by the IUCN SSC Conservation Planning Specialist Group (CPSG).

The workshop began with a series of presentations including an introduction to CPSG and the Species Conservation Planning workshop process, a presentation to clarify the current state of knowledge of the Korean Stumpy bullhead, and a report on the Population Viability Analysis process and results. Participants then worked collaboratively to agree what successful conservation of the Korean Stumpy bullhead could look like in 2050 (see **BOX 1**). This vision for the future served as a guide for the development of the rest of the species conservation action plan.

Next, workshop participants described the challenges to the Korean Stumpy bullhead's recovery and conservation. On days two through four, participants identified clear goals for addressing these challenges and recommend agreed-upon actions to achieve the goals. Discussions were supported by population simulation models that helped to quantify the relative risks of known threats to Korean Stumpy bullhead and the relative benefits of proposed conservation strategies.

BOX 1. Our 2050 Vision for Korean Stumpy Bullhead

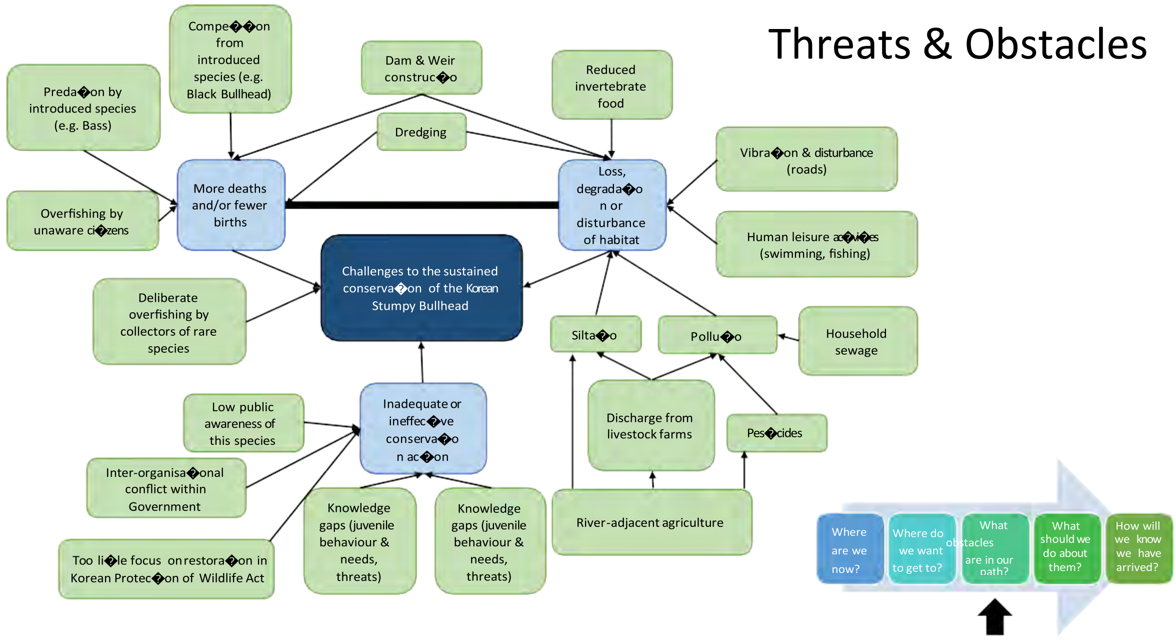
In English: Through improvements to the legal system and increased budget for conservation, reckless development has decreased, leading to improvements in the habitat of Korean Stumpy Bullhead and, through expanded education outreach, public awareness of the species has raised and collaboration among related agencies has been strengthened. Furthermore, as a result of recovery project such as the establishment of artificial captive breeding technology, habitat reconstruction, and the release of bred individuals, the habitat of Korean Stumpy Bullhead has expanded throughout the Nakdong River region, and the population has recovered to the level of the 1970s, leading to delisting from endangered species status.

In Korean: (protection) 법 제도 개선(예: 보호구역 확대, 환경영 향평가 강화) 및 보전 예산(예: 서식지 인공 조성 등) 확대로 무 분별한 개발이 줄어들어 꼬치동자개 서식지 환경(예: 수질 등) 이 개선되었고, 홍보 확대로 종에 대한 국민 인식 수준이 높아 지고 유관기관(예: 지자체 등 공공기관) 간 협력이 강화되었다.

(recovery) 또한 인공증식 기술 확립과 서식지 인공조성, 증식개
체 방사 등의 복원사업 결과, (species and habitat status) 꼬치동 자개 서식지는 낙동강 전역으로 확대되었고, 과거 1970년 수준

으로 개체수가 회복되어 멸종위기종에서 해제되었다.

CHALLENGES TO KOREAN STUMPY BULLHEAD RECOVERY AND CONSERVATION



Challenges to successful recovery and conservation of Korean Stumpy bullhead were condensed into four broad themes:
1) Lack of adequate habitat condition and protection;
2) Introduced species;
3) Lack of public awareness; and
4) Lack of knowledge of the species, its interactions, & of restoration technology.

Within each these, participants worked in 2 groups to describe each challenge, including a description of its causes and impacts, the facts and assumptions around it, and existing data gaps that need to be filled. This resulted in the following 8 detailed Issue Statements.

ISSUE STATEMENTS

Theme 1: Lack of adequate habitat condition and protection

1. *기후변화 및 인간의 필요에 따하천의 대형 건설(댐, 대형 보 등) 이 꼬치동자개의 서식지에 심각한 영향을 끼친다.*

Due to climate change and human needs, the large-scale construction of rivers (dams, large weirs, etc.) has a serious impact on the habitat of the Korean Stumpy Bullhead.

2. *물의 유량 유지 및 홍수 방지를 위한 주기적인 하천 정비 공사는 꼬치동자개의 서식지를 파괴한다.*

Periodic river maintenance work to maintain the flow of water and prevent flooding destroys the habitat of the pike.

3. *생활 하수 및 축산 폐수 등이 수질 오염의 꼬치동자개의 서식지 수질에 부정적 영향을 미친다.*

Water pollution, such as domestic sewage and livestock wastewater, has a negative impact on the water quality of the Korean Stumpy Bullhead breeding habitat.

4. *하천 변에서 이루어지는 인간의 여가활동이 꼬치동자개의 서식에 부정적 영향을 미친다.*

Human leisure activities along the riverside have a negative impact on the habitat of the Korean Stumpy Bullhead

Theme 2: Introduced species

5. *The emergence of introduced species affected the life condition of Korean stumpy bullhead. Bass, an invasive species in the Republic of Korea, appears to hunt Korean stumpy bullhead. The presence, and expansion of the habitat, of Bass is highly likely to lead to the decrease of the number of the Korean stumpy bullhead, as well as decline in genetic diversity. In addition, it is observed that the black bullhead has moved to Nakdong river area, resulting in overlapping habitats between black and Korean stumpy bullheads. The increasing number of introduced species seems to play a key role in the declining number of Korean stumpy bullhead, but more research is necessary regarding issues such as the diet and interbreeding.*

Theme 3: Lack of public awareness

6. ***Korea has awareness problems. ignorance and excessively undesirable interest (poaching). Many members of the general public do not have any knowledge of Korean stumpy bullhead and its value as an endangered species. However some catch them because they are fully aware the value***.

Theme 4: Lack of knowledge of the species, its interactions, & of restoration technology.

7. ***Institutional design -*** *Wildlife laws focus mainly on regulations on illegal fishing, and rarely mention the destruction of habitats or the need for efficacy of restoration. In addition, the lack of consistency in governmental staff positions leads to lack of coordination and cooperation across government agencies with regards to knowledge, administration, focus and follow-up.*
8. ***Need more research on living condition and behavioural status, in Nakdong river area -*** *The lack of research on the Korean stumpy bullhead makes it difficult to conduct a thorough status assessment and, therefore, to plan for the species recovery.*

GOALS TO ADDRESS THE ISSUES FACING KOREAN STUMPY BULLHEAD CONSERVATION AND RECOVERY

The following eighteen goals were identified to address the eight issues and prioritized by all participants on the basis of importance, urgency and feasibility.

No.	GOAL	Imp	Urg	Feas	Tot	HPQ	ISM	PA	IK
1	**Mandatory, strict and suitable EIA for the freshwater ecosystem applied before any construction of dams, weirs or other flow-regulating structure**	**6**	**5**	**2**	**13**	**X**			
2.	Conduct research on the influence and value (to flood control & water supply) of existing dams and big weirs. Remove those of insufficient value	1	1	2	4	X			X
3.	**Include EIA in the river maintenance plan in every region and establish conservation plans for any endangered species found**	**6**	**7**	**5**	**18**	**X**			
4.	Investigate and regulate pollution sources near the habitat of the species	0	1	3	4	X			
5.	Designate protected areas for the habitat of Korean Stumpy bullhead in areas popular for leisure activities	1	3	4	8	X			
6.	Reduce or eliminate Bass	0	0	0	0		X		
7	Physically prevent movement into KSB habitat	0	2	1	3		X		
8	Increase knowledge about the predator-prey relationship between Bass & KSB	0	0	1	1		X		
9	Reduce or eliminate Black Bullhead	0	0	0	0		X		
10	Analyse & compare the ecological niches of Korean Stumpy & Black Bullheads	0	0	2	2				X
11	Implement night surveillance in KSB habitat to prevent illegal over-fishing	0	0	1	1	X			
12	Provide guidance to the fishing community to reduce both legal and illegal catch	0	3	6	9			X	
13	**Implement education outreach in communities living around KSB habitat, and in the wider public visiting the habitat**	**5**	**1**	**5**	**11**			**X**	
14	Introduce new regulations or law for conservation planning and evaluation	3	5	1	9	X			
15	Designate legally protected areas for the KSB	1	3	3	7	X			
16	**Integrate the hands-on experience in decision-making processes**	**7**	**5**	**1**	**13**	**X**	**X**		
17	Raise funds for research	0	0	1	1				X
18	**Develop technology & expertise in translocation & ecosystem restoration**	**8**	**4**	**3**	**15**				**X**

ACTIONS TO ACHIEVE TOP PRIOIRTY GOALS FOR KOREAN STUMPY BULLHEAD CONSERVATION AND RECOVERY

Goal 1. Include EIA in the river maintenance plan in every region and establish conservation plans for any endangered species found

Actions:

a. Involve industry in conservation projects (i.e., ESG management).
b. Develop a framework for conservation project planning and evaluation, and apply it to all governmental organizations involved in species recovery projects.
c. Government agencies reinforce the EIA law for the river maintenance plan.
d. Persuade stakeholders to understand the needs for the law.
e. Review and, if necessary, revise 2015 Guideline for river maintenance.
f. Ministry of Environment designates the major habitats as wildlife protection areas (restricted area for public uses)

Goal 2. Develop technology & expertise in translocation & ecosystem restoration.

Action:

a. National Institute of Ecology Investigates pollution sources near the major habitats of the species (Daegacheon, Gokkangcheon, Jahocheon, and Deokcheongang).

Goal 3. Integrate the hands-on experience in decision-making processes.

Action:

a. Form an inter-governmental consultative group and regular meeting

Goal 4. Mandatory, strict and suitable EIA for the freshwater ecosystem applied before any construction of dams, weirs or other flow-regulating structure.

Actions:

a. Government agencies reinforce the EIA law for the construction of dams and weirs
b. Government make budget available for the research
c. Research institutes conduct the research

Goal 5. Implement education outreach in communities living around KSB habitat, and in the wider public visiting the habitat.

Actions:

a. Create educational audio/video content to be produced by famous YouTube creators
b. Develop a formal education program for local students (with off-line activity)
c. Conduct education outreach for the local residents
d. Related institutes make education program for the public
e. Related institutes publish books about the species
f. Propose to the Ministry of Environment they endangered species conservation be included in school textbooks

Detailed working group notes, including indicators of success, timelines and responsible parties for these recommended actions, can be found beginning on page 33.

PRELIMINARY POPULATION VIABILITY ANALYSIS FOR THE KOREAN STUMPY BULLHEAD, *PSEUDOBAGRUS BREVICORPUS*

Compiled by Caroline Lees (IUCN SSC CPSG) in preparation for the conservation planning workshop held in South Korea in 2023. The information and insights used to build this report were provided by a team of experts from the National Institute of Ecology ((NIE) and the National Institute of Biological Resources (NIBR). Details of this team are provided in Appendix I.

INTRODUCTION

The Korean Stumpy Bullhead, *Pseudobagrus brevicorpus* (Mori, 1936) is a small (8cm), nocturnal, freshwater Bagrid catfish, endemic to South Korea. Known habitats are the upstream parts of Nakdonggang River in Yeongcheon, Daegu, Bonghwa, Yeongju, Seongju, Miryang, Changnyeong, Sancheong, and Hamyang. It is found in clean waters with large stones and pebble substrates. Due to riverside development, and river and flood management measures, it has become a rare species and in recent years has not been found at all, or found only in small numbers, in habitat where it was previously more common. It feeds on the larvae of aquatic insects and lays its eggs in June-July. The species' average migration distance and home range (minimum convex polygon) are about 140 m and 512 m^2, respectively. With the rapid destruction of its natural habitat, the Korean stumpy bullhead has been listed as an endangered species by the South Korean Ministry of Environment, for its protection and management.

Photo. Korean Stumpy Bullhead, *Pseudobagrus brevicorpus*

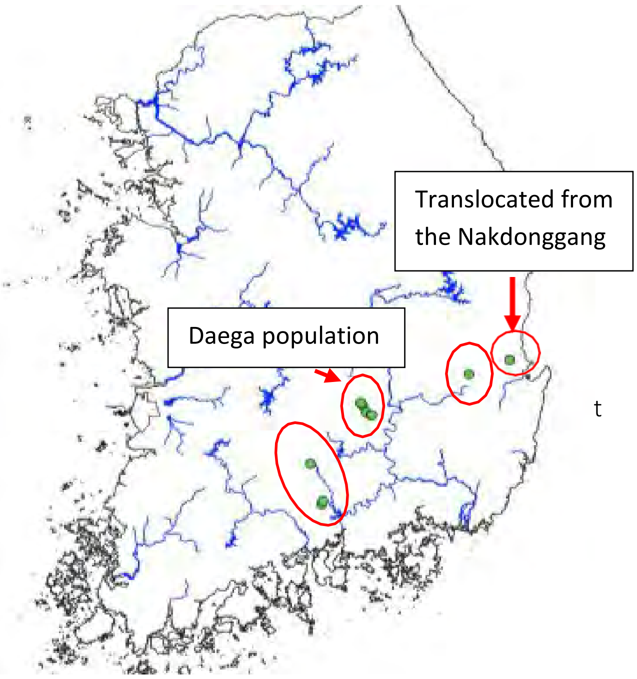


Figure 1. Map of South Korea, showing known locations of the species (PVA Team).

In 2021, the IUCN SSC Conservation Planning Specialist Group (CPSG) was invited to work with South Korean experts and stakeholders, to help to plan a future for this species. To support planning, a Population Viability Analysis workshop was held, 29-30th of November 2021, attended by 12 planning collaborators (see Appendix I.). This DRAFT document is an output of that workshop and will be used to inform discussions at a larger planning workshop to be held in 2022.

Background to the Conservation Project

The Korean Stumpy Bullhead currently occurs at 3-4 locations in South Korea (indicated by red circles, Figure 1.). One of these locations is the Daega Stream. Within the Daega Stream there are five smaller streams where the species occurs, which from here on will be referred to as "sites", denoted by green dots within the Daega red circle in Figure 1.

There are currently fish at all five sites, but the populations are small and decreasing. Each of the sites in the Daega Stream is assumed to be isolated from the others, as the species typically migrates over distances of only 100-200m, and the Daega Stream sites are separated by roughly 300-500m. The sites are roughly similar in size (average = 25000m^2; range=20000m^2 – 60000m^2) and though habitat quality appears the same, population sizes differ between sites and it is not clear why.

The species is known to be highly sensitive to physical alteration of habitat and the current low and declining numbers at sites are assumed to be the result of previous disturbances from dredging, building of weirs and habitat alteration for flood control. Every five years or so, the Korean local government constructs new banks or flood control instruments within the stream and this will probably continue. When these events occur, the fish disappear almost entirely. Following habitat alteration, natural unaided recovery may take around five years, but this is not known for certain. Sometimes fish populations recover at damaged sites and sometimes they do not.

The intended focus of the CPSG planning workshop, and therefore of this population viability analysis, is the five sites in the Daega River and an *ex situ* population that has been established from which to augment them. Releases from the *ex situ* population are currently designed to be annual, with the aim of making each of the populations at targeted wild sites larger and, ultimately, self-sustaining, if this is shown to be possible.

Alongside this project and also to be included within the 2022 planning discussions, are discussions with the relevant authorities about preventing or managing elements of stream construction to make provisions for protecting critical habitat for this species. Should this be successful it may reduce or remove the need for augmentation from an *ex situ* program. It may be possible to have representation from the relevant flood management agency at the planning workshop.

The *Ex situ* Population

Collection of founders began in 2019 and is intended to be an annual activity for as long as is needed, with a review after the first five years. At each capture event, 20 adults are captured (10 females, 10 males). Individuals come from the Jaho stream whose population is genetically like that of the Daega Stream.

Wild-caught founders are maintained separately, in annual cohorts, because Korean law requires them to be released after three years and so they must be readily identified. Those captured in 2019 and 2020 have bred successfully, to create an F1 population of approximately 2000 breeding adults. This, together with the wild founders, constitutes the breeding population. From this it should be possible to generate 3000 release individuals per year for release to each site. Annual cohorts of F1s and F2s are maintained separately, so that each cohort is identifiable. They are released only after 1.5 - 2years, to improve their survival rates in the wild.

Within the captive programme, fish breed once each year, though in the wild 2-3 times is reported. Every fish that when checked is found to be able to breed, is collected for breeding. The number could range from 20 pairs to 1000 pairs in one season. Breeding individuals are mixed such that one male can fertilise the eggs of many females. It is not currently possible to discern how many females have their eggs fertilised, or how many males successfully participate in breeding.

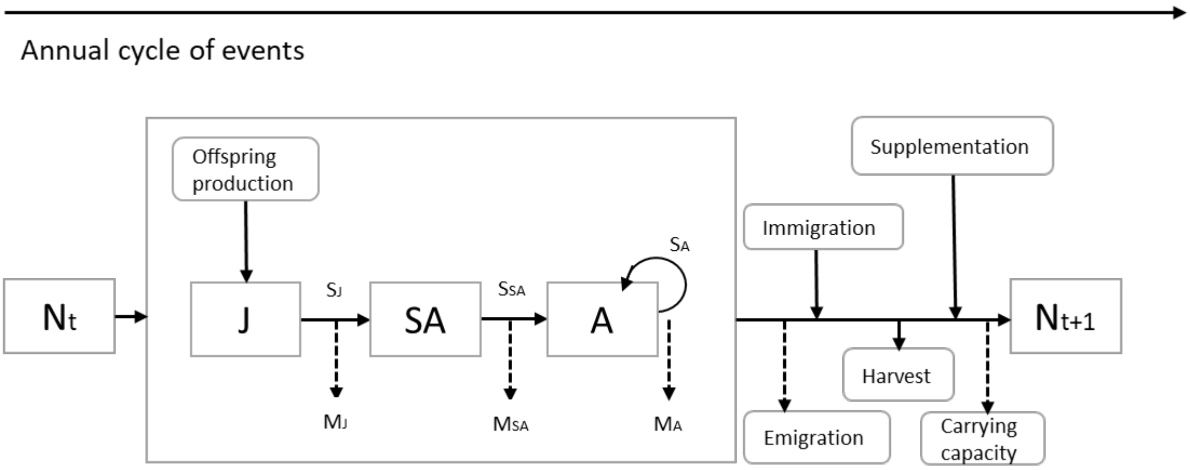
This approach will be reviewed after five years, by which time more data will be available on which to base management decisions.

VORTEX MODELS

Computer modelling can be a valuable tool for quantitatively assessing risk of decline and extinction of wildlife populations, both free ranging and managed. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to assess the relative impact of alternative management strategies, to help identify the most effective conservation actions for a population or species, and to identify research needs.

The software used in these analyses is the simulation program VORTEX. VORTEX is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events, on small wild or captive populations. VORTEX models population dynamics as discrete, sequential events that occur according to defined probabilities. The program begins by either creating individuals to form the starting population, or by importing individuals from a studbook database. It then steps through life cycle events (e.g., births, deaths, dispersal, catastrophic events), for each individual and typically on an annual basis. Events such as breeding success, brood size, sex at birth, and survival are determined based upon designated probabilities that incorporate both demographic stochasticity and annual environmental variation. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of VORTEX and its use in population viability analysis, see Lacy (1993, 2000) and Miller and Lacy (2005).

Figure 2. Diagram showing the series of events making up a typical annual cycle or timestep in VORTEX, that result in a simulated change in population abundance from Nt to Nt+1. The enclosed section of the diagram begins with the production of juveniles (J) followed by their transition through Subadult (SA) and Adult (A) life-stages. Mortality is imposed on each age-class cohort (Mx), the severity of which is determined by age-specific survival rates (Sx). On the right of the diagram, processes above the timeline act to increase abundance, while those beneath act to decrease it. The aggregate effect of these demographic processes results in a new population abundance at the end of the timestep.



GUIDANCE FOR PVA MODEL DEVELOPMENT

The demographic and genetic analysis described in this report were developed in close consultation and collaboration with participants of the virtual PVA workshop held 29-30 November, 2021. The modelling process, which included work before, during and after the workshop, included the following process steps:

1) Building baseline models a) of a representative Daega Stream wild population and b) of a representative *ex situ* population, incorporating known site- or management-specific risks, to establish baseline viability measures for those two different systems.
2) Testing the sensitivity of these baseline models to parameter variation, to establish pressure points for populations and key data gaps for further research.

3) Building different model scenarios to test the relative effectiveness of proposed alternative management strategies, on population performance (*for in situ* and *ex situ* populations).
4) Interpreting these results.

Model data were captured by questionnaire before the virtual PVA workshop. During the workshop the collective expertise and knowledge of participants was used to:

- Review and agree VORTEX parameters for the *in situ* and *ex situ* baseline models including those needed to describe:
  - the biological and human-mediated influences on population dynamics
  - any interactions among populations
  - initial ideas about conservation management interventions
  - estimated quantities for these, for inclusion in VORTEX models
- For any uncertain parameters, to elicit best estimates or a plausible range of values for use in sensitivity testing.
- Agree the questions to be pursued using the models.

WILD BASELINE MODELS

The Wild Baseline model is designed to represent a single, healthy population of the Stumpy Bullhead under benign conditions, in the Daega Stream. All models use an annual cycle of events, the modelling timeframe is 50 years, and each model run includes 500 iterations. Parameters and values included in the baseline models, along with the ranges agreed for sensitivity testing, are shown in Table 7.

With the model values described in Table 7, deterministic projections (i.e., without stochastic influences on reproduction and mortality rates) show a wild population that grows at an annual rate of 4.5% (λ =1.45). Generation time (T) for both sexes is approximately 3.25 years. Stable age structure for this modelled population is described in Figure 3 and illustrates the high mortality rate in the 0-1 age-class (90%) as well as the impact of the sex-ratio bias towards females at birth (45% males). Note that this age-structure does not include the egg stage.

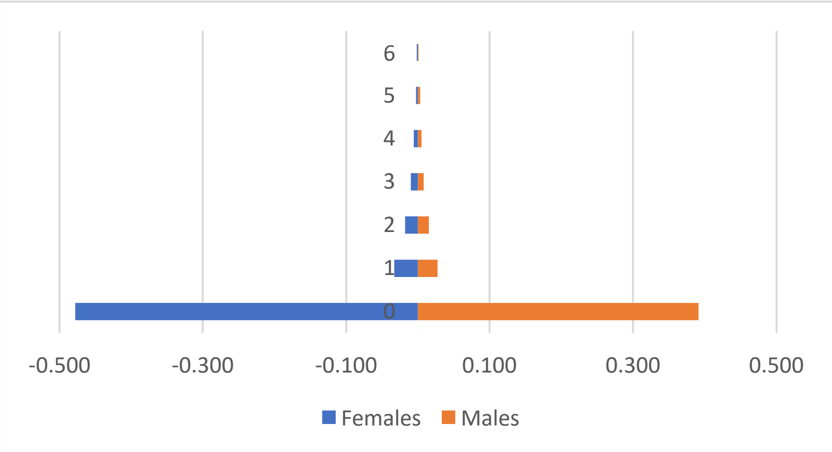


Figure 3. Age-pyramid portraying a stable-age structure for the Stumpy Bullhead, calculated using the input parameters provided. Numbers of males and females are shown on the X-axis; age-classes are shown on the Y-axis.

With stochastic elements included, instantaneous growth rate is reduced and there is high variability across iterations (stoc-r=0.2693 ± 0.4874). Risk of extinction over the 50-year period is low for the starting population size and carrying capacity modelled (Ni=K=200), at PE=0.038 or 3.8%. Among the populations that survive, numbers average N=171.63 individuals but with much variation (SD= 42.40). Gene Diversity at 50 years sits at 0.8978, below internationally recommended thresholds of 90 – 95%. See Figure 4 for an illustration of Wild Baseline model trajectories and Tables 1 and 2 for a comparison of deterministic and stochastic results.

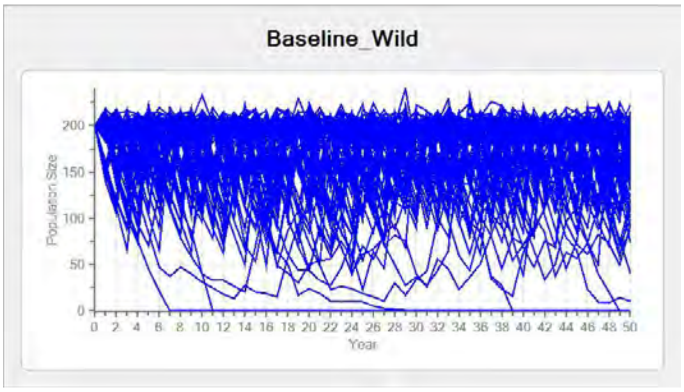


Figure 4. Examples of Wild Baseline model trajectories over 50 years, for the Stumpy Bullhead.

Tables 1 & 2. Summary of deterministic and stochastic results for the Wild Baseline model.

1. Deterministic rates	
Lambda (λ)	1.45
Generational growth (Ro)	3.32
Generation time (T)	3.25

2. Stochastic rates	
Instantaneous growth rate (r)	0.2693 ± 0.4874
Gene Diversity (GD) at 50 yrs	0.8978
Extinction Risk (PE)	0.038
N-Extant	171.63 ± 42.40

As shown above, the model grows strongly, with an instantaneous growth rate of r=0.269 which is somewhat greater than the range calculated by Wang et al., 2019, for 36 freshwater fish species of the Yangtze River, using similar methods (r=0.009 – 0.188). This may indicate overly optimistic parameterisation of the Stumpy Bullhead models, or it may simply reflect the more productive biology of this species. This can be discussed further at the planning workshop. Note that the introduction of stochastic elements to the models (including inbreeding depression, environmental variation, and demographic stochasticity) introduces high levels of population fluctuation with an overall depression in growth rate compared to the deterministic models.

Wild Model Sensitivity Tests

Though some of the life history traits and characteristics of this species are well-studied there remain many areas of uncertainty. Some of these will have more influence on population performance than others. Tests were carried out in which each parameter was varied in turn, holding all other parameters constant, to get an idea of which have most influence on key performance measures such as population growth, extinction risk and gene diversity retention. All tests were carried out on the Wild Baseline Model and Table 7. shows both the baseline parameters for this model and the values used in the sensitivity tests. The results of the tests are summarised below.

Low impact factors (relatively small change in growth rate across the range modelled)

- % males contributing to breeding (varied from 50-100%).
- Adult mortality rate (varied from 15-25%): note changes to females had a bigger impact than changes to males.
- 0-1 year mortality in males (varied from 85-95%)
- Oldest age of breeding (for either sex) (varied from age 5-9 years)
- Extent of correlation between good years for breeding and good years for survival (varied from 0-100% correlated)

Medium impact factors (medium-sized change in growth rate across the range modelled)

- Annual percentage of females breeding (varied from 70-100%)
- Sex-ratio at birth (described as percentage of males) (varied from 35-55%)
- Maximum number of broods per year (varied from 1–3)

High impact (relatively large change in growth rate across the range modelled)

- 0-1 year mortality in females (varied from 85-95%)
- Mean progeny per brood (varied from 10-20)
- Age at first breeding (varied from 1-3 years)

High and medium impact factors should be targets for additional data collection (to ensure that the models include representative values). In addition, these are useful targets for planning discussions, as thinking about how these aspects of life history might be manipulated, either in the wild or captivity, may provide useful directions for conservation action.

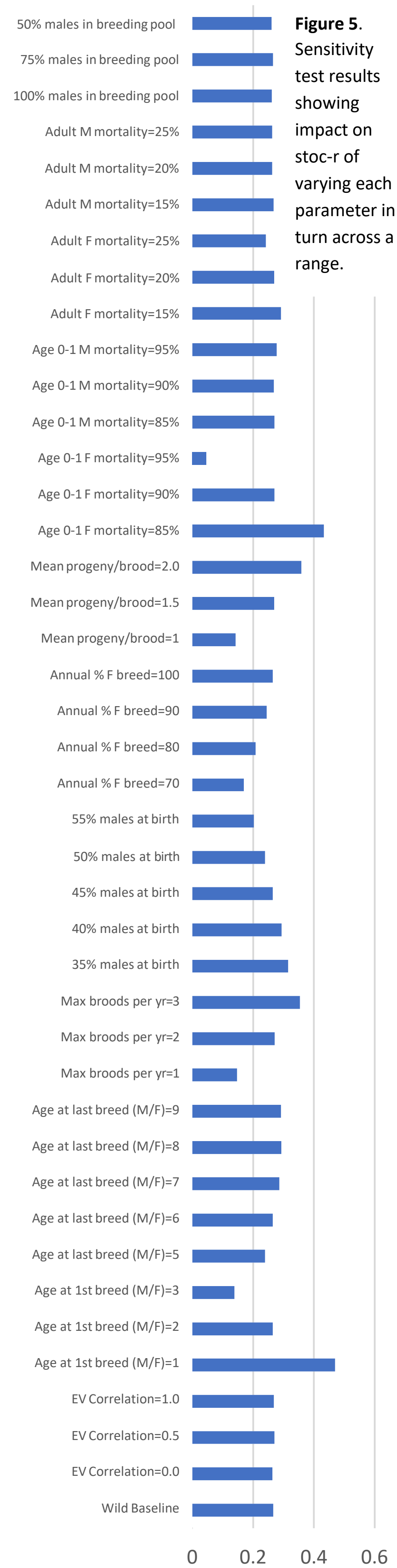


Figure 5. Sensitivity test results showing impact on stoc-r of varying each parameter in turn across a range.

Wild Model Scenarios

Building from the Wild Baseline, models were constructed to answer specific questions. The results of these analyses are described below.

Question 1: What is the Minimum Viable Population Size (MVP)? Where MVP is defined as the smallest size of population that can persist for 100 years, with an extinction risk of <1% and with >90% gene diversity retained?

Models were built to evaluate the performance of different populations that varied only in their population size. To achieve this, starting size (Ni) and carrying capacity (K) were set to the same value and were varied from Ni=K=50 to Ni=K=700. The timeframe was set to 100 years. The results are shown below:

Ni=K: 50-700	Stoch-r	PE	N-all	SD(N-all)	GD	MeanTE
50	0.0777	0.24	21.54	16.36	0.5026	84.5
60	0.0958	0.08	40.89	20.35	0.5591	88.5
70	0.1053	0.02	51.83	18.91	0.6292	78
80	0.1273	0.03	66.74	17.44	0.6796	79.3
90	0.1335	0.02	76.43	18.21	0.6986	81.3
100	0.1324	0.01	89.44	19.69	0.723	95
150	0.1589	0	139.32	21.61	0.8082	0
200	0.1739	0	188.06	23.45	0.8562	0
250	0.1803	0	239.3	23.69	0.8808	0
300	0.1866	0	286.53	28.8	0.9039	0
350	0.1933	0	342.34	23.67	0.9148	0
400	0.1924	0	386.59	32.96	0.9264	0
450	0.1948	0	435.63	33.94	0.93	0
500	0.1996	0	485.58	37.92	0.9399	0
550	0.1999	0	530.02	49.89	0.9429	0
600	0.2033	0	577.27	54.04	0.948	0
650	0.2033	0	627.62	52.3	0.9529	0
700	0.2041	0	673.94	59.77	0.956	0

Table 3. Results of Minimum Viable Population Size tests for population sizes (and carrying capacities) ranging from 50 – 700, where MVP is defined as <1% extinction risk over 100 years and retention of >90% gene diversity. Orange shading: meets neither criteria; Yellow shading: meets extinction risk but not gene diversity retention criteria; Green shading: meets both criteria.

Figure 5a. MVP Tests: graph of average N across all iterations over 100 years, for Ni=K ranging from 50-700.

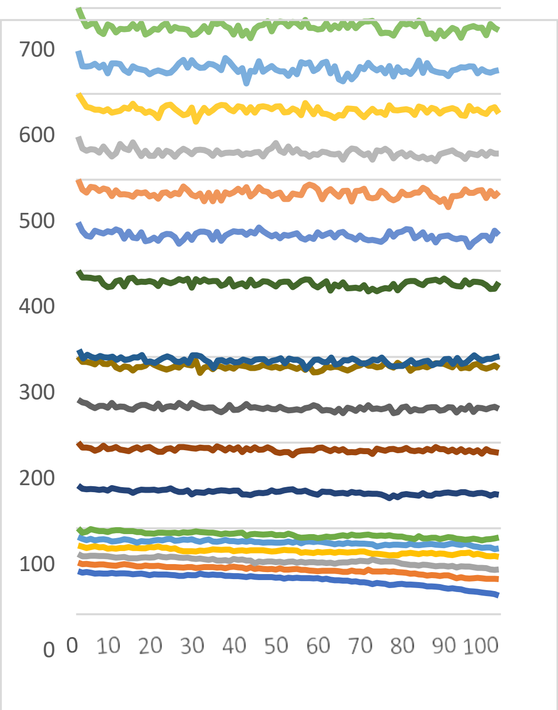
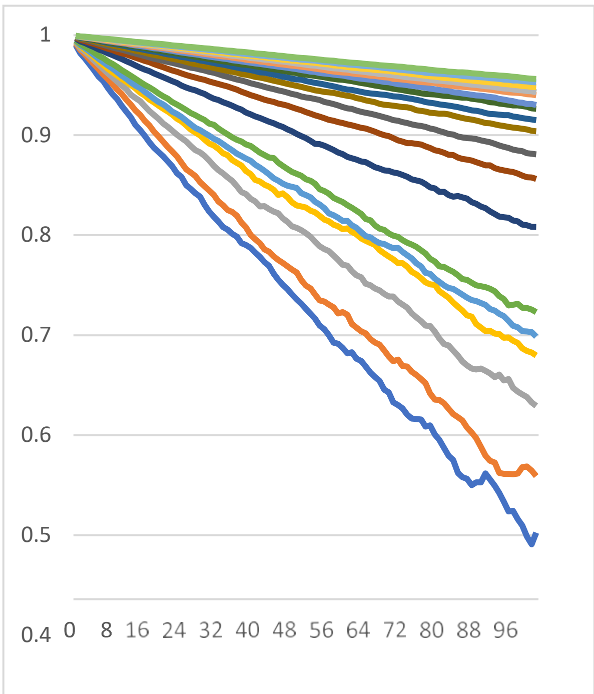


Figure 5b. MVP Tests: graph of average GD across all iterations over 100 years, for Ni=K ranging from 50-700.



- Larger populations show higher average growth rates as small population pressures are decreased.
- As population size/carrying capacity increases, variability (measured as Standard Deviation about the average size) decreases as a proportion of the mean – populations become more stable and more predictable.
- For the conditions specified in these models, populations beginning with fewer than 150 individuals and unable to grow larger do not reliably meet the MVP criteria set (<1% extinction risk over 100 years and >90% gene diversity retained).
- Smaller populations (N=100-50) show 100-year extinction risks ranging from 1-24% respectively, however extinctions are usually towards the end of the 100-year period (Mean Time to Extinction ranges from 78-95 years).
- MVPs in this analysis may be optimistic as no catastrophes are included in the models and growth rates are relatively high compared to other rates found in the literature for freshwater fishes.

Question 2. What is the expected impact of flood mitigation on a population of Stumpy Bullheads?

These scenarios assume a starting population of 500 individuals and flood mitigation (through dredging) at intervals of 20, 10 and 5 years, with an impact of 90% loss of habitat (and, therefore, 90% loss of population) in the year of occurrence.

1) Twenty-year dredging with varied habitat recovery rate: allows habitat recovery to begin immediately following a dredging event, and to continue at a steady rate over the following 1, 2, 3, 4 or 5 years.

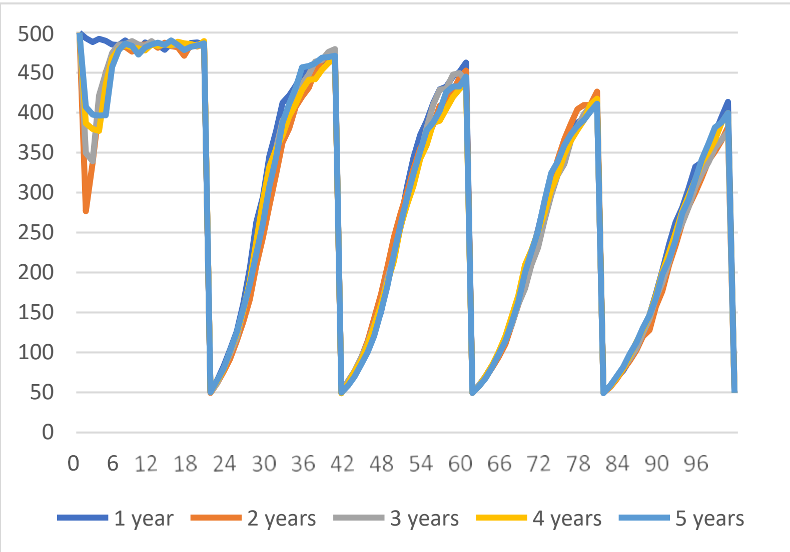


Figure 6. Shows mean wild population size over time, across iterations, for a 100 year period, with dredging occurring every 20 years and habitat recovery taking place at an even rate over the following 1, 2, 3, 4 or 5 years.

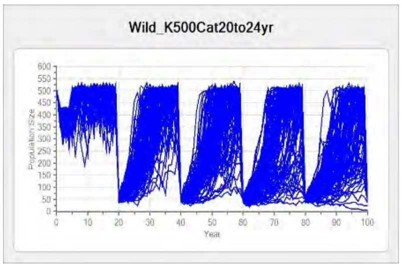


Table 4. 100-year wild population results for 20-yearly dredging recovery over 1, 2, 3, 4 and 5 years.

Even restoration rate over X years	Stoch-r	PE	N-all	SD(N-all)	GD
1 year	0.1711	0.00	49.69	7.14	0.8245
2 years	0.1675	0.00	50.34	8.00	0.8128
3 years	0.1674	0.00	49.5	6.29	0.8317
4 years	0.1688	0.01	49.17	8.34	0.8198
5 years	0.1669	0.00	49.61	7.76	0.8269

As illustrated in Figure 6., after the first dredging event, on average the simulated populations recover almost to carrying capacity. However, the ability to recover gradually diminishes over time due to inbreeding, which is exacerbated by the regular population bottlenecks. As shown in Figure 6 and Table 4, varying the recovery time of habitat over 1, 2, 3, 4 or 5 years makes little difference to this overall pattern of fish population recovery. This is because population growth is only partly governed by the amount of available habitat and is also governed by the species' biology (as described in the models). As a result, the species' population growth cannot keep pace with habitat recovery as described here, even at the slower rates modelled. Despite this, the populations recover reasonably well under all scenarios with little risk of extinction (PE≤1% for all). All five scenarios perform poorly with respect to gene diversity retention, which is below recommended target levels of 90-95% at 100 years (GD=0.8128 – 0.8198).

2) Ten-year dredging with varied habitat recovery rate: allows habitat recovery to begin immediately following a dredging event, and to continue at a steady rate over the following 1, 2, 3, 4 or 5years.

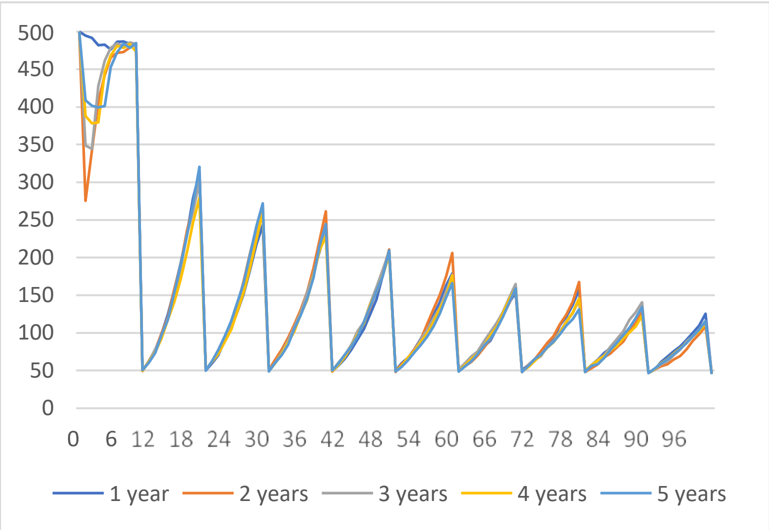


Figure 7. Shows mean wild population size over time, across iterations, for a 100-year period, with dredging occurring every 10 years and habitat recovery taking place at an even rate over the following 1, 2, 3, 4 or 5 years.

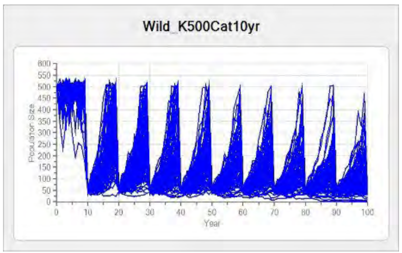


Table 5. 100-year wild population results for 10-yearly dredging recovery over 1, 2, 3, 4 and 5 years.

Even restoration rate over X years	Stoch-r	PE	N-all	SD(N-all)	GD
1 year	0.1422	0.02	46.02	11.91	0.7122
2 years	0.1410	0.01	46.89	10.78	0.6981
3 years	0.1396	0.00	45.58	10.30	0.7026
4 years	0.1436	0.00	47.06	11.11	0.7218
5 years	0.1403	0.02	45.54	12.39	0.7061

As shown in Figure 7 and Table 5, with dredging frequency increased to every 10-years, populations are even less able to recover and rarely exceed N=300 before the next dredging event. Again, and for the same reasons, varying the habitat recovery time from 1-5 years makes little difference. Extinction risk is higher but remains low (PE<5% for all five scenarios). However, the gradual inbreeding-induced decline is even more pronounced with final gene diversity retention even lower (GD=0.6981 – 0.7218), which might be expected from a population at constant carrying capacity of 90-100 individuals (see Table 3.).

3) Five-year dredging with varied habitat recovery rate: allows habitat recovery to begin immediately following a dredging event, and to continue at a steady rate over the following 1, 2, 3, 4 or 5years.

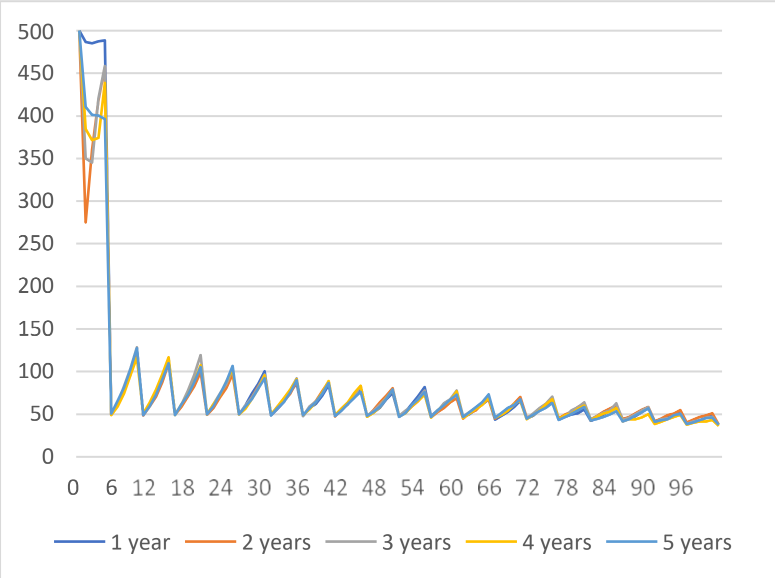


Figure 8. Shows mean wild population size over time, across iterations, for a 100 year period, with dredging occurring every 5 years and habitat recovery taking place at an even rate over the following 1, 2, 3, 4 or 5 years.

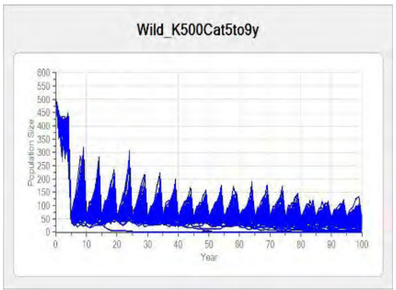


Table 6. 100-year wild population results for 5-yearly dredging recovery over 1, 2, 3, 4 and 5 years.

Even restoration rate over X years	Stoch-r	PE	N-all	SD(N-all)	GD
1 year	0.1079	0.08	37.51	16.45	0.6197
2 years	0.1086	0.05	37.64	16.89	0.6147
3 years	0.1121	0.08	37.44	16.17	0.6078
4 years	0.1087	0.08	36.04	17.35	0.6042
5 years	0.1075	0.10	37.47	18.3	0.616

As expected, Figure 8. and Table 6. show that dredging at 5-year intervals generate results that are worse than those of 10 and 20-year dredging frequencies. The population shows elevated extinction risk (ranging from PE=0.08-0.10 across the scenarios modelled) and mean population size and gene diversity are both further reduced.

In summary, the impact of periodic dredging on this species will be highly influenced by the maximum growth rate of the species, the rate of habitat recovery, the severity of impact of the dredging operation on the species and its habitat, and the influence of inbreeding accumulation on species fitness over time. Here we are only estimating these parameters but based on these estimates we expect population fitness to decline over time at each of the three dredging intervals considered (20, 10 and 5 years) and, as expected, more severely and more rapidly where dredging is more frequent.

Note that we assume no re-colonisation from elsewhere due to the small migration distances of this species and the long distances between occupied sites. Migration in post-dredging from other populations could offset some of the inbreeding effects. Note also that these results are premised on a starting population Ni-500 such that a 90% reduction at each dredging event still leaves 50 individuals. Post-dredging recovery would be depressed at lower starting sizes.

EX SITU MANAGEMENT AND MODELLING

Ex situ management of populations can play many roles in the conservation of threatened species. Here we focus only on *ex situ* management for supplementing or reintroducing wild populations. The focus here is on management of *ex situ* stocks and not on preparing the ground for reintroduction *in situ*, which is a connected but additional piece of work.

An *ex situ* population of a threatened species can have the following advantages over an *in situ* population:

1) It can be protected from the threats that have driven the wild population towards extinction
2) It can be protected from other, natural mortality factors that affect wild populations and as a result can grow faster and more consistently
3) It can be managed to retain more genetic diversity than a wild population of the same size

An *ex situ* population of a threatened species can have the following disadvantages:

Husbandry challenges. Detached from natural food sources, photoperiods and other environmental triggers and influences target survival and reproduction rates can be hard to achieve, at least in the early years of a program (which is often a time when individuals of the species are at their most precious due to limited supply).

Adaptation to captivity. Natural selection pressures in the wild ensure that in general, individuals that are fit-for-purpose there. These pressures are released and sometimes replaced in *ex situ* environments, inadvertently driving phenotypes in directions that will work less well in the wild. This can be particularly detrimental if accompanied by acute loss of gene diversity and, therefore, of phenotypic plasticity such that release populations may struggle to re-adapt to wild conditions.

Small population effects. *Ex situ* populations are usually small compared to their wild counterparts and are also often localised. Small, localised populations are at greater risk to demographic stochastic or "chance" events such as fire, flood or disease outbreak at a single facility; a few poorer breeding or survival years; or an unusual sex-ratio bias in a year's reproductive output. They are also at risk to genetic stochastic events: small populations lose genetic diversity by chance (rather than selection), through a process known as "genetic drift", whereby rare alleles, which are, by definition, held in relatively fewer copies in the population, are not transmitted to the next generation. The rate of loss of genetic diversity through drift is inversely proportional to the genetically effective size of the population, according to the following equation:

$$H_t = (1-1/2Ne)^t H_0$$

Where H_0= initial heterozygosity; H_t= heterozygosity after t generations; and Ne=the effective population size.

Effective Population Size is defined as the, "*size of an idealised population (i.e., one that meets all the Hardy-Weinberg assumptions) that would lose heterozygosity at a rate equal to that of the observed population*". Hardy-Weinberg assumptions are satisfied when there is:

- No mutation;
- No gene-flow;
- No genetic selection;
- Random mating;
- Large and constant population size.

The closer the population conforms to these idealised characteristics, the closer the genetically effective size will be to the actual, census size and, therefore, the more efficiently it will retain gene diversity. In captive populations, effective sizes are usually 20-40% of the census population size (i.e. the Ne/N ratio=0.2-0.4). However, the average across wild populations of multiple taxa has been found to be as low as 0.1 (Frankham 1995) and as a taxonomic group, fish often sit at the lower end of effective to actual population size ratios.

For *ex situ* management of populations for reintroduction, to minimise the impact of genetic drift and other small population effects, and to reduce the likelihood of strong selection for life in captivity, the following steps are recommended[1]:

STEPS FOR MANAGING *EX SITU* POPULATIONS FOR WILD RELEASE PROGRAMS

1) Take a representative sample of individuals from the wild by:
    a. sampling randomly across the species' range;
    b. taking enough individuals to capture a representative amount of gene diversity, (example approaches below):
        i. 20 individuals (97.8% population heterozygosity);
        ii. 30-50 individuals (a representative sample of rare alleles those with a frequency of ≥5%);
        iii. 150 individuals (a 95% chance of capturing all population alleles occurring at a frequency of ≥ 1%).
2) Suspend evolution in the *ex situ* population by maintaining wild gene pool composition throughout the program as follows:
    a. grow the founder group as quickly as possible to target size[2] to reduce drift during the "founder phase", ensuring each founder contributes the same number of offspring.
    b. once grown, maintain the population at constant, maximum size until releases begin, to prevent further genetic bottlenecks and demographic instability;
    c. maximise effective population size by breeding from as many individuals as possible while at the same time maintaining equal founder contributions through subsequent generations (adjusted for any unequal retention of founder genes due to individual lineage bottlenecks);
    d. slow the accumulation of inbreeding by avoiding pairings between close relatives to support population health (where "close" is measured with respect the population average);
    e. minimise the number of generations in captivity (as gene diversity is lost generationally);
    f. maintain steady breeding rates that are designed to keep the population within available capacity by creating a stable age-structure and avoiding demographic "bubbles" that can lead to population crashes.
3) Set targets and endpoints for *in situ* re-establishment and determine the optimal characteristics of release cohorts to achieve them, considering:
    a. Number of individuals.
    b. Release frequency & timing.
    c. Age structure and sex-ratio.
    d. Previous experience of breeding/survival under specific pressures/disease exposure (where relevant).
4) Once the ground is prepared for release, shift *ex situ* program management towards creating release cohorts, ensuring that the removal of such cohorts will not damage the demographic or genetic integrity of the *ex situ* programme and its ability to meet future targets.
5) Proceed with releases, monitoring both *in situ* and *ex situ* results, and adjust targets and management as needed.

[1] Note that this piece of work is directed towards population management issues – no consideration is given here for how to accelerate the development of good husbandry practice.

[2] Target population size is that calculated to ensure the program's genetic and demographic goals will be met (e.g. the size required to retain 95% gene diversity for 50 years).

6) Grow the wild population to a size expected to allow natural selection (rather than drift) to be the dominant force shaping the gene pool.

NOTE. Species in need of conservation are often compromised, persisting in small or dwindling populations that can be hard to find and individuals hard to capture. Species and their environments are complex, imperfectly understood not easily controlled either *in situ* or *ex situ*. Further, the conservation resources needed to run such programs are often inadequate or fluctuating. For all these reasons, few if any programs manage to execute all of these steps perfectly.

GENETIC MANAGEMENT STRATEGIES FOR SUPPORTING THE IMPLEMENTATION OF THESE STEPS:

Implementing the above steps effectively required data collection tools for demographic and genetic information, and tools able to analyse those data information at the population level, to support decisions. The right tools will depend on species life history traits, on how much and what kinds of information can be collected as well as on the kinds of management intervention that are possible given facilities and resourcing. The following are examples of management schemes aimed at genetic and/or demographic management:

Management by Mean Kinship: individual-based management requiring detailed information on parentage, birth and death dates and age-specific reproductive history to generate a pedigree and life-table. These can then be used to set demographic and genetic goals, annual breeding rate targets, and to create optimal annual pairing schemes for breeding that support equalised contribution of founder lines to the standing population, by prioritising breeding from individuals most likely to contain rare alleles. The PMx application (produced by the Species Conservation Toolkit Initiative: https://scti.tools/) is explicitly designed to run the necessary analyses and to generate a range of outputs based on the data described.

Maximum Avoidance of Inbreeding Schemes: group-based management, usually applied to species where individuals are not easily managed except as part of groups. Populations are separated at the founder phase into several groups (the number of which is ideally a power of 2). Each generation, males are separated out from each group and moved to another group according to a pre-determined round robin scheme, ensuring the slowest possible accumulation of inbreeding across the population. The scheme works best where generations are discrete.

Controlled Gene-flow: group-based management where the population is managed as a single unit in which breeding is expected to be reasonably random. Genetic and demographic health can be maintained by the introduction to the population of additional unrelated individuals. The number and frequency of individuals introduced is guided by targets for gene diversity, inbreeding management, and demographic stability. PVA models can support this style of management where parameters are well known or can be reliably estimated.

EX SITU POPULATION MODELS

Ex situ models were built using the values described in Table 7. The main differences between wild and captive parameters are the extended lifespan in captivity, and the much larger number of hatchlings. Due to this very large number of year 1 offspring, captive models run much slower than the wild models and, where inbreeding is included in the models (which requires an extra processing step) progress is particularly slow. Therefore, for some sets of models, the number of iterations is reduced to 100 and, where it is unlikely to affect results, inbreeding depression is switched off. Questions investigated using the captive models are described below, along with the results.

1) What is the impact on gene diversity retention of decreasing the percentage of females contributing annually to the gene pool?

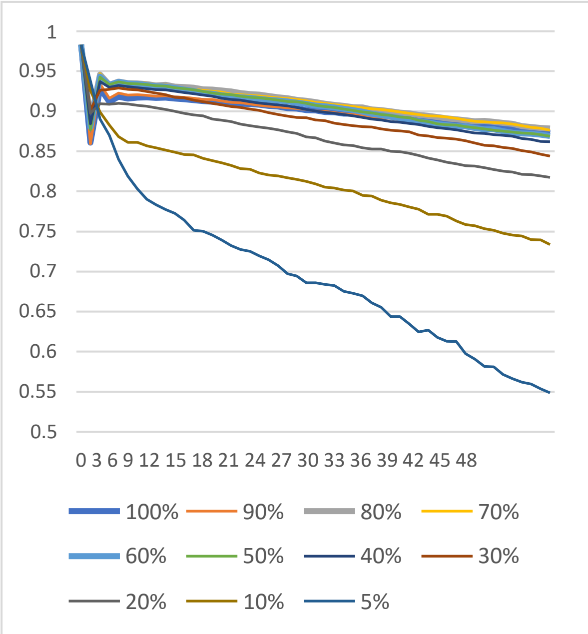


Figure 9. Impact on population gene diversity of reducing the percentage of females contributing to breeding from 100% per year to 5% per year at 10% increments. All simulations begin with 30 founders and run for 50 years.

2) What is the impact on gene diversity retention of decreasing the percentage of males contributing annually to the gene pool?

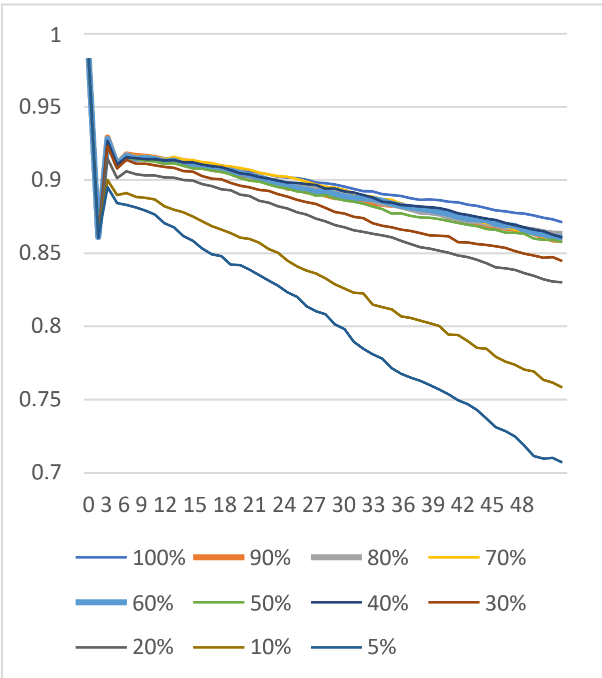


Figure 10. Impact on population gene diversity of reducing the percentage of males contributing to breeding from 100% to 5% at 10% increments. All simulations begin with 30 founders and run for 50 years.

3) What is the impact on gene diversity retention of increasing the number of founders?

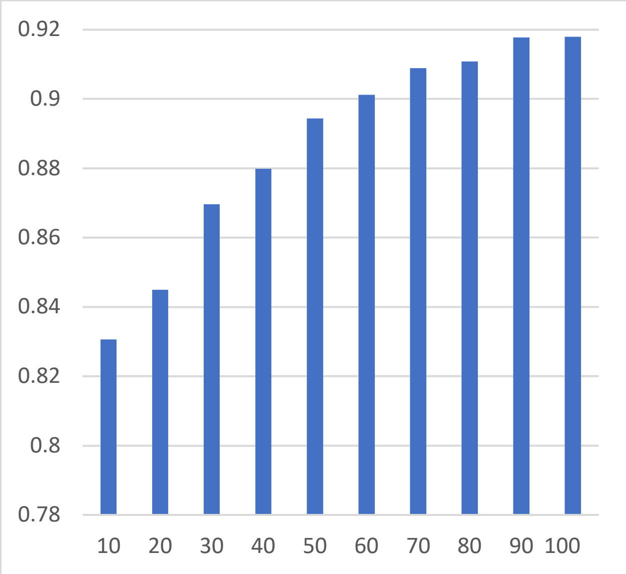


Figure 11. Impact on population gene diversity at 50 years, of increasing the number of founders from 10-100. Carrying capacity is K=200 in each case.

Full details of the performance of captive models under these different scenarios are provided in a summary table in Appendix III.

1) A captive population of N=200 retains ≥ 90% gene diversity for 50 years when founded with 60 founders or more.
2) Gene diversity retention increases as more females contribute to the gene pool.
3) Gene diversity retention increases as more males contribute to the gene pool.

2) and 3) Are not related to population size, which is fixed in these models, but rather to the increased chance of more alleles being transmitted successfully from one generation to the next.

Table 7. Parameter values used in the Stumpy Bullhead baseline model and in sensitivity tests.

Vortex Parameters	**Ex situ Base Model**	**Wild Base Model**	**Rationale & details (unless otherwise stated, source is the S. Korean Stumpy Bullhead PVA Team)**	**Sensitivity Tests?**
Number of years (timesteps)	50	50	Sufficient to expose longer-term effects of genetic deterioration.	-
Number of populations	1	Metapopulation (5 populations)	In the Daegu wild metapopulation there is almost population interconnectivity due to instream structures such as dams, weirs and the limited migration ability of the species.	-
Species Description				
Inbreeding depression	Yes	Yes	No reason to expect the species is immune to this widespread effect.	-
Lethal equivalents	3.14	6.29	No species-specific data. VORTEX defaults used for captive (Ralls & Ballou 1988) and wild (O'Grady et al. 2006)	-
Percent due to recessive alleles	50%	50%	VORTEX defaults applied in absence of species or taxon-specific knowledge.	-
EV correlation between reproduction and survival	0	0	No expected correlation in captivity. There are theories for why it may be the case in the wild but no data.	0, 0.5, 1 (use conservative value in baseline)
Reproductive System				
Breeding system	Short-term polygynous	Short-term polygynous	Males can breed with multiple females in a year, and with a different group of females in subsequent years.	-
Age of first offspring	2	2	Team knowledge, also reflects studies on similar species (Wang et al.2019)	1, 2, 3
Maximum age of reproduction	8	6	Team knowledge/estimates, also reflects studies on similar species (Wan1g et al. 2019)	5, 6, 7, 8, 9
Maximum lifespan	8	6	Team knowledge, also reflects studies on similar species (Wang et al. 2019)	5, 6, 7, 8, 9
Maximum number of broods per female per year	1	1	Wild females may breed 2-3 times per year but captive females are limited to once. Here. Wild females also have only 1 brood as a precaution (no data on the distribution of brood numbers or of the relative success of successive broods).	Wild: 1, 2, 3 (where >1, each equally likely)
Progeny per brood	1300 (eggs)	Normal dist. Mean=15 SD=0	Wild: based on per capita female production of 1 yr-olds estimated from other bagrid catfish (from Wang et al 2019), back-calculated to find the number of Year 0 young assuming 10% post-hatch mortality in age-class 0 - 1, as per Wang et al., 2019.	-
Sex-ratio at birth in % males	45%	45%	Team observations in captivity.	35, 40, 45, 50, 55
Reproductive Rates (SD due to EV)				
% adult females breeding	100 (10)	100 (10)	Team estimation.	70, 80, 90, 100
Distribution of number of offspring per female per brood				

Vortex Parameters	Ex situ Base Model	Wild Base Model	Rationale & details (unless otherwise stated, source is the S. Korean Stumpy Bullhead PVA Team)	Sensitivity Tests?
Use normal distribution	Yes	Yes		-
Mean Standard Dev		15+/2.5	Estimated by Team (captive) and inferred from similar species in Wang et al. 2017 (wild), and Ferosekhana et al. 2019 (captive) (latter report approx. 64% hatch rate).	Wild: 1, 2, 3
Mortality Rates				
Females: mortality rates & (SD in mortality due to EV)				
Age 0 to 1	30% (1.5)	90% (5)	Estimated by Team. Note model highly sensitive to SD in age-class 0-1 mortality.	85, 90, 95
Age 1 to 2	20% (1)	20% (2)	Estimated by Team.	-
After age 2	20% (1)	20% (2)	Estimated by Team.	15, 20, 25
Males (mortality rates and SD in mortality due to EV)				
Age 0 to 1	30% (1.5)	90% (5)	Estimated by Team. Note model highly sensitive to SD in age-class 0-1 mortality.	85, 90, 95
Age 1 to 2	20% (1)	20% (2)	Estimated by Team.	-
After age 2	20% (1)	20% (2)	Estimated by Team.	15, 20, 25
Male monopolisation				
% Males in breeding pool	100%	100%	Estimated by Team.	100, 75, 50
Population size				
Starting population size	200	200	Does not reflect any actual populations – used only to test model characteristics	-
Carrying capacity	200	200	Does not reflect any actual populations – used only to test model characteristics	-
Catastrophes included				
	Human error – one of eight tanks lost each year (0.86 impact on survival)	Flood mitigation - once every 10 years: >90% of habitat lost, recovers over 5-10 years	Note: excluded from the wild baseline, included in the captive baseline.	-

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Appendix I. PVA Participants

No.	Affiliation	Title	Name	Note
1	National Institute of Ecology (NIE)	Division director	CHEONG, Seokwan	Division of Restoration Strategy
2	National Institute of Ecology (NIE)	Team leader	LEE, Jeeong-hyun	Research Planning Team
3	National Institute of Ecology (NIE)	Associate researcher	SHIN, Moonhyun	
4	National Institute of Ecology (NIE)	Associate researcher	BAK, Gippeum	
5	National Institute of Ecology (NIE)	Team leader	YOON, Ju-Duk	Fish & Amphibians, Reptile Team
6	National Institute of Ecology (NIE)	Associate researcher	KANG, DongWon	
7	National Institute of Ecology (NIE)	Associate researcher	PARK, Chang-Deuk	
8	National Institute of Ecology (NIE)	Associate researcher	KWON, Kwanik	
9	National Institute of Ecology (NIE)	Associate researcher	YOO, NaKyung	
10	National Institute of Ecology (NIE)	Associate researcher	YOO, Jeongwoo	
11	National Institute of Biological Resources (NIBR)	Research officer	JUNG, Seunggyu	
12	National Institute of Biological Resources (NIBR)	Researcher	LEE, So-Hee	

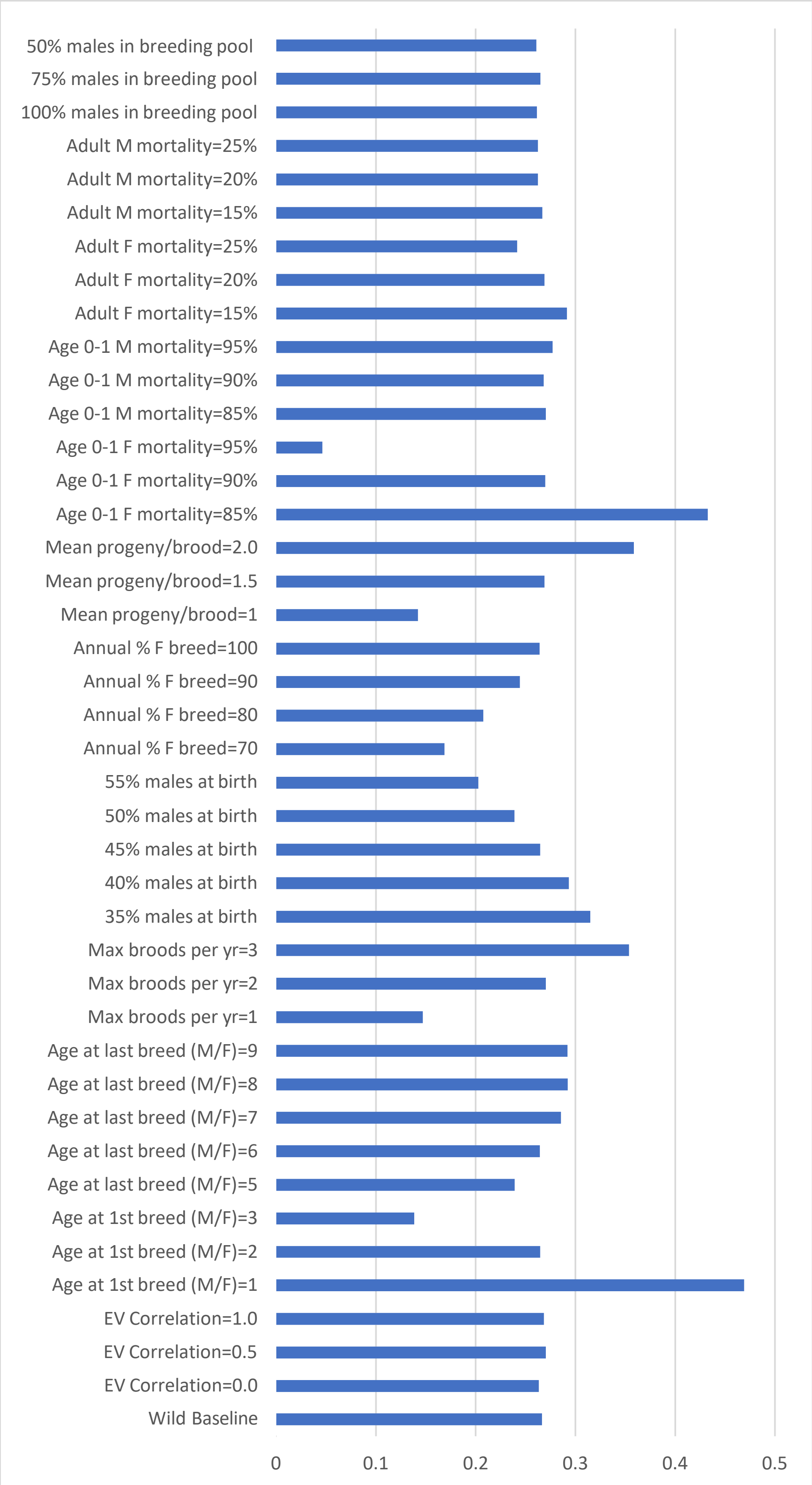
Appendix II. Sensitivity Tests

Table 8. Results of Wild Baseline Model Sensitivity Tests (det-r=deterministic growth; stoch-r=stochastic growth; PE=50-year extinction risk; N-extant=mean population size at 50 years for simulations that did not go extinct; N-all=mean population size at 50 years across all simulations; GeneDiv= gene diversity retained at 50 years; nAlleles=number of alleles retained at 50 years; meanTE=mean time to extinction for simulations that went extinct over the 50-year period).

Scenario (500 runs)	det-r	stoch-r	SD(r)	PE	N-extant	SD(N-ext)	N-all	SD(N-all)	GeneDiv	SD(GD)	nAlleles	SD(nA)	meanTE
Wild Baseline	0.3704	0.2664	0.4863	0.038	169.22	42.71	162.79	52.95	0.8996	0.0346	18.86	3.38	27.2
EV Correlation=0.0	0.3704	0.2632	0.4848	0.032	171.99	42.45	166.49	51.6	0.8993	0.0317	18.6	3.4	30.4
EV Correlation=0.5	0.3704	0.2703	0.487	0.032	172.21	42.35	166.7	51.54	0.9022	0.026	18.92	3.15	26.1
EV Correlation=1.0	0.3704	0.2684	0.485	0.022	171.47	41.54	167.69	48.18	0.8994	0.0391	18.69	3.11	29.2
Age at 1st breed (M/F)=1	0.7095	0.4692	0.5728	0.02	175.45	39.19	171.94	45.93	0.8866	0.0292	16.43	2.55	32.6
Age at 1st breed (M/F)=2	0.3704	0.2646	0.4849	0.036	166.87	44.54	160.86	53.67	0.8992	0.0302	18.56	3.38	30.6
Age at 1st breed (M/F)=3	0.2069	0.1383	0.4134	0.05	160.81	49.62	152.77	59.74	0.8998	0.0614	19.47	4.46	27.5
Age at last breed (M/F)=5	0.3546	0.239	0.4768	0.11	172.38	43.68	153.42	67.92	0.8853	0.0436	16.6	3.45	28.3
Age at last breed (M/F)=6	0.3704	0.2644	0.4859	0.036	171.62	42.52	165.44	52.6	0.9003	0.0301	18.65	3.51	24.1
Age at last breed (M/F)=7	0.3783	0.2855	0.4822	0.002	178.39	35.16	178.03	36.01	0.9076	0.0236	19.82	3.01	41
Age at last breed (M/F)=8	0.3823	0.2924	0.4756	0.004	179.48	34.64	178.76	36.38	0.9104	0.0204	20.5	2.74	17.5
Age at last breed (M/F)=9	0.3844	0.2919	0.4808	0.002	175.65	35.75	175.3	36.56	0.9118	0.0188	20.48	2.93	9
Max broods per yr=1	0.2378	0.1469	0.4036	0.048	153.51	53.93	146.15	62.03	0.8979	0.049	19.05	4.87	27.4
Max broods per yr=2	0.3704	0.2704	0.4817	0.032	172.57	41.83	167.05	51.17	0.9009	0.0253	18.67	3.25	18.7
Max broods per yr=3	0.4714	0.3536	0.5578	0.038	176.17	37.79	169.48	50.08	0.8926	0.0334	17.44	3.09	31
35% males at birth	0.4275	0.3149	0.5195	0.02	175.48	37.78	171.97	44.76	0.8953	0.0332	18	3.06	29.8
40% males at birth	0.4	0.2933	0.5059	0.024	171.51	42.79	167.39	49.78	0.8989	0.0309	18.5	3.33	31.1
45% males at birth	0.3704	0.2647	0.49	0.042	171.78	42.28	164.57	53.87	0.8977	0.0401	18.57	3.49	23.2
50% males at birth	0.3385	0.2388	0.4688	0.028	169.66	44.59	164.91	52.13	0.9002	0.0329	18.57	3.58	26.1
55% males at birth	0.3037	0.2026	0.4466	0.032	165.45	49.77	160.16	56.98	0.8923	0.0405	17.72	3.88	31.3
Annual % F breed=70	0.2533	0.1688	0.4288	0.042	158.8	52.52	152.14	60.47	0.8828	0.0517	16.42	4.04	28.2
Annual % F breed=80	0.2964	0.2076	0.459	0.046	167.88	45.93	160.15	57.02	0.8942	0.0374	17.68	3.65	27.9
Annual % F breed=90	0.3352	0.2443	0.4763	0.04	168.82	45.25	162.07	55.34	0.8985	0.0313	18.48	3.4	30.1
Annual % F breed=100	0.3704	0.2641	0.4901	0.03	170.69	44.89	165.57	52.95	0.8989	0.0519	18.73	3.44	27.5
Mean progeny/brood=1	0.2378	0.1422	0.4068	0.048	149.09	57.2	141.93	64.27	0.8955	0.0486	18.6	4.83	32.1

Scenario (500 runs)	det-r	stoch-r	SD(r)	PE	N-extant	SD(N-ext)	N-all	SD(N-all)	GeneDiv	SD(GD)	nAlleles	SD(nA)	meanTE
Mean progeny/brood=1.5	0.3704	0.2688	0.4861	0.022	168.38	44.69	164.68	50.64	0.8991	0.034	18.59	3.49	32.1
Mean progeny/brood=2.0	0.4697	0.3585	0.5504	0.038	177	39.29	170.27	51.31	0.8972	0.0259	17.95	2.7	23.9
Age 0-1 F mortality=85%	0.5115	0.4327	0.4391	0.028	192.16	19.26	186.86	36.62	0.8914	0.0266	17.36	2.36	25.4
Age 0-1 F mortality=90%	0.3704	0.2698	0.4866	0.034	173.35	42.35	167.45	52.16	0.8997	0.031	18.76	3.39	31.5
Age 0-1 F mortality=95%	0.1485	0.0461	0.4118	0.946	123.96	60.01	6.9	31.27	0.8615	0.1039	14.22	4.48	16.8
Age 0-1 F mortality=85%	0.3704	0.2702	0.3866	0.022	185.11	28.11	181.04	38.88	0.9033	0.0274	19.14	3.12	24
Age 0-1 M mortality=90%	0.3704	0.268	0.4885	0.024	174.6	42.12	170.41	49.47	0.8994	0.0336	18.49	3.42	24.2
Age 0-1 M mortality=95%	0.3704	0.2771	0.5422	0.934	175.21	37.49	14.74	47.55	0.8878	0.0289	16.61	3.17	18.3
Adult F mortality=15%	0.3905	0.2914	0.4923	0.03	175.98	38.11	170.7	48.08	0.9055	0.0229	19.38	2.94	32.8
Adult F mortality=20%	0.3704	0.269	0.4881	0.032	170.13	43.42	164.69	52.19	0.9006	0.0285	18.6	3.08	30.4
Adult F mortality=25%	0.3499	0.2415	0.4849	0.036	164.23	45.96	158.32	54.53	0.8971	0.033	18.16	3.52	25.5
Adult M mortality=15%	0.3704	0.2667	0.4716	0.042	175.93	40.9	168.55	53.38	0.9032	0.03	19.22	3.07	29.7
Adult M mortality=20%	0.3704	0.2625	0.4882	0.032	171.93	41.09	166.43	50.51	0.8999	0.0312	18.45	3.41	23.6
Adult M mortality=25%	0.3704	0.2625	0.4948	0.046	171.17	42.53	163.3	54.9	0.8972	0.0374	18.21	3.43	26.7
100% males in breeding pool	0.3704	0.2614	0.4876	0.032	171.87	42.09	166.37	51.3	0.8993	0.0396	18.67	3.38	26
75% males in breeding pool	0.3704	0.2648	0.4839	0.032	169.14	45.05	163.72	53.41	0.8908	0.0465	17.47	3.52	31.1
50% males in breeding pool	0.3704	0.2608	0.484	0.03	173.64	40.53	168.44	49.71	0.8792	0.0463	15.91	3.21	27

Figure 5. Sensitivity Test Results for Stochastic Growth rate



Appendix III

Table 9. Impacts of variations in founder number and percentages of males and females contributing to the breeding pool on model performance.

Scenarios	stoch-r	SD(r)	PE	N-extant	SD(N-ext)	N-all	SD(N-all)	GeneDiv	SD(GD)	nAlleles	SD(nA)
Founders											
10	2.8162	0.6366	0.0000	200.04	8.50	200.04	8.50	0.8306	0.0479	9.75	2.35
20	2.9099	0.3458	0.0000	199.35	7.94	199.35	7.94	0.8805	0.0276	15.22	2.21
30	2.9184	0.2942	0.0000	200.57	8.55	200.57	8.55	0.8696	0.0327	15.18	2.26
40	2.9221	0.3168	0.0000	200.14	8.68	200.14	8.68	0.8799	0.0393	16.07	2.95
50	2.9510	0.2778	0.0000	199.74	9.15	199.74	9.15	0.8944	0.0289	18.00	2.49
60	2.9613	0.2814	0.0000	202.41	8.71	202.41	8.71	0.9012	0.0280	19.32	2.60
70	2.9756	0.2486	0.0000	200.98	8.65	200.98	8.65	0.9089	0.0234	20.54	2.56
80	2.9742	0.2513	0.0000	198.40	7.56	198.40	7.56	0.9108	0.0184	20.93	2.61
90	2.9868	0.2452	0.0000	198.37	7.92	198.37	7.92	0.9178	0.0167	22.26	2.41
100	2.9869	0.2500	0.0000	199.85	7.79	199.85	7.79	0.9180	0.0212	23.05	3.15
Percentage females breeding											
100	2.9224	0.2972	0.0000	200.14	7.80	200.14	7.80	0.8723	0.0319	15.08	2.59
90	2.8151	0.3163	0.0000	200.82	7.55	200.82	7.55	0.8704	0.0349	15.25	2.22
80	2.7072	0.3091	0.0000	200.13	8.85	200.13	8.85	0.8785	0.0295	15.57	2.59
70	2.5798	0.3153	0.0000	200.65	8.36	200.65	8.36	0.8763	0.0305	15.36	2.19
60	2.2580	0.3017	0.0000	200.19	8.00	200.19	8.00	0.8691	0.0344	14.32	2.26
50	2.2553	0.3247	0.0000	199.12	8.27	199.12	8.27	0.8688	0.0382	14.19	2.12
40	2.0525	0.3284	0.0000	198.57	7.65	198.57	7.65	0.8620	0.0377	13.10	2.42
30	1.7729	0.3415	0.0000	198.95	7.76	198.95	7.76	0.8440	0.0430	11.68	2.20
20	1.3999	0.3476	0.0000	199.25	8.02	199.25	8.02	0.8175	0.0514	9.65	1.87
10	0.7934	0.3965	0.0100	199.63	7.83	197.63	21.43	0.7336	0.0908	6.52	1.65
5	0.2895	0.4213	0.1600	191.37	23.30	160.75	73.67	0.5669	0.1670	3.85	1.14
Percentage males breeding											
100	2.9172	0.2951	0.0000	199.47	7.44	199.47	7.44	0.8712	0.0351	14.69	2.36
90	2.9189	0.2964	0.0000	201.01	8.54	201.01	8.54	0.8590	0.0463	14.67	2.25
80	2.9206	0.2948	0.0000	198.55	8.15	198.55	8.15	0.8634	0.0383	15.01	2.84
70	2.9164	0.2968	0.0000	200.91	8.85	200.91	8.85	0.8577	0.0443	14.45	2.42

Scenarios	stoch-r	SD(r)	PE	N-extant	SD(N-ext)	N-all	SD(N-all)	GeneDiv	SD(GD)	nAlleles	SD(nA)
60	2.9116	0.2925	0.0000	199.13	8.22	199.13	8.22	0.8607	0.0387	14.07	2.31
50	2.9098	0.2945	0.0000	199.59	9.46	199.59	9.46	0.8576	0.0495	14.14	2.19
40	2.9125	0.2946	0.0000	201.06	8.35	201.06	8.35	0.8608	0.0374	13.74	2.23
30	2.9094	0.2927	0.0000	199.52	9.22	199.52	9.22	0.8446	0.0456	12.82	2.33
20	2.8939	0.2924	0.0000	200.00	7.74	200.00	7.74	0.8301	0.0510	11.46	1.88
10	2.8682	0.2891	0.0000	200.73	8.72	200.73	8.72	0.7583	0.0823	8.48	1.71
5	2.8239	0.2893	0.0000	199.75	7.64	199.75	7.64	0.7070	0.1091	6.72	1.59

WORKING GROUP NOTES:

Members: Ahreum Choi, Won Jae Choi, Jin Choi, Dongsu Ha, Jeong-Ho Han, Hye-Rin Joo, Jin-Yong Kim, Joung Won Kim, Sarah Kim, Myeong-Hun Ko, Eunok Lee, Hakbong Lee, Jung-Hyun Lee, Sungchae Moon, Moonhyun Shin, Sang-Ho Son, Ha Youn Song, Sung-Yeon Yoo

ISSUE STATEMENTS

Group title: Habitat Conservation
Group members: Dr. Myeong-Hun Ko, Dr. Ahreum Choi, Jin Choi, Joung Won Kim, Dr. Sungchae Moon, Moonhyun Shin

Issue 1

Issue	***Habitat destruction by construction***
Description:	*The Constructions have hugely impacted on many habitats of the species. The physical alternation of the habitats is serious*
Impact:	*Physical alternation of the habitats*
Causes:	*Because of climate change and human use (drinking water & industrial water), to prevent flow reduction, flood and drought, government have to build a lot of DAM and weir.*
What do we know?	*DAM and weir are needed (FACT), 5 DAMs and 8 big weirs are constructed in the Nakdonggang river area*
What do we assume?	*Do we need more DAMs and weirs?*
What more do we need to know?	*Research on the impacts of DAM and big weir construction*
STATEMENT	*기후변화 및 인간의 필요에 따라 하천의 대형 건설(댐, 대형 보 등)이 꼬치동자개의 서식지에 심각한 영향을 끼친다.* ***Due to climate change and human needs, the large-scale construction of rivers (dams, large weirs, etc.) has a serious impact on the habitat of the Korean Stumpy Bullhead.***
GOAL 1:	*Strict and suitable EIA for freshwater ecosystem must be applied before the construction is implemented*
GOAL 2:	*Research on the influence and value of the existing dams and big weirs must be conducted and if some of them are not worthy enough, they should be removed.*

Issue 2

Issue	***River maintenance***
Description:	*Mainly River dredging every 3 to 10 years by mainly local government*
Impact:	*Physically alternation of the habitat environment of the species*
Causes:	*To prevent flood and to maintain streamflow*
What do we know?	*Periodically dredged in every 3 to 10 years. It benefits to a lot of developers (Stakeholders). Local government is in charge of the local river (branches) maintenance (most of the habitats of the species), but the main stream management is up to central government.*

What do we assume?	*directly impacts on the habitat qualities. environmental impact assessment is not properly implemented for the habitats before the maintenance works.*
What more do we need to know?	*How serious impact on the habitat and the species? Does river maintenance need every 3 to 10 years?*
STATEMENT	*물의유량유지 및 홍수방지를 위한 주기적인 하천정비공사는 꼬치동자개의 서식지를 파괴한다.* ***Periodic river maintenance work to maintain the flow of water and prevent flooding destroys the habitat of the pike.***
GOAL 1:	*EIA must be included in the river maintenance plan in every region*
GOAL 2:	*If endangered species is found, conservation plan of the species must be set*
GOAL 3:	*Scientific and systematic guideline for river maintenance is established*

Issue 3

Issue:	*Pollution*
Description:	*Industrial water and domestic sewage especially near the big cities flows to the river. Livestock wastewater and pesticide from near rivers*
Impact:	*A decline in water quality*
Causes:	*Near the rivers, there are too many agricultural lands and livestock farms and big cities and manufacturing areas.*
What do we know?	*There are many agricultural lands and livestock farms near the rivers, especially upstream area. Also, the rivers go through big cities and industrial areas in many regions in Nangdonggang river. The species lives in only clean water.*
What do we assume?	*The pollutions seriously Impact on the habitat qualities.*
What more do we need to know?	*What type and degree of contamination that could kill the species.*
STATEMENT	*생활하수 및 축산폐수 등의 수질오염이 꼬치동자개의 서식지 수질에 부정적 영향을 미친다.* ***Water pollution, such as domestic sewage and livestock wastewater, has a negative impact on the water quality of the Korean Stumpy Bullhead breeding habitat.***
GOAL 1:	*Investigation and regulation for pollution sources near the habitat of the species must be conducted and established*

Issue 4

Issue:	***Human leisure activity***
Description:	*Korean people like to visit riverside and do many activities including fishing, riding, swimming, camping, and eating near the rivers, car wash.*
Impact:	*Capturing the species (they even don't recognise that is endangered species). Intensive visits during the summertime could impact on the habitat qualities*
Causes:	*Headwater sites are really famous places for the leisure activities. And lack of education for the habitat and species conservation*
What do we know?	*Many habitats of the species used by human leisure activities. The season of summer exodus is right after the breading season of the species.*

What do we assume?	*Human leisure activities impact on the decrease of the individuals of the species.*
What more do we need to know?	*How much do human leisure activities impacts on the species and habitats.*
STATEMENT	*하천 변에서 이루어지는 인간의 여가활동이 꼬치동자개의 서식에 부정적 영향을 미친다.* ***Human leisure activities along the riverside have a negative impact on the habitat of the Korean Stumpy Bullhead***
GOAL 1:	*Designate protected areas for the habitat of Korean Stumpy bullhead*
GOAL 2:	*Reinforce conservation education for public and observation for illegal behaviours*

Group title: Group 2
Group members: Eunok Lee (Facilitator), Sung-yeon Yoo (Presenter), Won Jae Choi (Computer Recorder), Hakbong Lee (Timekeeper), Jung-hyun Lee, Sang-ho Son

Issue 1

Issue:	***The emergence of introduced species***
Description:	*Korean stumpy bullhead is struggling with its survival from introduced species. Bass (Micropterus salmoides) appears to hunt Korean stumpy bullhead. Also it is competing against Pseudobagrus koraenus(black bullhead, 눈동자개).*
Impact:	*The number of Korean stumpy bullheads is decreasing.*
Causes:	*The expansion of habitat of Bass.*
What do we know?	*Bass prefers living in a deeper water with aquatic plant, while Korean stumpy bullhead live shallow water. The characteristic of Pseudobagrus koraenus and Korean stumpy bullhead's habitats are similar.*
What do we assume?	*Bass usually hunts Korean stumpy bullhead for food.* *Interbreeding among similar species are fairly likely.*
What more do we need to know?	*The diet of Bass it is not clear if Korean stumpy bullhead is a main prey of Bass.*
STATEMENT	***The emergence of introduced species affected the life condition of Korean stumpy bullhead. Bass, an invasive species in the Republic of Korea, appears to hunt Korean stumpy bullhead. The presence, and expansion of the habitat, of Bass is highly likely to lead to the decrease of the number of the Korean stumpy bullhead, as well as decline in genetic diversity. In addition, it is observed that the black bullhead has moved to Nakdong river area, resulting in overlapping habitats between black and Korean stumpy bullheads. The increasing number of introduced species seems to play a key role in the declining number of Korean stumpy bullhead, but more research is necessary regarding issues such as the diet and interbreeding.***
GOAL 1:	*Reducing Bass (e.g. Fishing contest)*
GOAL 2:	*Physically prevent movement into KSB habitat*
GOAL 3:	*Increase knowledge about the predator-prey relationship between Bass & KSB*

Issue 2

Issue:	***Lack of awareness***
Description:	*The general absence of awareness of Korean stumpy bullhead to general public led to the decline in the population of Korean stumpy bullhead. Meanwhile, some collectors poach Korean stumpy bullhead for leisure.*
Impact:	*Decrease of population and generic diversity.*
Causes:	*Illegal overfishing due to the lack of awareness.*
What do we know?	*Most of Korean people don't know about the species and can't recognize differences between the species and other Bagrid*
What do we assume?	*More and more people have cared about endangered species in Republic of Korea. Education program for public and local community regarding the Korean stumpy bullhead was not enough.*
What more do we need to know?	*Unsure about the exact current status (e.g. the number of the fish)*
STATEMENT	***Korea has awareness problems. Ignorance and excessively undesirable interest (poaching). Many members of the general public do not have any knowledge of Korean stumpy bullhead and its value as an endangered species. Whereas, some catch them because they are fully aware the value**.*
GOAL 1:	*Better engagement from local community*

Issue 3

Issue:	***Institutional design***
Description:	*More active cooperation across government agencies (Ministry of Environment, Land, Transport, Maritime Affairs and Agriculture, Food and Rural Affairs, K-Water, and Cultural Heritage Administration, Subnational government) is necessary with regards to knowledge, administration etc. The law on wild creatures is mainly focusing on regulations on illegal fishing, while it rarely mentions the way for the restoration.*
Impact:	*The lack of coordination negatively affects the efficacy of restoration and destruction of habitats* *Inappropriate follow-up actions or implementation*
Causes:	*The government agencies have less incentives to cooperate.* *The lack of understanding of laws on wildlife species.* *Bureaucratic context in Korea (Frequent job rotation)*
What do we know?	*There is much room for development for legal protection of wild animals.*
What do we assume?	*Job rotation necessarily has a negative impact on expertise.*
What more do we need to know?	
STATEMENT	*Wildlife laws focus mainly on regulations on illegal fishing, and rarely mention the destruction of habitats or the need for efficacy of restoration. In addition, the lack of consistency in governmental staff positions leads to lack of coordination and cooperation across government agencies with regards to knowledge, administration, focus and follow-up.*
GOAL 1	*Change in bureaucratic organisational culture of Korea*
GOAL 2	*The launch of joint association*

Issue 4

Issue:	***Need more research on living condition and behavioural status, in Nakdong river area***
Description:	*The lack of research on Korean stumpy bullhead*
Impact:	*Difficulty in planning restoration strategy and grasping the current status of Korean stumpy bullhead*
Causes:	*Fishery restoration research is more centered on artificial breeding.* *The lack of research pool.*
What do we know?	
What do we assume?	
What more do we need to know?	*Habitat condition, behavioural cycle, predator relation, causality*
STATEMENT	The lack of research on the Korean stumpy bullhead makes it difficult to conduct a thorough status assessment and, therefore, to plan for the species recovery.
GOAL 1:	*Fundamental study about Korean stumpy bullhead in Deaga stream*
GOAL 2:	*Budget for long-term research*

ACTIONS TO ACHIEVE GOALS FOR KOREAN STUMPY BULLHEAD CONSERVATION AND RECOVERY

Two working groups were formed to discuss these goals and consider alternative ways of achieving them.

Group 1
Group Members: Son, Sang Ho, Hakbong Lee, Hye-Rin Joo, Sarah Kim

GOAL 1: Night surveillance

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Imposition of penalty for illegal fishing**	**Number of inspections per year**	**Ministry of Environment/ local government**	**Install facilities**	**Open recruitment and monitoring**	**-**

GOAL 2: Guiding them not to catch the fish

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Making audio/ video contents for education produced by famous youtube creators**	**Public knowledge level**	**Ministry of Environment/ National Institute of Ecology**	**Survey**	**Producing education contents**	**Disseminating the contents and monitoring**

GOAL 3: Raising research fund

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Involving company in conservation project (i.e., ESG management)**	**Budget**	**National Institute of Ecology/**	**Planning**	**Demand survey/ seeking companies**	**monitoring**

GOAL 4: Implementing education outreach in local society

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Development of formal education program for local students (with off-line activity)**	**Knowledge level of local students about the species**	**Academic society/ local society**	**Gathering opinion on education subject from professionals and local residents**	**Meetings and development of education program**	**Applying the program to local school/ monitoring**
2	**Education outreach for the local residents**	**Knowledge level of local residents**	**Professionals, National Institute of Ecology**	**Aggregate professionals**	**Development of education program**	**application**

GOAL 5: Introducing new regulations or law for conservation planning & evaluation

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Developing a framework for conservation project planning and evaluation, and applying them to all governmental organization involved in species recovery project.**	**Application of the framework**	**Governmental organizations/ Ministry of Environment**	**Collecting case studies**	**Testing the framework**	**Application of the framework to all conservation projects**
2	**Persuading stakeholders to understand the needs for the law**	**Amendment of law**	**National Institute of Ecology/ Ministry of Environment**	**Providing information to stakeholders and explaining it**	**Meeting and writing a draft/review**	**legislation**

GOAL 6: Integrate the hands-on experiences in decision making process

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Formation of inter-governmental consultative group and regular meeting**	**Information (e.g., related project details, plan, outcomes, etc.) shared among governmental organization**	**Ministry of Environment/ National Institute of Ecology/ Cultural Heritage Administration**	**Formation of inter-governmental consultative group**	**Sharing information**	**continued**

Group Name: Group 2
Group Members: Jin CHOI, Moonhyun SHIN, Sung Yeon YOO
ISSUE 1 GOAL 1: Strict and suitable EIA for freshwater ecosystem must be applied before the construction is implemented

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Government agencies reinforce the EIA law for the construction of dams and weirs**	**Legislation**	**member of the National Assembly**	**Analysis of current status**	**making publicized, Propose amendment of law**	**Legislation**

ISSUE 1 GOAL 2: Conduct research on the influence and value (flood control and water supply) of the existing dams and big weirs, and if some of them are not worthy enough they should be removed (using techniques sensitive to all ecological values and species groups to avoid inadvertent damage)

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Government make budget for the research**	**Budget for the research**	**Ministry of Environment**	**making publicized**	**Making budget**	

2	**Research institutes conduct the research**	**Research reports**	**Research Institutes**			**Conducting the research**

ISSUE 2 GOAL 1-2: EIA must be included in the river maintenance plan in every region and If endangered species is found, conservation plan of the species must be set

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Government agencies reinforce the EIA law for the river maintenance plan**	**Legislation**	**member of the National Assembly**	**Analysis of current status**	**making publicized, Propose amendment of law**	**Legislation**

ISSUE 2 GOAL 3: Scientific and systematic guideline for river maintenance is established

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Guideline is already established in 2015.**					

ISSUE 3 GOAL 1: Investigation and regulation for pollution sources near the habitat of the species must be conducted and established

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**National Institute of Ecology Investigates pollution sources near the major habitats of the species (Daegacheon, Gokkangcheon, Jahocheon, and Deokcheongang)**	**Investigation reports**	**Government agencies (National institute of Environmental Research)**	**Making Budget**	**Conducting investigation**	
2	**Ministry of Environment designates the major habitats as wildlife protection areas (Pollution control)**	**Designation**	**Local government, Research institute**		**making publicized, Propose amendment of law**	**Legislation**

ISSUE 4 GOAL 1: Designate protected areas for the habitat of Korean Stumpy Bullhead

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Ministry of Environment designates the major habitats as wildlife protection areas (restricted area for public uses)**	**Designation**	**Local government, Research institute**		**making publicized, Propose amendment of law**	**Legislation**

ISSUE 4 GOAL 2: Reinforce conservation education for public and observation for illegal behaviours

No.	Action description	Success Indicators	LEAD (Collaborators)	0-1 year	1-5 years	5-10 years
1	**Related institutes make education program for public**	**Education**	**Related institutes**	**Making Budget**	**Make and manage the programs**	
2	**Related institutes publish books about the species**	**Publication**	**Related institutes**	**Making Budget**	**Publication**	
3	**Ministry of Environment propose to put endangered species conservation in school textbook**	**Publication**	**Ministry of Education**	**making publicized**	**making publicized**	**Revise school textbook**

APPENDIX I. PARTICIPANTS OF THE 2023 KOREAN STUMPY BULLHEAD SPECIES CONSERVATION ACTION PLANNING WORKSHOP

NO.	NAME	AFFILIATION
1.	Han, Jeong Ho (한정호)	Korea Water Resources Corporation (한국수자원공사)
2.	Ko, Myeong-Hun (고명훈)	Kosoo Biology Institute (고수생태연구소)
3.	Song, Ha Youn (송하윤)	National Institute of Fisheries Science Inland Fisheries Research Institute (국립수산과학원 중앙내수면연구소)
4.	Son, Sang-Ho (손상호)	Freelancer
5.	Ha, Dongsu (하동수)	Yesan Oriental Stork Park (예산황새공원)
6.	Moon, Sungchae (문성채)	Yesan Oriental Stork Park (예산황새공원)
7.	Joo, Hye-Rin (주혜린)	Seoul National University (서울대학교)
8.	Lee, Jung-Hyun (이정현)	National Institute of Ecology (국립생태원)
9.	Lee, Eunok (이은옥)	National Institute of Ecology (국립생태원)
10.	Choi, Ahreum (최아름)	National Institute of Ecology (국립생태원)
11.	Choi, Jin (최진)	National Institute of Ecology (국립생태원)
12.	Yoo, Sung-Yeon (유성연)	National Institute of Ecology (국립생태원)
13.	Kim, Jin-Yong (김진용)	National Institute of Ecology (국립생태원)
14.	Kim, Sarah (김목영)	National Institute of Ecology (국립생태원)
15.	Kim, Joung Won (김정원)	National Institute of Ecology (국립생태원)
16.	Shin, Moonhyun (신문현)	National Institute of Ecology (국립생태원)
17.	Lee, Hakbong (이학봉)	National Institute of Ecology (국립생태원)
18.	Choi, Won Jae (최원재)	National Institute of Ecology (국립생태원)
19	Choi, Seung-woon (최승운)	National Institute of Ecology (국립생태원)
20	Cheong, Seok Wan (정석환)	National Institute of Ecology (국립생태원)
21	Lee, Hyung Jong	National Institute of Ecology (국립생태원)
22	Lees, Caroline	IUCN CPSG (IUCN 종보전계획수립 전문가그룹)
23	Nguyen, Dao	IUCN

APPENDIX II. PLENARY SESSION NOTES

DAY 1: Issues raised by participants

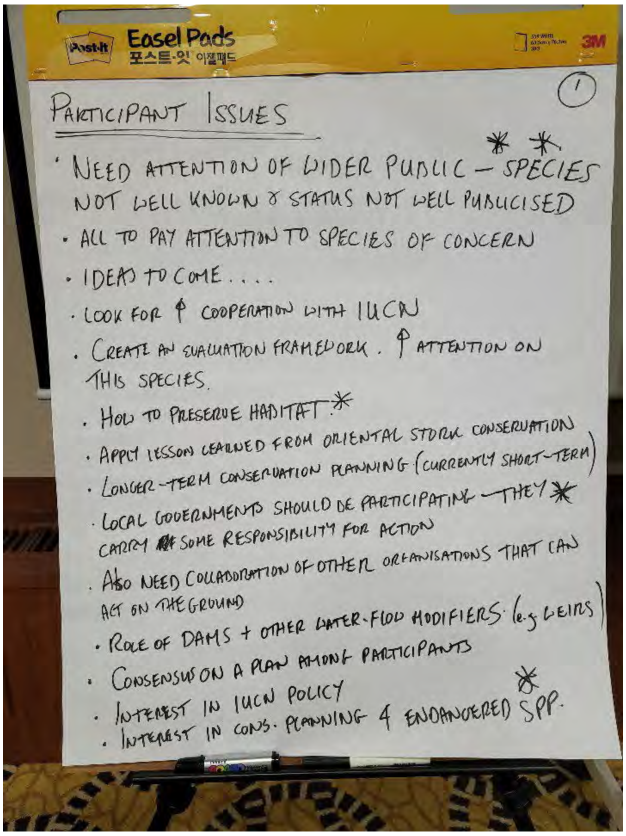
In general participants emphasised the importance of the following:

- PUBLIC AWARENESS
- HABITAT
- STAKEHOLDER ENGAGEMENT
- LONGER-TERM PLANNING

Specifically:

- Very little <u>public awareness</u> of this fish and its poor conservation status
- Need more people to pay attention to species of concern
- Important to pay more attention to <u>habitat</u>
- Need to move to <u>longer-term</u> conservation planning – at present it is mostly short-term
- <u>Engage more stakeholders</u>: local governments and other organisations with influence over freshwater systems need to be engaged in this effort.
- Consider the role of dams and other flow modifying structures (e.g. weirs) in this conservation project
- Need to reach consensus on a plan among the participants present
- Apply lessons learned from oriental stork conservation

Other participants were primarily in attendance to learn more about IUCN policy and conservation planning for endangered species. One participant is charged with developing an evaluation framework for the planning process and resulting plan.



DAY 4 Notes
Under Public Awareness:
Should encourage local communities around the habitat of the KSB to engage with conservation efforts – they often know more about the species and its habitat.
Encourage forums where experts connect with local communities to share knowledge
Work with communities to design conservation projects. Because there are multiple communities around the river system it is possible to trial different interventions in different places, to monitor and compare the outcomes so that management can be adapted on the basis of the shared results.
Q. re pollution actions (GOAL 3 actions, 1 & 2) what about areas where the species used to be but is lost from? Will these be covered?
A. It is not realistic to include all past and future sites for the KSB – this action was just about protecting current KSB populations from the impacts of pollutants. Realistically these measures could be applied to protect two major habitats for the KSB.
GOAL 4. Designation of protected areas – this designation would restrict public uses of these areas, protecting them from pollution from human leisure activities and from illegal fishing activities.

Issue 4 GOAL 2
Incorporating Korean SB into curriculum text books – there are Yellowstone wolves in Korean text books – would be good to have Korean species.
Comments: Animal people engaging in these efforts include fish curators – we have none in our institute. In the past, some experts from the National Museum came to communicate with the public and those kinds of initiatives can be effective.
There are talks about establishing a national museum of natural history in Korea – this could be important for raising the interest of the general public.
Zoos an associations are usually focused on captive breeding – also good at public engagement, hosting events, fund-raising (GROUP 1 has actions for Zoos & Aquaria) – I didn't see them in the wrap-up
GROUP 1 – Reduction of risk factors and raining public awareness
ESG – Environment, Social & Governance
Continuity of personnel in conservation projects is important and should be made possible even when employees shift organisations (which is frequent in Korea) – need to ensure continuity of knowledge and experience within projects.
Funding issue: Patagonia has offered some funding for environmental projects – could encourage private companies to get involved.
No objective criteria to tell people with good intentions from people with bad intentions!

Appendix III: KOREAN STUMPY BULLHEAD (*PSEUDOBAGRUS BREVICORPUS*) CONSERVATION PLANNING WORKSHOP (SCP|PVA)

14-17 FEBRUARY 2023, SEOUL, SOUTH KOREA

WORKSHOP HANDBOOK

The IUCN SSC Conservation Planning Specialist Group's ***One Plan Approach*** *supports the collaborative development of species conservation plans by diverse communities of stakeholders who are willing and able to act for the species.*

KOREAN STUMPY BULLHEAD CONSERVATION PLANNING WORKSHOP (PHVA)

14-17 FEBRUARY 2023, SEOUL, SOUTH KOREA

WORKSHOP ROLES

WORKSHOP FACILITATORS:	Caroline Lees (IUCN SSC CPSG)
WORKING GROUP FACILITATORS:	Mr. Moonhyun Shin and Ms. Gippeum Bak
OVERVIEW SESSION CHAIRS:	
TRANSLATORS:	National Institute of Ecology (NIE) (presentations to be written/given in English)
PVA MODELLER:	Caroline Lees (IUCN SSC CPSG)
COMPUTER RECORDERS:	

DESCRIPTION OF PRIMARY ROLES

Role	Responsibilities
FACILITATOR	- sets time and tasks - facilitates plenary discussions - encourages equal participation - maintains focus on overall workshop theme - maintains the integrity of the workshop design
WORKING GROUP FACILITATORS	- support working groups to stay on task and on time - encourage equal participation - ensure reports are delivered at the end of each day
PARTICIPANTS:	- manage their own working group discussions - provide information, determine issues of concern - create the vision and propose goals and actions
SESSION CHAIR	- introduces speakers in plenary sessions - keeps speakers to time
TRANSLATORS	- provide support during plenary and in working groups - interpret for local context - translate written materials and slide content as needed
PVA MODELLERS	- elicit participant input to the PVA models - created PVA models and ran models in response to questions from PVA working group in advance of the workshop and present results on Day 1 of the workshop - write a modelling report after the workshop
COMPUTER RECORDERS	- record plenary and working group discussions

Working Agreement

Leave all personal and institutional agendas at the door to focus on the task at hand

All ideas are valid

Everything is recorded on flip charts

Everyone participates; no one dominates

Listen to each other

Treat each other with respect

Assume good will

Seek common ground

Personal differences and problems are acknowledged - not "worked"

Observe time frames

Complete a draft report by the end of the meeting

KOREAN STUMPY BULLHEAD CONSERVATION PLANNING WORKSHOP (PHVA)

14-17 FEBRUARY 2023, SEOUL, SOUTH KOREA

OVERVIEW OF WORKING GROUP MECHANICS

1. Working groups will operate in either KOREAN or ENGLISH – the group can choose.

2. Report-back and other plenary sessions will be held in ENGLISH. Translation support will be provided.

3. The Facilitator will provide each Computer Recorder with a flash-drive containing an electronic template for recording ISSUE Statements, GOALS, ACTIONS and other NOTES.

4. Working groups will record ISSUE STATEMENTS, GOALS and ACTIONS in English or will translate them into English before the end of each day. Translation support will be provided.

5. Where possible, ISSUE STATEMENTS, GOALS and ACTIONS to be presented in PowerPoint or on flipcharts will be translated into English in advance of report-back sessions. Translation support will be provided.

6. Detailed NOTES can be recorded in the language chosen by the group.

7. The full record of the day's discussions will be handed to the Facilitator (on the flash-drives provided) at the end of each day. Flash-drives will be returned to each Computer Recorder at the start of the following day.

KOREAN STUMPY BULLHEAD CONSERVATION PLANNING WORKSHOP (PHVA)

14-17 FEBRUARY 2023, SEOUL, SOUTH KOREA

OVERVIEW OF WORKING GROUP PROCESS

Together, participants will generate an inter-connected list of the "Issues" that need to be considered in moving forward with Stumpy bullhead conservation. Working groups will be formed and a subset of these "Issues" will be assigned to each.

TASK I. **Develop "Issue Statements":** for each Issue, write three sentences to describe: 1) what it is; 2) what impact it has on Stumpy bullhead conservation; and 3) why it occurs. Indicate any differences between Sites. Prioritise your Issues. Ideally there will be no more than 5. If you have more, consider grouping them. *This is not the time to develop solutions, actions or research directions; this will be done in later steps.*

TASK II. **Assemble information and identify gaps:** review each Issue Statement and agree: what is FACT, what is ASSUMPTION and what is an important DATA GAP. Amend statements to reflect this and add supporting information or references.

TASK III. **Set Goals in response to each Issue Statement.** Goals describe things we will try to achieve in order to remove or reduce the impact of a particular Issue. Make Goals site-specific where necessary. An Issue may require more than one Goal. *Goals will be prioritised by all workshop participants.*

Issue-themed working groups will be re-organised to form Site-themed working groups if appropriate.

TASK IV. **Recommend Action steps for each Goal**. Action steps are the things we need to do to achieve our Goals. For each Action step, document WHAT it is that will be done, WHO will do it, WHEN it will be done and HOW progress will be measured. Consider 1, 5 and 10-year timelines. These actions will form the main recommendations from the workshop.

KOREAN STUMPY BULLHEAD CONSERVATION PLANNING WORKSHOP (PHVA)

14-17 FEBRUARY 2023, SEOUL, SOUTH KOREA

WORKING GROUPS: LEADERSHIP ROLES

Each small working group manages its own discussions, data gathering, time, and report production. Here are brief descriptions of the various roles to be played by different people in your group so that you can function effectively during the workshop. Leadership roles can be rotated; divide the work as you wish.

However, remember to assign these roles at the beginning of each working group session.

Discussion facilitator – Ensures that each person wanting to speak is heard within the time available. Keeps track of discussion using flip-charts. Keeps the group task front and centre at all times.

Flip chart Recorder – May be (but does not have to be) a person other than the discussion facilitator. Records ideas using brief phrases to provide group memory and a visible record of issues, ideas, and discussions. Checks with the person speaking that the phrase recorded is an accurate representation of their contribution.

Computer Recorder – Keeps track of group discussion using a computer. This should not simply be a recording of the flip chart points or detailed minutes of the session. Instead this should be an accurate and clear summary of the group's discussion, including any major viewpoints, information and decisions. It is important for the recorder to ask participants to briefly restate long ideas so that they can be accurately captured. **This computer record will be the basis of the report from the wider workshop.**

Timekeeper – Keeps the group aware of the time remaining for each working group session.

Reporter – Presents the working group report in plenary. It is particularly important that this role is assigned **at the beginning** of each session so that the person has enough time to prepare.

TASKS I: ISSUE STATEMENTS

Purpose: to focus the discussion by clearly describing and prioritising your group's ISSUES, and by identifying the underlying causes of those issues.

STEPS:

1. Assign roles for this session – INCLUDING THE PRESENTER! Record who is in the group.
2. Write the list of issues on a flip-chart.
3. Read them out in turn and check that everyone has the same understanding of each.
4. Add any issues you feel are missing (use brainstorming).
5. Cluster and consolidate issues under headings. Keep a list of the original 'brainstorm' items under each new heading.
6. For each issue, write 3 sentences that will explain, <u>to someone not at the workshop</u>:
    a. what the issue is;
    b. what causes it; and
    c. why it is a problem for the conservation of the Stumpy bullhead.
7. With reference to each issue, if there are differences between Sites, make sure these are described.
8. Try not to discuss "what needs to be done" – this comes later.
9. As a group, prioritise your issues according to their overall impact on Stumpy bullhead conservation.

THINGS TO CONSIDER:

- Is the issue stated objectively? (i.e. does not include implied solutions – **<u>solutions come later</u>**)
- Is the issue within the scope of the workshop and the people involved?
- Does everyone have the same understanding of the issue?
- Does the statement identify both the impact of the issue and its underlying causes or drivers – have you applied the **"5 WHYS"?**

ISSUE STATEMENT EXAMPLES:

A GOOD EXAMPLE:

Issue: Fire

a) Wild-fires burn through cockatoo habitat periodically.
b) Fires temporarily reduce the productivity of cockatoo food trees and as a result there is not enough food to support a growing population of birds.
c) Fire is a natural part of the ecology of cockatoo habitat but the frequency and intensity of fires is increasing due to the combined effects of introduced weeds (which burn more intensely than native vegetation), loss of traditional burning practices (which restricted the extent and intensity of fires) and climate change.

In the above statement it is clear **what** the problem is, **how** it affects the species and **why** it occurs. This is sufficient for an issue statement.

A POOR EXAMPLE:

Issue: Fire

We need to prevent fire in black cockatoo habitat so that the population can grow.

In the above statement the cause of fire is not clear, “issues” and “needs” are confused and solutions are implied – this one needs some more work.

TASK II: ASSEMBLE INFORMATION AND IDENTIFY GAPS

Purpose: to clarify, for each issue, what is FACT, what is ASSUMPTION and what are the key INFORMATION GAPS

STEPS:

1. Assign roles.
2. Taking each issue statement in turn, review the text carefully.
3. Discuss what is **KNOWN** about this issue (and how), what is **ASSUMED** (and why), and what more we **NEED TO KNOW**, before effective action can be taken.
4. Make sure that differences between Sites are considered, if appropriate.
5. Where necessary, edit the issue statements to make clear what is FACT and what is ASSUMPTION.
6. List KEY INFORMATION GAPS.
7. Record these discussions carefully, especially information relating to sources of evidence or justification.

INFORMATION ASSEMBLY EXAMPLE

Issue: Hybridisation

Description: *Emydura macquarii* is a common Australian native turtle **known** to have been introduced historically into the Bellinger River (Georges, et al., 2007; Georges, et al., 2011). *E. macquarii* are **known** to hybridise with the Endangered Bellinger River Snapping Turtle - BRST (Georges & Spencer, 2015).

Cause: In the past the two species occupied different areas in the river (Cann, et al., 2015) and hybridisation events are **assumed** to have been rare (Blamires & Spencer, 2013). Following a recent disease outbreak in BRST there is evidence that *E. macquarii* has become the dominant turtle species in the Bellinger River (Chessman, 2015).

Impact: It is **assumed** that the rate of hybridisation could increase under the current situation. It is **assumed** that an increase in the hybridisation rate will result in the BRST becoming rarer.

Key information gap: Is the rate of hybridisation increasing?

TASK III: GOALS

Purpose: to agree what we will try to achieve in order to reduce or remove the issues identified.

STEPS:

1. Assign roles.
2. Review the issue statements and information gaps.
3. Think about the different ways in which those issues could be addressed. Which are most likely to get done? Which do the people in this room have most influence over?
4. With this in mind, develop goals to address each issue. Where relevant, goals should be SITE-SPECIFIC.
5. There can be more than one goal for each issue.
6. Develop goals to fill each information gap *considered to be an obstacle to Stumpy bullhead conservation*.
7. If there is time, include an indication of how progress towards achieving each goal will be measured or evaluated.

GOAL EXAMPLE:

Issue Statement: Fire

a) Wild-fires burn through cockatoo habitat periodically.
b) Fires temporarily reduce the productivity of cockatoo food trees and as a result there is not enough food to support a growing population of birds.
c) Fire is a natural part of the ecology of cockatoo habitat but the frequency and intensity of fires is increasing due to the combined effects of introduced weeds (which burn more intensely than native vegetation), loss of traditional burning practices (which restricted the extent and intensity of fires) and climate change.

GOAL 1: Supplement food for black cockatoos after fires.

GOAL 2: Restore traditional burning around cockatoo feeding grounds.

TASK IV: ACTIONS

Purpose: to recommend action steps that will enable goals to be achieved.

STEPS:

1. Assign roles. Make a list of who is in the group.
2. Take each goal in turn and write it on a flip-chart.
3. Brainstorm actions that could be taken to achieve that goal. Think about which ones will have the most impact on Stumpy bullhead conservation and which are most achievable given the resources available.
4. Recommend one or more actions to achieve each goal.
5. Document details for each action:
    a. a description of WHAT the action is
    b. WHERE it needs to be done
    c. WHEN it should be done (consider 1, 5 and 10-year time-frames)
    d. WHO (which agency or agencies IN THIS ROOM) could lead it, and who the key collaborators could be.
    e. what INDICATORS or MEASURES will be used to track or demonstrate its completion?
6. Check each agreed action conforms to S.M.A.R.T. characteristics (see below).

THINGS TO CONSIDER:

Actions should conform to **S.M.A.R.T** characteristics:

- ***Specific*** – it must be clear what is to be done, by whom, where.
- ***Measurable*** – concrete outcomes or indicators are defined that allow progress to be assessed
- ***Attainable*** – can be accomplished under current conditions
- ***Relevant*** – helps solve the specific issue targeted (i.e. helps achieve one of the associated goals) and needs to be done
- ***Time-bound*** – is grounded in a realistic timeframe

EXAMPLE OF A COMPLETED ACTION STEP (MODIFIED FROM ORIGINAL)

Issue: Habitat Fragmentation

In Singapore, the habitat of Raffles' Banded Langur consists of small forest fragments. This is due to the creation of roads and the removal of forest in some areas to allow for other forms of land-use. As a result, the langur population persists only in small, isolated groups, each one susceptible to significant losses due to chance demographic events and inbreeding depression.

GOAL

Restore connectivity between isolated/fragmented groups of Raffles' Banded Langur in Singapore

ACTION 1.

Details: Identify sites in Singapore where there is a need for human-mediated movement (due to loss of connectivity, lack of canopy cover, obstructions, roads, water bodies etc.) and test the use of rope bridges in appropriate locations.

Responsibility: Raffles' Banded Langur Coordinator.

Timeline: permits and proposal by early 2017; construction of first rope bridge by mid-2017, monitoring till mid-2018

Collaborators: JGIS, MINDEF, Singapore NParks, WRS, and volunteers

Measures: camera trap photos of langurs using the bridges.