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Circumstance of Protection for Threatened Freshwater Fishes in Japan

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INTRODUCTION

The wild animals have been on the way to extinction all over the world due to the drastic change to artificial environments. Among them, freshwater fishes have become one of the most typical target groups to affect by human activities, because they occur in such closed habitats as aquatic environment where various negative factors bring about direct influence. In this report, the basic idea to protect wild freshwater fishes is provided by referring to the case in Japanese threatened species. The substantial approach by different techniques viz., "*In situ* Conservation" and "*Ex situ* Preservation" is also proposed with future prospect.

Japanese threatened species

The Japanese archipelago runs parallels to the eastern rim of the Eurasian continent, extending north-southward from 22° to 45° N in latitude along the 'Kurosiwo' current. It mainly belongs to the Temperate Monsoon Zone, covering subtropical region in the Ryukyu islands to the sub-arctic region in the Kuril islands. These geological locations produce the rich biodiversity in freshwater fishes which are summed up ca 280 native species in total (Kawanabe *et al.*, 2001). The number is comparable with, or more than those in Korea, 204 spp. (Kim and Park, 2002), and in entire Europe ca 200 spp. (Maitland, 1977).

The Ministry of Environment, Government of Japan (2007), has just released new Red List of Japanese freshwater fishes to public together with other taxonomic groups in Japan (Table 1). The Red List was revised on the basis of the quantitative criteria of IUCN (International Union for Conservation of Nature and Natural Resources). The new list includes 174 species or subspecies which is identical with ca half of the Japanese freshwater fishes in number. They are categorized as five ranks in proportion to gravity, viz., "Extinct" abbreviated as Ex for 4 spp., "Critically Endangered" as IA for 61 spp., "Endangered" as IB for 48 spp., "Vulnerable" as II for 35 spp. and "Near threatened" as NT for 26 spp.

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Negative factors to Japanese freshwater fishes

The Government of Japan classifies negative factors to the native biota as three major crises in "the National Biodiversity Strategy of Japan".

The first crisis: Development and other human activities are causing species loss and extinction, as well as the destruction and fragmentation of ecosystem. Fish species populations are decreasing in size due to various exploitations. Dam construction and cross-sectioning in rivers must constrain the migration of sea-run fishes such as Sakhalin green sturgeon *Acipencer medirostris* (EX), anadoromous salmons and amphidromous gobies. Even consolidation of paddy field results in the disappearance of two local forms of killifishes *Oryzias latipes* (II) from traditional habitats.

The second crisis: Nature in paddy field has automatically changed to more dry stages as natural succession, unless human activities keep moderate interference to paddy field. The balance between interference and biodiversity are getting worse by cultivation abandonment, particularly in small paddy fields by traditional rice farming.

The third crisis: Invasive alien species and chemical materials are adversely affecting fish biodiversity. Both are in common as exotic elements to release to indigenous ecosystem by human beings outside, without any consideration. Major problems of invasive alien species in Japanese freshwaters are typified by predation of Black bass and genetic pollution of Rosy bitterling from continental to Japanese forms. Chemical compounds toxic to fishes include PCB, DDT and dioxin. The Japanese consumptions of these organochlorine or organophosphorus inseciticides reached to the peak in early 1960s when the sudden decrease of freshwater fishes occurring in paddy fields, has just started. This has partly contributed to extinction of Southern ninespine stickleback *Pungitius kaibarae* (Ex) from Kyoto and Hyogo prefec-

Table 1. Red list of Japanese freshwater fshies, released August 3rd, 2007 from the Minisitry of Environment, Government of Japan

1. Extinct (EX)

Acipenser medirostris
Gnathopogon elongatus suwae
Oncorhynchus nerka kawamurae
Pungitius kaibarae

2. Critically Endangered (IA)

Uropterygius concolor
Echidna rhodochilus
Tanakia tanago
Acheilognathus cyanostigma
Acheilognathus longipinnis
Acheilognathus tabira nakamurae
Acheilognathus typus
Rhodeus ocellatus kurumeus
Rhodeus atremius suigensis
Aphyocypris chinensis
Pseudorasbora pumila pumila
Pseudorasbora pumila subsp.
Sarcocheilichthys biwaensis
Gnathopogon caerulescens
Cobitis sp. S San-yo form
Leptobotia curta
Plecoglossus altivelis ryukyuensis
Salanx ariakensis
Neosalanx reganius
Oncorhynchus nerka nerka
Gasterosteus aculeatus leiurus
Pungitius sp. 1
Pungitius sp. 2
Microphis (C oelonotus) argulus
Microphis (L ophocampus) retzii
Microphis (O ostethus) jagorii
Cestraeus plicatilis
Tetraroge barbata
Tetraroge niger
Apogon hyalosoma
Lutjanus goldiei
Sillago parvisquamis
Mesopristes cancellatus
Mesopristes argenteus
Mesopristes iravi
Enneapterygius cheni
Omox biporos
Omobranchus ferox
Rhyacichthys aspro
Scartelaos histophorus
Lentipes armatus
Sicyopus leprurus
Sicyopus zosterophorum
Stiphodon imperiorientis
Stiphodon atropurpureus
Luciogobius albus
Callogobius sp.
Eviota ocellifer
Oxyurichthys sp.
Cristatogobius aurimaculatus
Cristatogobius nonatoae
Gymnogobius isaza
Gymnogobius cylindricus
Glossogobius bicirrhosus
Glossogobius aureus
Bathygobius sp.
Mugilogobius parvus
Rhinogobius sp. BI
Parioglossus taeniatus
Parioglossus interruptus
Macropodus opercularis

3. Endangered (IB)

Nematalosa japonica
Carassius cuvieri
Carassius auratus grandoculis
Acheilognathus melanogaster
Acheilognathus tabira tabira
Acheilognathus tabira subsp.
Rhodeus atremius atremius
Ischikauia steenackeri
Hemigrammocypris rasborella
Tribolodon nakamurai
Cobitis takatsuensis
Cobitis shikokuensis
Cobitis sp. L
Cobitis sp. S Tokai form
Cobitis sp. S Biwako form
Cobitis sp. S San-in form
Cobitis sp. S Kyushu form
Lefua nikkonis
Lefua echigonia
Lefua sp.
Pseudobagrus ichikawai
Hucho perryi
Monopterus albus
Hippichthys (Hippichthys) heptagonus
Crenimugil heterocheilos
Trachidermus fasciatus
Cottus reinii
Cottus sp.
Lates japonicus
Sillago macrolepis
Kuhlia munda
Butis amboinensis
Bostrychus sinensis
Hypseleotris cyprinoides
Ophieleotris sp. 1
Apocryptodon punctatus
Boleophthalmus pectinirostris
Taenioides cirratus
Sicyopterus lagocephalus
Cristatogobius lophius
Gymnogobius scrobiculatus
Gymnogobius sp.
Schismatogobius ampluvinculus
Schismatogobius roxasi
Pandaka lidwilli
Rhinogobius sp. BB
Rhinogobius sp. YB
Parioglossus rainfordi

4. Vulnerable (II)

Lethenteron sp. 1
Lethenteron sp. 2
Lethenteron japonicum
Coilia nasus
Opsariichthys uncirostris uncirostris
Abbottina rivularis
Squalidus japonicus japonicus
Niwaella delicata
Cobitis matsubarae
Cobitis sp. M
Pseudobagrus tokiensis
Liobagrus reini
Salvelinus malma krascheninnikovi
Salvelinus malma miyabei
Salvelinus leucomaenis imbrius
Oryzias latipes subsp.
Oryzias latipes latipes
Cottus kazika
Ambassis interrupta
Coreoperca kawamebari
Ophiocara porocephala
Brachyamblyopus anotus
Odontamblyopus lacepedii
Taenioides limicola
Leucopsarion petersii
Luciogobius sp.
Gymnogobius macrognathos
Gymnogobius uchidai
Gymnogobius taranetzi
Acanthogobius hasta
Acanthogobius insularis
Pseudogobius masago
Acentrogobius viridipunctatus
Pandaka sp.
Parioglossus palustris

5. Near Threatened (NT)

Lethenteron kessleri
Carassius auratus subsp. 2
Tanakia lanceolata
Tanakia limbata
Phoxinus percnurus sachalinensis
Sarcocheilichthys variegatus variegatus
Squalidus chankaensis biwae
Pseudobagrus aurantiacus
Silurus lithophilus
Hypomesus olidus
Oncorhynchus masou masou
Oncorhynchus masou ishikawae
Oncorhynchus masou subsp.
ungitius sp. 3
Pungitius tymensis
Zenarchopterus dunckeri
Hyporhamphus intermedius
Cottus pollux
Acanthopagrus berda
Ophieleotris sp. 2
Periophthalmus modestus
Luciogobius pallidus
Eutaeniichthys gilli
Acentrogobius caninus
Rhinogobius sp. TO
Tridentiger barbatus

6. Data Deficiency (DD)

Anguilla japonica
Anguilla bicolor pacifica
Carassius sp.
Carassius auratus subsp. 1
Phoxinus lagowskii yamamotis
Salvelinus leucomaenis pluvius
Chelon subviridis
Ellochelon vaigiensis
Moolgarda pedaraki
Moolgarda engeli
Ambassis commersoni
Apogon lateralis
Pseudamia amblyuroptera
Plectorhinchus albovittatus
Toxotes jaculatorix
Omobranchus elongatus
Pseudocalliurichthys ikedai
Odontobutis hikimius
Belobranchus belobranchus
Bunaka gyrinoides
Stiphodon surrufus
Luciogobius dormitoris
Stenogobius ophthalmoporus
Gymnogobius mororanus
Glossogobius circumspectus
Glossogobius sp.
Pseudogobius sp.
Silhouettea sp.
Silhouettea dotui
Redigobius balteatus
Mugilogobius fusca
Mugilogobius sp.
Acentrogobius audax
Acentrogobius suluensis
Parkraemeria ornata
Rhinogobius sp. BW
Gobitrichinotus radiocularis
Kraemeria tongaensis
Parioglossus lineatus

7. Threatened local Population (LP)

Entosphenus tridentatus (Population in Tochigi Prefucture)
Clupea pallasii (Lake type populations in the side of Pacific)
Cyprinus carpio (Wild type population in Lake Biwa)
Tribolodon brandti (Populations in Honsyu along the Sea of Japan)
Tribolodon sachalinensis (Populations in Tohoku District)
Spirinchus lanceolatus (Populations in Erimo Cape and westward)
Salvelinus leucomaenis japonicus (Populations in Kii Peninsula)
Gasterosteus aculeatus aculeatus (The land-rocked pacific type populations in Fukushima prefucture and southward)
Gasterosteus aculeatus aculeatus (Japan Sea type populations in Honsyu)
Pungitius pungitius (freshwater type populations in Honsyu)
Cottus hangiongensis (Populations in Tohoku and Hokuriku Districts)
Cottus nozawae (Populations in Tohoku District)
Lateolabrax japonicus (Populations in the Sea of Ariake)
Gymnogobius petschiliensis (Populations in south Hokkaido and Tohoku Districts)
Gymnogobius castaneus (Populations in the region around of Choukaisan)
Gymnogobius castaneus (Populations in Toyama plain field)
Takifugu niphobles (Populations in Okinawa Island)

tures.

Above classification on negative factors may conform to the case of freshwater fishes in some sense. However, it is difficult to specify the key factor to decrease fish population size or individual numbers, because some crises are co-related each other. To the true freshwater fishes (Primary and Secondary Divisions) inhabiting the Japan proper, i.e., Hokkaido, Honshu, Shikoku, and Kyushu, consolidation of paddy field and introduction of invasive alien fishes seem to the largest problems so far.

Consolidation of paddy field

Japan is a typical rice cropping country. Paddy field had originally been modified from swampland on the back of rivers or floodplain since the “Jomon Era”. Fishes occurring in such an unstable habitat have been utilizing it as spawning-, nursery-, feeding- grounds, and refuge even after remodeling to paddy field in balance with rice cropping. The annual farming activities related to traditional rice cropping, play a role as ecological interference with which freshwater fishes make their life-cycles synchronize very harmoniously.

To enhance the efficiency to produce agricultural food, the Ministry of Agriculture, Government of Japan has been promoting a national project to consolidate traditional paddy field to new one since early 1960s. The consolidation adopts several modern engineering ways; enlargement of a paddy field by uniting small fields, and transformation from irregular shape to square (Fig. 1). This causes the remarkable loss of habitat variation and relevant biodiversity. The change of watering system, from the traditional dual-purpose canal to independent setting of irrigation and drainage canals, completely interrupts fish migration between rivers and paddy fields. Fishes in reproduction season tend to move upward to paddy fields through not irrigation but drainage, by physiologically detecting the soil matter from paddy field. In the new watering system, the drainage canal is always set lower than the surface of paddy field by 0.3 ∼1.0 m height in order to drain better. Any Japanese freshwater fishes can not jump over this gap from drainage canal to paddy field. The canals, by themselves, were modernized from complicated natural soil canal to simple artificial one with concrete-ling on three faces of the canal. This remodeling lightened one of farmer’s burdens to manage canals, i.e., mowing and dredging, while destroyed fish habitats and an ecological role as ecotone at all.

In the new Red List of Japanese freshwater fishes, 16 spp. in 61 CR spp. (26%) inhabit paddy field or adjacent waters. Metropolitan bitterling *Tanakia tanago*, Suwon rosy bitterling *Rhodeus atremius suigensis*, Venus fish *Aphyocypris chinensis*, Small striated spined loach *Cobitis* sp. S San-yo form, and Ayumodoki loach *Leptobotia curta*, all the species are canal dwellers depending on the traditional rice cropping.

Invasive alien fishes

The release of artificial fish seedlings into natural waters to sustain the natural bioresources has been traditionally adopted by Japanese fishermen. Also, alien fishes were actively introduced to freshwaters in Japan, resulting in the establishment of new commercial fishes, such as rainbow trout *Oncorhynchus mykiss*. However, some of them often have become pest species in the Japanese natural ecosystem, bringing such biological hazards as heavy predation and genetic pollution. The mechanisms, in which the Japanese indigenous fishes were reduced by the introduction of invasive alien fishes, are exemplified by the two cases below.

Bass problem: Black bass as Japanese common name contains taxonomically two different species. Largemouth bass *Micropterus salmoides* (Fig. 2, A) was initially introduced from the USA to Lake Ashinoko near Mt. Fuji in 1925 by a Japanese businessman Tetsuma Akahoshi. The bass had strictly been confined to the lake until the 1960s when modern lure fishing was introduced from the USA. The bass had gradually been spreading in accordance with the boom into all freshwaters in Japan by personal transplantation. They easily established new predacious niche, because there had been no such perch-like competitor. Another Black bass, Smallmouth bass *M. dolomieu* (Fig. 2, B) was added in 1990s by irregular transplantation from the USA which accelerates range extension of Black bass. Since then, the composition of Japanese indigenous ichthyofauna has been simplified, with exposure to heavy feeding pressure by the new strong predator. The Black bass established in freshwaters in Japan, feed on a wide variety of aquatic organisms as has been reported in original distribution of the USA. It is notable that the bass feed well on crustaceans throughout the year, and on fishes from summer to fall. Their feeding habit reduced some endemic small cyprinids such as Striped bitterling *Acheilognathus cyanostigma*, Small scale bitterling *A. typus*, and Shinai top mouth gudgeon *Psuedorasbora pumilla*. Accordingly, all these prey fishes are now ranked as “Critically Endangered”.

Genetic Pollution: the Continental rosy bitterling *Rhodeus ocellatus ocellatus* (Fig. 3, A) contaminated in the seedlings of the Chinese major carps, viz., *Ctenopharyngodon idellus*, *Mylopharyngodon piceus*, *Hypophthalmichthys moltrix* and *Aristichthys nobilis* from the Yangtze-Kiang, Changjiang, during the World War II. The Japanese endemic subspecies *R. ocellatus kurumeus* (Fig. 3, B) originally inhabited the western part of Japan where the continental type subspecies soon invaded. Both subspecies are well distinguished by the coloration along the anterior margin of the ventral fins; the conti-

Fig. 1. Comparison of landscape with irrigation ditch between traditional paddy field (left) and consolidated paddy field (right) in Gifu Prefecture.

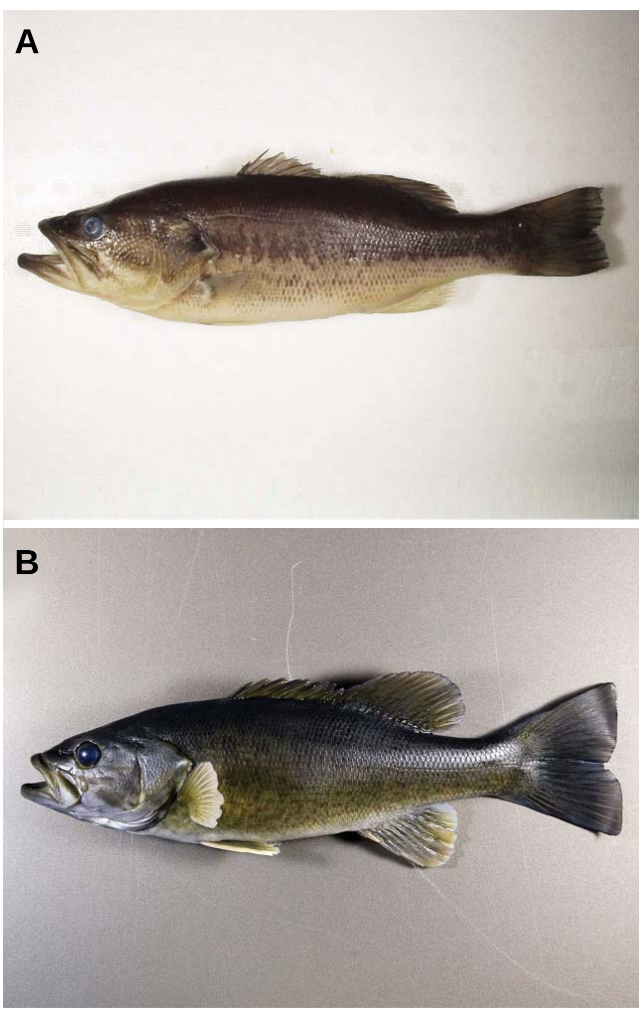

Fig. 2. Two black basses introduced to Japan. A. Large mouth bass, *Micropterus salmoider*; B. Small mouth bass, *M. dolomieu*.

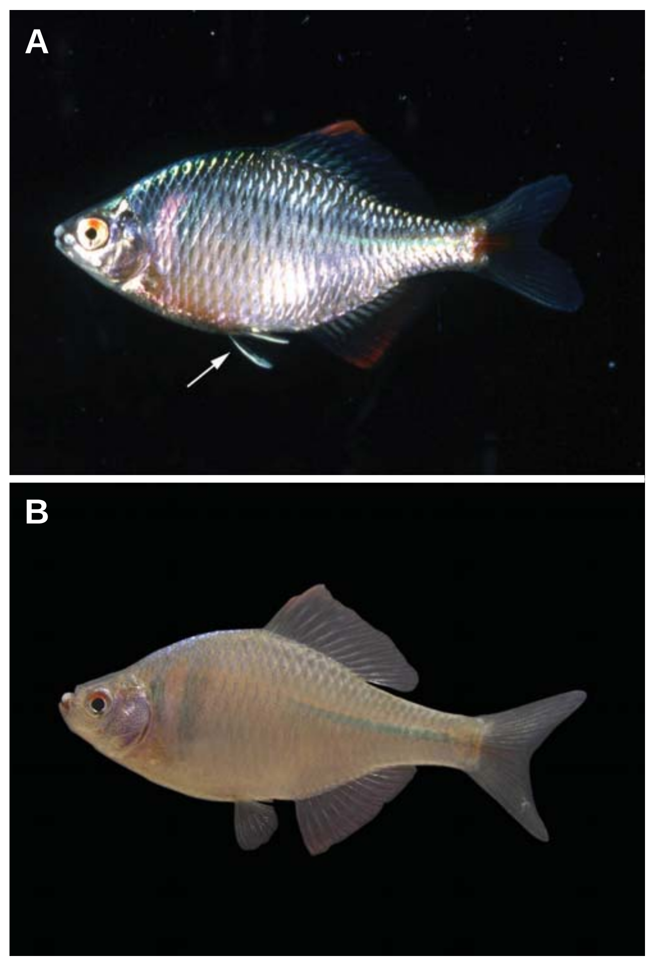

Fig. 3. Two subspecies of the rosy bitterlings. A. The condinental rosy bitterling, *Rhodeus ocellatus ocellatus*; B. The Japanese rosy bitterling, *R. ocellatus kurumeus*. Note the difference of the coloration along the anterior margin of ventral fins in males by an arrow.

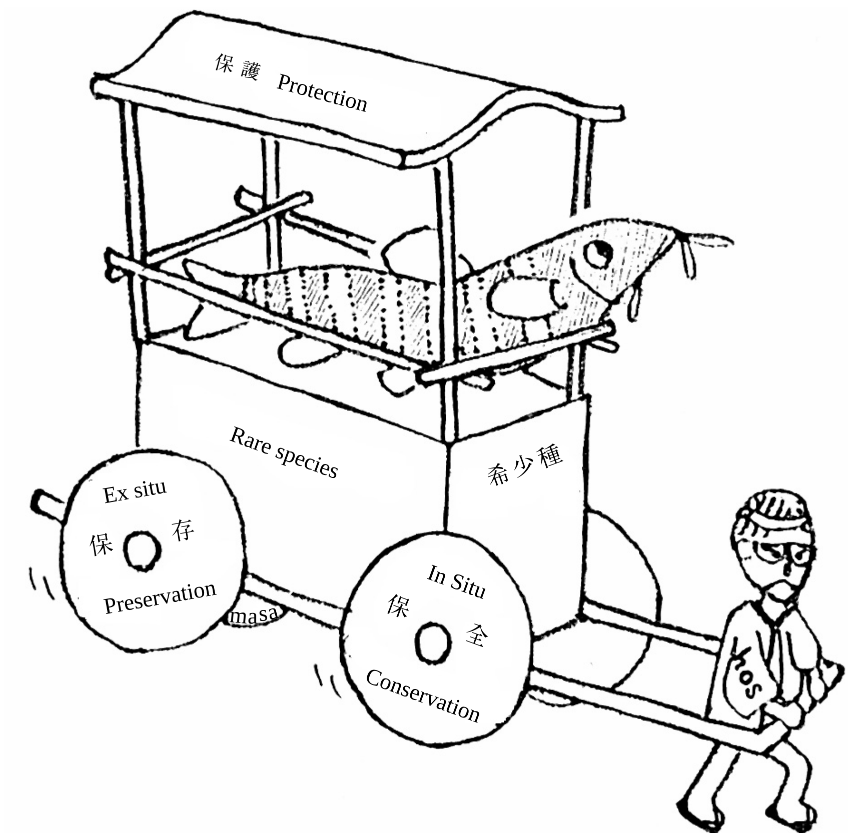

Fig. 4. Image to protect the threatened species. Both "*In situ Conservation*" and "*Ex situ Preservation*" invitable to the promotion of "Protection".

nental subspecies has a remarkable white band while the Japanese subspecies has no such band at all. They easily hybridize to produce a reproductive F_1 with a white band along the anterior margin of the ventral fins. The appearance of the white band follows the Mendelian rule as a superior character. In the populations of the Japanese subspecies, once genetically introgressed by the continental subspecies, bitterling produce a white band soon. The genetic pollution through the hybridization with the continental rosy bitterling results in large scale reduction in the Japanese pure form, which are now confined to a few of ponds in Osaka and the Chikugo River in the north-western part of Kyushu, as ranked in "Critically Endangered". The mechanisms of replacement from the Japanese subspecies to the continental subspecies, were already elucidated in terms of genetics.

Protection of threatened species

More or less, every indigenous species of Japanese freshwater fishes has been driven to the brink of extinction. Then, it is an urgent issue for the Government of Japan to make a strategy for saving the fishes, by using every possible way. To make the goal clear to save the wild life, the efficient and realistic countermeasures must be planned by sharing biological philosophy. However, its related terminology seems a little bit confused, i.e., "Protection", "Conservation", and "Preservation".

Conservation vs. Preservation: "Protection" provides an inclusive and abstract idea to save wild life. It has wider meaning that can be divided into "Conservation" and "Preservation" in my sense (Fig. 4).

"*In situ* Conservation" literally means to protect the whole population without any changes in natural environment such as national park and fish sanctuary where they actually occur in original distribution. Species designated as threatened by a competent authority should be protected by law. Threatened species legislation always must prohibit the fishing, keeping in a private aquarium, trade, and even sampling for laboratory works by researchers on listed species.

"*Ex situ* Preservation" aims to keep each threatened species as stocks or gene-bank by gathering some individuals from natural environment to artificial equipments. Japan, a nation of fisheries, has developed unique original techniques to enhance resources of the valuable food fishes by aquaculture. These techniques are now utilized to propagate the wild threatened fishes of non-commercial value in some inland fisheries research centers. The Time-capsule Project promoted by the Ministry of Environment, has already succeeded in the cryopreservation of sperm of some "Critically Endangered" (IA) species such as *R. ocellatus kurumeus*, *Tanakia tanago, Acheilognathus cyanostigma, A. typus, Aphyo-*

cypris chinensis, *Psuedorasbora pumilla*, and *Leptobotia curta*, and some "Endangered" (IB) species such as Japanese huchen *Hucho perryi*, Siro-hire-tabira bitterling, *Acheilognathus tabira tabira*, and Golden venus fish *Hemigrammocypris rasborella*, etc.

Some radical ecologists, or conservationists fear that giving greater emphasis to "*Ex situ* Preservation" may permit governments to regard it as a substitute rather than a complement to "*In situ* Conservation" in the wild. However, many species and populations will slip through the cracks and be lost, if the facilities based on "*Ex situ* Preservation" are not strengthened. Also, "*Ex situ* Preservation" provides people for increasing awareness and findings of natural history of wild animals. In step with their changing role in "*Ex situ* Preservation", the goal of public aquarium like in "Co-ex", Seoul, is changing as well. Some Japanese aquaria have already been becoming "Biological ponds" or "Biodiversity Preservation Centers".

Both "*In situ* Conservation" and "*Ex situ* Preservation" are needed, and two must be coordinated as parts of unified programs as far as "Protection" for threatened freshwater fishes are concerned (Fig. 4).

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This small paper was revised from the abstract in the proceedings for Chuncheon Water Forum 2007 held in Chuncheon, Korea to dedicate to my sincere elder colleague, Professor Ik-Soo Kim for his retirement with compliments. Also, I wish the information in this paper will contribute to the practical protection for Korean threatened freshwater fishes.

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