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應用高密度聚乙烯波紋螺旋管於水田魚梯對大鱗副泥鰍遷移之探討

Study on Migration of *Paramisgurnus Dabryanus* through Corrugated High-Density Polyethylene Fishways

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摘要

大鱗副泥鰍 (*Paramisgurnus dabryanus*)，是一種全台灣很常見的淡水魚但與其相關資訊卻十分稀少。他屬於鰍科，居於稻田之中又時常被錯認為泥鰍 (*Misgurnus anguillicaudatus*)。大鱗副泥鰍利用稻田繁殖育苗也從中獲取食物，換句話說，稻田也屬於它們生命週期的一部分。由於現代排水系統的改良，水田、灌溉溝渠和小溪之間的連接已沒了，而魚類種群的數目也開始下降。因此，魚道的出現就是為了重現這些特徵之間的連接。此研究所選用的魚道材料為高密度波浪型聚乙烯管，一種便宜又簡易使用的管子。此實驗的目的是建立魚道以及尋找管道放置角度和排放的最佳組合範例，大鱗副泥鰍為研究的目標種類。在此研究當中，嘗試使用不同管道角度以及排放位置來找出最適當的組合，發現到不同的角度、不同斜率、性別及年齡皆會影響魚遷移地成功率。之後，這個實驗被測試於台灣宜蘭元善區的大湖農田之中，發現無論是在室內的實驗當中或者在田地實驗當中，泥鰍都能夠成功地在上游遷移。

關鍵字：大鱗副泥鰍、中國泥鰍、魚道、高密度波浪型聚乙烯管

Abstract

Paramisgurnus dabryanus also known as the Chinese loach (Lin et al. 1991), is a common fresh water fish that can be found all around Taiwan but little information is known from it. It belongs to the Cobitidae family, can be found habiting paddy fields and is usually mixed and confused with the *Misgurnus anguillicadatus*.

Loaches uses paddy fields to reproduce, nursery ground and obtain food, in other words paddy fields are part of their life cycle. Due to the modern drainage systems, the connection between paddy fields, irrigation ditches and creeks has been lost. As a result of this, the population of fish started to decline. In order to restore back the connection between these features, a fishway is needed. The fishway material chosen for this study was that of corrugated high-density polyethylene pipe or HDPE pipe, a cheap and easy to use kind of pipe. The purpose of this experiment is to provide the best combination of angles and discharges to build a fishway using corrugated HDPE pipe having *Paramisgurnus dabryanus* as the target species.

During this experiment, fishes where tested in a variety of angles and discharges to see which combination suited them the most. It was found in this experiment that different angles, different slopes, gender and age class had influence on the success percentage of loach migration. After this, the experiment was taken and tested in the

field at Taiwan, Yilan County, Yuan-shan district, Dahu area. The loaches were successful for the upstream migration during the indoor experiment as well as the field experiment.

Key words: *Paramisgurnus dabryanus*, Chinese loach, fishway, corrugated pipe and HDPE pipe.

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1 Introduction

1.1 Fishways

A fishway, fish ladder or fish passage is a corridor or waterway build in order to let fishes pass an obstacle blocking their migrating route (Katopodis *et al*., 1992, Agostinho *et al*., 2007).Obstacles are may be natural or artificial such as dams, waterfalls and rapids (McLeod *et al*., 1941). Usually it is built for overcoming artificial obstacles, reconnecting habitats for adult spawners trying to migrate back to the spawning area such as the case of *Misgurnus anguillicaudatus* migrating back to paddy fields (Naruse and Oishi, 1996), adult European eels migration through culvert fishways (Newbold *et al*., 2014) and common carp migrating through different types of corrugated fishways (Newbold and Kemp, 2015). In some countries, it is obligatory to build a fish ladder at any dam constructed (McLeod *et al*., 1941).

According to Katopodis (1992), fish ladders usually consists of an angled channel which is partitioned and has openings for fish to swim through. The channel is designed differently to produce discharge conditions in which the fish can swim in and migrate through.

1.1.1 Fishway designs

When designing a fishway, the most important issue to be consider is the swimming ability of the target species (Larinier, 2009). Katopodis (1992) believes that in order to build a fishway, swimming ability of the target species should be known and studied.

During migration through fish passage, fishes must undergo different combinations of discharge and water velocities mixed along with different gradients in which the fish ladder is built. For each combination, the fish has different swimming performances which has been classified as burst speed (highest speed attainable and maintained for less than 15 seconds), prolonged speed (a moderate speed that can be maintained for up to 200 minutes) and sustained speed (a speed maintained indefinitely)(Katopodis *et al.*, 1992, Larinier, 2009). Fishes tend to migrate with prolonged speed and only use the burst speed to overcome high water velocities. Fishes swimming velocity must exceed the one of water velocity going through the fishway

After understanding the swimming abilities of the target species, the type of fish ladder is selected and combined with different angles and discharges to find the most suitable combination for the target species. Each fishway has its own characteristics which are explained on the following sections.

1.1.2 Different types of fishways, traditional fishways

The most common fishways are vertical slot fishways, denil fishways, weir fishways and culvert fishways. In this research, we will denominate them as traditional fish ladders (Katopodis *et al.*, 1992).

1. Vertical slot fishways

   The vertical slot fishway is designed with pools which are regularly separated. This pools main goal is to provide a resting area for the migrating fishes. In order to pass from one pool to the other, burst speed from fishes is needed. Usually this kind of fishways are built with a slope of 10%.

Fig 1.1. Ventrical slot fishway (FAO)

2. Denil Fishways

The Denil fishways consists of rectangular chutes with closely spaced baffles which are located at the sides or bottom. The discharge that passes through the fishway is usually turbulent. There exists two different denil fishways: Plain Denil fishway and (2) Steeppass Denil fishway

1. This type of denil fishway is usually built at a slope of 45° and the velocity is low at the lower section and high at the upper section.
2. This style of fishway tend to have high water discharge velocities at the bottom area and slow near the surface.

Fig 1.2a. Plain denil fishway (DNR, 2010)

Fig 1.2b. Steeppass denil fishway (DNR, 2010)

3. Weir fishways

It consists of a number of pools located at different heights which are separated by weirs. In order for the fish to migrate, this ones have to jump from pool to pool using a burst speed. The usual slope for this kind of fishway is of 10%.

Fig 1.3. Weir fishway (DNR, 2010)

4. Culvert fishways

This kind of fishway is used to conduct water from one side of the road to the other. Its shape may vary: circular, elliptic, pipe-arch, rectangular or square cross-sections. Sometimes, small weirs or rocks are introduced inside the culvert as the discharge in it is usually high. The usual slope for the culverts are 0.5% and 5%.

Fig 1.4. Culvert fishway (WFL)

1.1.3 HDPE pipe fishways

The high-density polyethylene (HDPE) pipe fishway (Fig 1.5) or corrugated pipe fishway, could be said to be a small scale of the culvert fishway as both look alike. Usually both of them are pipes with undulations inside but with the difference of size. The HDPE pipe fish ladder are of much smaller in size and are much lighter.

Fig 1.5. HDPE pipe fishways and an L shape connector.

This kind of fish passage is mainly designed for bottom dwelling fishes such as Misgurnus Anguillicaudatus (Takabayashi Kazuyoshi, 2005, Sato Takenobu, 2008, Chen *et al.*, 2014). Takabayashi (2005) has made and outfield experiment of a fishway using HDPE pipes and having Misgurnus anguillicaudatus as its target species. The angle degree chosen by this researcher was of 10° and the result was species were 52 loaches were able to migrate through this kind of fish passage. Furthermore, not only this species could use the HDPE pipes, species such as *Oreochromis spp*, *Gambusia affinis*, frogs, tadpole, goby, *Macrobrachium asperulum* and *Zacco pachcephalus* were able to migrate through this kind of fish ladder (Chen *et al.*, 2014).

Chen (2014) concludes that due to the unevenness of the pipe, it can retain water and provides roughness, facilitating upstream migration. Furthermore its cost is really low and the installation is really simple. Finally, Chen (2014) also mentions that the pipe can be buried in the soil to match surrounding environment and also can be used in both concrete and earth canals. Traditional fish passage can also be built in the same environment as the HDPE pipes, but only the culvert ones can be buried.

1.1.4 Comparison between old fishways and HDPE pipe fishways

In the following tables (Table 1.1 and Table 1.2), pros and cons of using HDPE pipes and the traditional pipes can be seen.

Table 1.1. Pros and cons of the traditional fishways and HDPE pipe fishways.

Fishways	**Pros**	**Cons**
Traditional	● Variety of species can use the fishway. (Katopodis *et al.*, 1992) ● Techniques have been developed for a long time.	● Fixed, cannot be moved to other places ● Difficult to introduce changes (Katopodis, Freshwater *et al.*, 1992) ● Difficult to maintain, expensive ●
HDPE pipe	● Not made of concrete material ● Portable ● Changes/ adaptations can be introduce easily (Chen *et al.*, 2014) ● Cheap (Chen *et al*. 2014)	● Limited fish species have been recorded to use the fishway(Takabayashi Kazuyoshi, 2005, Chen *et al*., 2014) ● Technique is new ● Steep slopes are not favorable for fish migration (Masaki Suzuki 2001)

In regards to cost differences, Tu (涂，2006), research on modified Larnier fishway mentioned that the price of just modifying 1m of this kind of fish passage costs: 3869 NTD/m for modification of 105m, 1.65m wide and a slope of 11.7% ; 14165 NTD/m for a reconstruction of a 60m long, 1.65m wide and a slope of 12.5%. See table 1.2 for HDPE pipe's price in Taiwan.

Table 1.2. Price for HDPE pipe in Taiwan.

Product	**Price in NTD**
4 inch HDPE pipe (price per 1m)	100NTD
4 inch HDPE 90°connector (price per 1unit)	280NTD
4 inch HDPE straight connector (price per 1unit)	30NTD

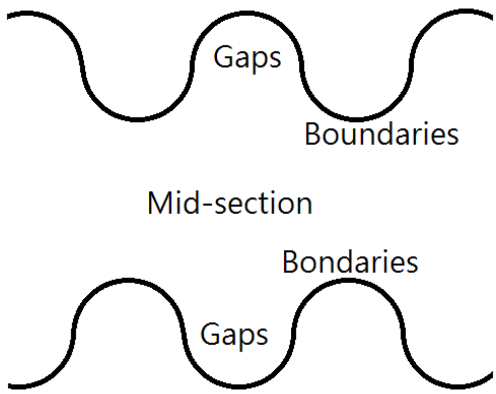

Fig 1.6. Corrugation inside of corrugates HDPE pipes.

The low price (Clay 1995), the easiness and the success of previous researchers are some of the reasons which lead to the use of HDPE pipe to build the fish ladder in this research. Another important factor for choosing this kind of pipe are the physical properties given by this corrugations. Corrugations around the pipe (fig 1.6) offers large areas of low discharge velocity near the boundaries of the pipes (Barnard *et al.*, 2013, Newbold and Kemp, 2015). As a result of this, mid sections of the pipes have higher discharge velocities than those on the boundaries; so if the velocity at mid-section of the pipe exceeds that from the fishes swimming ability, fishes can use the boundaries velocity to migrate (Clark *et al.*, 2014). Another physical feature provided by corrugated HDPE pipes, are the wave length and amplitude of corrugations which I will call gaps. These gaps can provide a resting area for migrating fish if they get tired during action or when facing high discharge velocities; in order to become a resting area, the fish size must be smaller than that of the gaps (Nikora *et al*., 2003, Khodier, 2014, Powers, 1997, Gerstner, 2006). As a result of this facts, this kind of fishway is suitable for bottom dwelling with an anguilliform shape fishes such as loaches.

1.2 Chinese loach (*Paramisgurnus dabryanus*)

Paramisgurnus dabryanus, known as loach or Chinese loach (Lin *et al*., 1991), belongs to the Cypriniformes order, Cobitidae family. It is a bottom dwelling fish (Naruse and Oishi 1996). In Taiwan there are only three fishes that belong to the Cobitidae family: *Cobitis Sinesis, Misgurnus anguillicaudatus* and *Paramisgurnus dabryanus.* In this research Chinese loach will be used as the target species due to its easy access in Taiwan.

Paramisgurnus dabryanus is native in Taiwan and the Southern China (Shao 2001). There are also information of seeing this fish in Russia, on the border separating Russia and China (Seriously-Fish). In Taiwan, this fish is distributed all the way from North to the South as shown in Fig 1.7.

Fig 1.7. Distribution of *Paramisgurnus dabryanus* in Taiwan. (Light green area are the places where *P.dabryanus* can be found, Seriously-Fish)

1.2.1 Confusion with *Misgurnus anguillicaudatus*

Nowadays, there is a problem when differentiating *Paramisgurnus dabryanus* and *Misgurnus anguillicaudatus*. Their appearance, living habitats and even sex definition are almost the same (Shao, 2001, Naruse, 1996). Both fishes have and anguilliform shape body, both fishes are found in the same habitats and both fishes can be sex define by the same mechanism. There are ways to differentiate these two species, by DNA and by physical appearance. In this research we will define each species by their physical appearance. The physical differences that can be found in these two species are shown in table 1.3.

Table 1.3. Difference between *Paramisgurnus dabryanus* and *Misgurnus Anguillicaudatus*

	Misgurnus anguillicaudatus	***Paramisgurnus dabryanus***
Size	small	big
Body color	dark taupe, dark gray	taupe, dull brown or reddish
Abdomen color	white or yellowish	pale-yellow
Black spot at the base of the caudal fin	present	absent
Photo	 Fig 1.8a. *Misgurnus anguillicaudatus* (NIES)	 Fig 1.8b. *Paramisgurnus dabryanus* (J.Bohlen)

Due to the difficult differentiation in color and size, in this research the presence of black spot at the base of the caudal fin will be used to differentiate these two species.

1.2.2 Habitat

Paramisgurnus dabryanus inhabits in slow moving or calm fresh waters, including rivers, streams, swamps and paddy fields (Seriously-Fish). The temperatures in which the *P. dabryanus* can live in range from 16 to 23℃, the pH 6.0 to 8.0, and the hardness 18 to 357 ppm (Seriously-Fish). *P. dabryanus* breathes with gills in water and also through moist skin during dry periods (Seriously-Fish). It has been recorded that this fish may survive periods of moist sand or mud when there is lack of water, but it is not sure for how long (Seriously-Fish).

1.2.3 Uses

The Chinese loach is commonly sold as human food, bait for fishing, or aquaculture (Shao, 2001, seriously-Fish). The fish is mixed with *M. Anguillicaudatus* due to its alikeness when selling at markets (NIES). In agriculture environments provides several benefits. Some farmers allow the presence of this fish in their paddy fields as it can provide nutrients such as nitrogen and phosphorous to the soil (Noorhosseini-Niyaki and Bagherzadeh-Lakani 2013), improve soil quality due to the bioturbation done by the fish when swimming (Hu et al. 2010) and it may also lower mosquito population due to its diet similarities with the *M. Anguillicaudatus* (Frable 2008).

1.2.4 Features for identification

According to Shao (2001), *P. dabryanus* has an anguilliform shape fish with maximum length 20 cm. The body is elongated, compressed, and cylindrical. It has irregular dark blotches around the body. Its color is usually taupe, dull brown, and sometimes reddish. The abdominal color is pale-yellow without dark spots on the base of the caudal fin (Fig. 1.9). The body is covered by mucus which makes it slippery. The head is compressed with eyes located at the upper section of the head. The inferior mouth is arched shaped and surrounded by five pairs of barbells. It has dorsal fin rays, pelvic fin rays, and anal fin rays. The locations of the fin rays are shown in Fig. 1.9.

Sex can be identified by the size of body and pectoral fins. Females are usually bigger and heavier than males (Seriously-Fish). In regards to the pectoral fin, the males have enlarged thickened pectoral fins as shown in Fig. 1.10a and 1.10b.

Fig 1.9. *Paramisgurnus dabryanus* (J.Bohlen)

Fig 1.10a. Male Chinese loach with enlarged thickened pectoral fins.

Fig 1.10b. Female Chinese loach without enlarged thickened pectoral fin rays.

1.2.5 Diet and reproduction

The Chinese loach is considered a predator which feeds on insect larvae, small crustaceans, and some alga or water plants (Seriously-Fish). It is said that it can also be given dried food when raised in aquariums but should be also fed with small living or frozen fare such as *Daphina, Artemia* and bloodworm (Seriously-Fish).

P. dabryanus spawning season is similar to the one of *M. fossilis* (Kottelat and Freyhof, 2007, Seriously-Fish). *P. dabryanus* starts to spawn at the age of 2 to 3, 11cm in length, from March to July; Females lead males to reproduction site (Seriously-Fish). The spawning season of the Chinese loach is almost the same as the one of the *M. Anguillicaudatus,* from May to July (Fujimoto *et al*. 2007).

1.3 Fishes and paddy fields

Floodplains offers spawning and nursery area for fishes such as loach and as a result, these plains are part of loaches life cycle (Turner *et al*., 1994, Grift *et al*., 2001, Katano *et al*., 2003, Amilhat and Lorenzen, 2005). During flooding seasons, loaches migrate from rivers or ditches to paddy fields, which is a substitute of floodplain, to reproduce and to find food (Kwak, 1988, Sommer *et al*., 2002). Fishes such as loach, use the paddy fields as a substitute for the floodplains (Saitoh *et al*., 1988, Fujimoto *et al*., 2007). According to Fujimoto (2007) in Asia, rice cultivation in these floodplains, have been well developed due to the benefits obtain from it. Rice fields, provide not only provides water storage area (Yu *et al*., 2006, Huang *et al*., 2007) but also food such as rice and fish (Coche, 1967, Yu *et al*., 2006, Huang *et al*., 2007). In order to have fishes in the fields, fishes should be allowed an able to migrate into them. Fujimoto (2007) and Katayama (2001) stated that before the introduction of modern drainage, water level at the paddy fields, where nearly at the same level to the ditches, and these ones to the rivers. As a result of this, fishes where able to migrate easily from river to ditches and then into the fields.

Benefits of having fishes in the paddy fields have been proven. According to (Natuhara 2013), rice fields are monoculture systems which leads to produce only one product, in this case rice. By the introduction of fishes, farmers can obtain a second product which is fish (Coche, 1967). Furthermore, by having fishes in the fields, reduction on the usage of fertilizers can be done due to the fish lifestyle. Bioturbation done by the movement of fishes can lead to improvement of the living environment for microorganisms which leads to improvement of soil quality (Hu *et al*., 2010). In addition to this, fish bioturbation can also release fixed nutrients from soil to water followed by making the soil porous for nutrients ready to be taken by the rice roots (Vromant and Chau, 2005, Tsuruta *et al*., 2011). In addition, fish presence can also improve soil quality by providing nutrients to the soil through there excrements (Frei and Becker, 2005, Tsuruta *et al*., 2011). Presence of fishes can lead to reduction on the usage of pesticides and fertilizers as they feed on weed, algae, mosquito larvae and also snails (Coche, 1967, Frable, 2008). Tsuruta (2011) found that due to fish eating up the weeds and algae, rice competition to obtain nutrients is reduced. Reducing the number of mosquito larvae, snails and other pests without the use of pesticides is preferable by consumers (Tsuruta *et al*., 2011). Common fish species used in fish-farming are: cyprinids, catfishes and loaches (Saitoh *et al*., 1988, Katayama *et al*., 2011).

1.3 Research gap and motivation

Modern irrigation systems may improve agriculture productivity; however, the change also creates habitat fragmentation problems. Gaps between the outlets of paddy fields and the water table of the concrete drainage ditches are widely observed. The obstacle makes fish, like loaches, unable to migrate back to the paddy fields (Fujimoto *et al*., 2007, Katayama *et al*., 2011). The loaches are attracted to paddy fields due to spawning area, nursery grounds, and food abundance (Naruse and Oishi, 1996, Fujimoto *et al*., 2007). Because of the disconnection between the paddy fields and the drainage ditches a decrease in loaches population and other fish species has been noted (Lane and Fujioka, 1998, Katano *et al*., 2003, Katayama *et al*., 2011). Furthermore, the decrease in fish population, has also affected the abundance and distributions of avian predators (Fujioka and Yoshida, 2001). As a result, conservation of fish population, such as loach, is crucial for preservation of biodiversity around the paddy fields (Katayama *et al*., 2011).

A fishway is potential solution to reconnect paddy fields and irrigation channels. However, designs of traditional fishway may be unsuitable for the agriculture environments. In Japan, Takabayashi (2005) and Sato (2008) have evaluated using HDPE currogated pipes as a new fishway design to reconnect the habitats between the paddy fields and the drainage ditches. The results of the studies were discussed in

Section 1.1.3. However, the application of the new type fishway in Taiwan is rare and has only been documented in limited studies (Chen *et al*., 2014).

Paramisgurnus dabryanus was selected as target species in this study as it is a common fresh water fish found in Taiwan paddy fields (Shao, 2001). Additionally, *P. dabryanus* belongs to the same family as *Misgurnus anguillicaudatus*, which succesully migrtated into paddy fields through the HDPE currogated pipe fishways in Japan (Takabayashi Kazuyoshi, 2005, Sato, 2007). Both of the species are bottom dewelling fish with anguilliform swimming style. Dispite of the similarity between the two species, information regarding *P. dabryanus* using the HDPE currogated pipe fishways was not available.

1.5 Research purpose

The purpose of the research is to evaluate the most suitable design criteria when installing a HDPE corrugated pipe fishway to reconnect paddy fields and drainage channels. The criteria include angles and discharges with *P. dabryanus* as the target species.

2. Materials and methods

2.1 Indoor experiment design

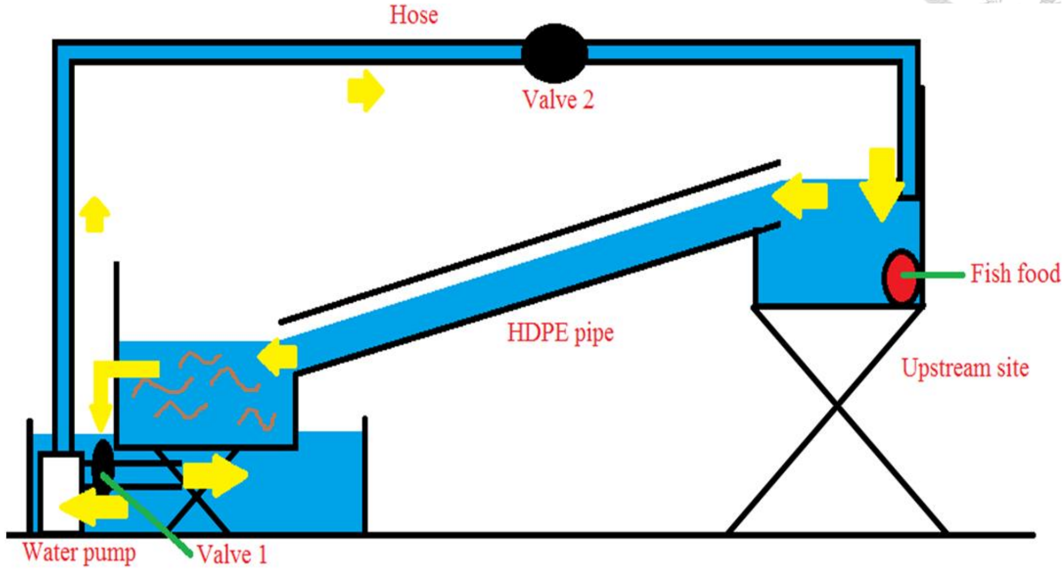

Fig 2.1a. Indoor experiment design. Arrows shows discharge direction. Valve 2 controls the water going up stream and valve 1 is use to increase or decrease discharge going up stream. Brown lines represent loaches.

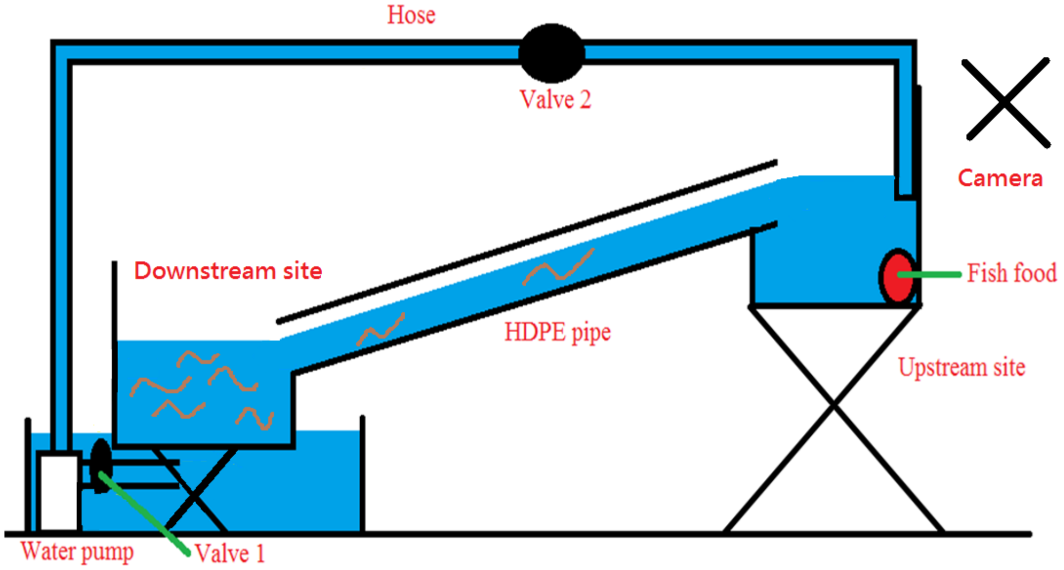

Fig 2.1b. When pump is turned on, fishes migrate from downstream site to the upstream site where food is located. A camcorder is located on top of the upstream site.

An indoor experiment was carried out from 2015/3/7 to 2015/5/14. The experiment was designed to evaluate the influences of two designing factors on the *P. dabryanus*'s migration behaviors. The factors include fishway slopes (0°, 3°, 6°, 10°, 12°, and 15°) and water discharge rates (100, 316, and 653 ml/s). The discharge was chosen by using Suzuki (2001) research as a reference. In Suzuki's (2001) research, during the discharge of 315ml/s, loaches were able to migrate when slope was that of 10° but when increasing the slope to 20°, no loaches were able to successfully migrate. After obtaining a discharge of 316ml/s, which is similar to that of 315ml/s, the discharge was divided by 2 and multiplied by 2 to obtain the rest of the discharges, but only approximations to the multiplication's result was used. The reason for choosing these slopes were because information about slopes using HDPE fishways for loaches tend to be that of 10° or higher than this one (Masaki Suzuki, 2001, Takabayashi Kazuyoshi , 2005, Sato, 2007). No information about slopes below 10° or below 20° (Masaki Suzuki, 2001) was found. Furthermore, Suzuki's (2001) results showed that loaches only able to migrate until the angle of 10° during the discharge of 315ml/s.

Materials used to build the system are two plastic boxes (45×8.5×19.5 cm, L×W×H), a Styrofoam box (56×36×23 cm, L×W×H), a corrugated HDPE pipe (11.69×100 cm, ∅×L, due to indoor experiment surface area limitations), a portable plastic submersible pump (max: 85L/min, brand TCF-120), an air-pumper (2.5w, Lung GX-100), and a water filter. The corrugation gap of the HDPE pipe is 1.4 cm. The HDPE pipe was cut in half longitudinally to observe the fish movements in the fishway. The plastic boxes were used as downstream and upstream tanks connected by the HDPE corrugated pipe. The downstream tank was put in the Styrofoam box. The water discharged from the upstream tank, passed HDPE corrugated pipes, entered downstream tank, and spilled into the Styrofoam box. Then, the portable plastic submersible pump in the Styrofoam box lifted the water to the upstream tank. The water was cycled within the system continuously (fig 2.1). There were two valves used to control discharge rate. The air-pumper and the water filter were applied to maintain water quality and dissolved oxygen levels.

P. dabryanus were bought from a loaches farm on (2015/1/15) and kept in the indoor environments. The acclimation period of the fishes was of 1 day before the beginning of the experiment. Fishes were separated into 4 groups: adult male (ADM), adult female (ADF), juvenile male (JVM) and juvenile female (JVF), having 5 fishes in each group. The age class was decided by the length of the fish, but each author has their own measurements. Naruse (1995) juveniles were those ≤9cm and adults, those 〉9cm and Fujimoto (2007) juveniles were those ≤8cm and adults, those 〉8cm. In this experiment, due to the size of the fishes bought, juveniles were those <10cm and adults were those ≥10cm.

There were 18 treatments tested in turns (6 angles×3 discharge rates). The following are the operation procedures of the indoor experiment:

1. Twenty loaches were randomly selected with 10 adult fishes, 10 juvenile fishes. There were 5 males and 5 females in each age class group.
2. The 20 fishes measured for their body size and weight before put at the downstream tank (2.1). They were kept in the tank without feeding.
3. After 24 hours of acclimatization, the experiment started by turning on the pump. A bag of food was kept at the upstream tank to attract fishes. Loaches feed due to chemical stimuli released by the food (Watanabe 1983).
4. Discharge, EC, DO, pH and water temperature are recorded at the beginning and the end of each experiment.
5. Water temperature was controlled by air conditioning and heat bars between 19°~28°C. The temperature was settle to this range due to the fact that loaches feed when water temperature are between this range (Watanabe, 1983).
6. Each experiment tapped by a camcorder located on top of the upstream box as shown in fig 2.1b and was last for 6 hrs.
7. At the end of each experiment, loaches in the upstream tank were measured, weighted and sexually defined.

8. The video was used to study the behavior of the loaches during their migration and their swimming velocity.

9. At the end of each experiment, all of the 20 loaches were put in the downstream tank, fed, and left to rest for a whole day. The experiment water was replaced before the beginning of the next experiment.

10. The fishway was adjusted to six different degrees in turns (0°, 3°, 6°, 10°, 12°, and 15°). One slope angle was tested three times with different discharge rates (100, 316, and 653 ml/s). Totally 18 experiments with different combination were conducted with no replicate (*n*=1).

Fig 2.2. Weighting fish.

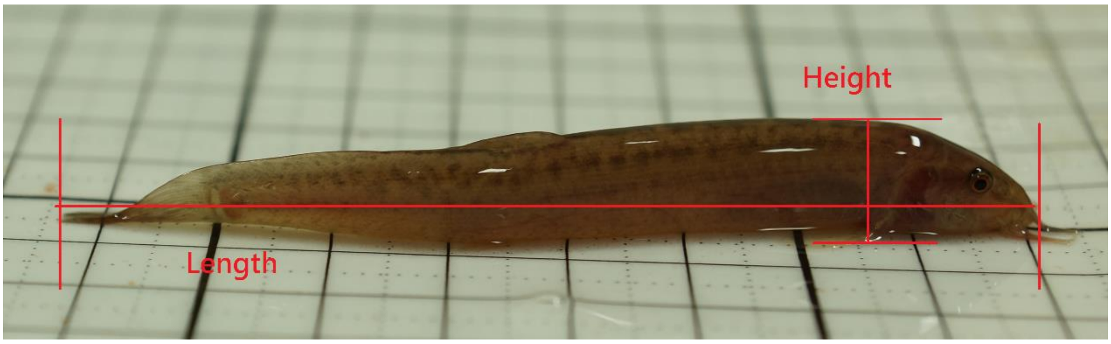

Fig 2.3. Measurement of fish length and height.

The whole experiment was carried out with the same group of fishes and done sequentially meaning that the slopes were increasing from the lowest to the highest but slope 0° was tested after angle 15° with a different group of fishes. Discharge order was tested by first doing 316ml/s followed by 100ml/s and finally 653ml/s.

2.2 Study site

This study was conducted in a rice paddy field and creek located at Taiwan, Yi-lan County, Yuan-shan district, Dahu area, Chuantsaitou creek, 24°44’36.85” North 121°41’26.49” East.

Fig 2.4. Location of study site, Taiwan, Yi-lan County, Yuan-shan district, Dahu area. (Google-maps)

Fig 2.5. Picture of the paddy field.

Fig 2.6. Creek site.

The area is a flat lowland which consists only of rice fields. Field working here is natural farming, meaning that there are no chemicals add into the field. Here farmers only work the land once a year, from mid-May to mid-July. The rest of the days, field is left to rest and filled with water. Unwanted plants and animals are removed by hand or machine and not with pesticides and chemicals. Birds, fishes, shrimps and frogs are welcome to the field and won't be driven away by farmers. Although fishes are allowed into the paddy fields, but only those entering through irrigation channels or underground water are able to enter the paddy field. Those fishes found in creeks, or those who swim to the creeks, are not able to go back to the paddy field as the connection has been lost.

The height difference between paddy field and creek was of first drop stage: 23cm and a second drop stage of 60cm. First drop stage belongs to a small ditch where water from paddy field or output to. Here, there is presence of water all the year and no disturbance is made as there is no farming action. Second drop stage enters the paddy field. We decided to try the fishway only to the first drop stage due to some issues with new construction planning's from farmers.

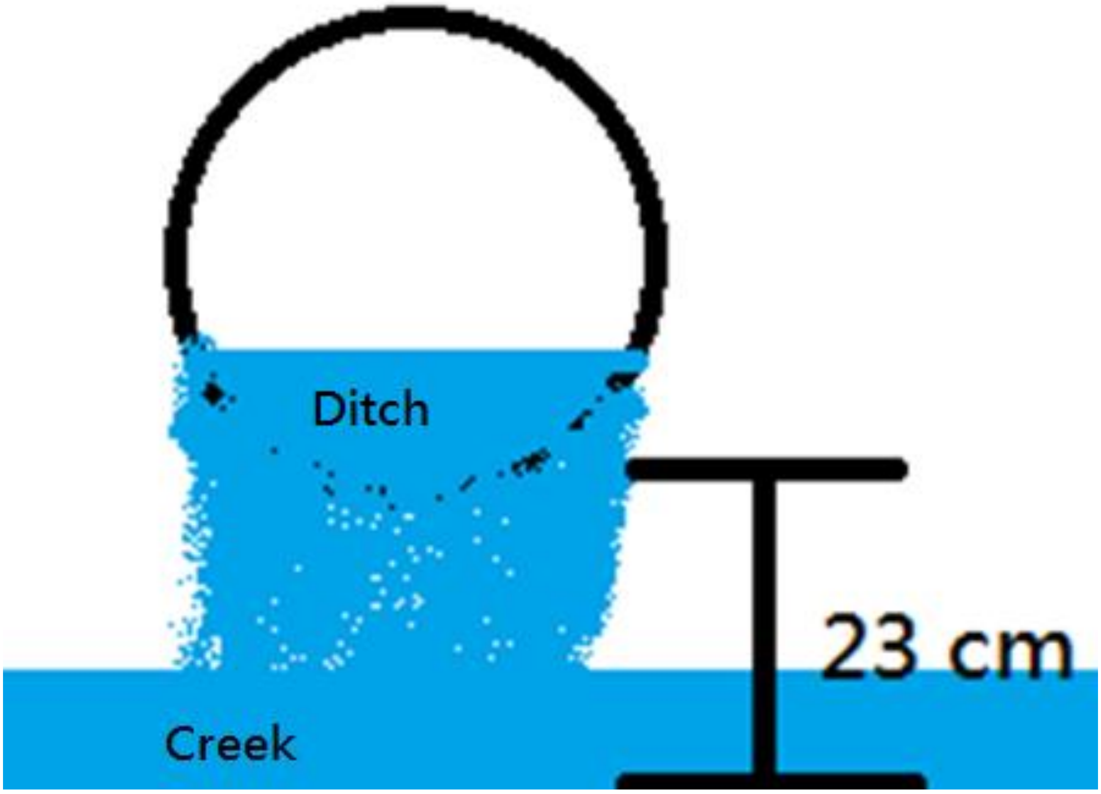

Fig 2.7. First drop stage

2.3 Environmental data

A biological survey of the study site was carried out during 2015/1/27 to 2015/1/28 to see what kind of aquatic species could be found at this study site and if there was presence of any kind of loach. Water samples were collected and fish traps were set on the 27th and left with food till the 28th, about 24hrs for the fishes to swim in the trap. After 24hrs, the traps were collected and species inside it were record and measured. Water samples were analyzed once back to the laboratory. The following photos represents how the fields where divided for the survey.

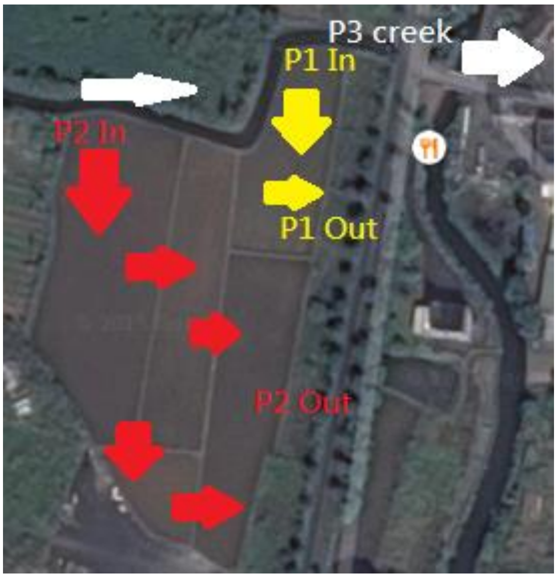

Fig 2.8. Water sample tested with arrows showing discharge direction. P2 discharge doesn't go into P1 and either vice versa. (Google-maps)

Fig 2.9. Field division for biological survey, Surface area: Da-hu field1= 2212.5m^2, Da-hu field2= 445156m^2, Da-hu field3= 890.89m^2, Da-hu field4= 3813.28m^2, Da-hu field5= 2701.56m^2. (Google-maps)

2.4 Field experiment design

The aim of the field experiment was to evaluate if the fish ladder could be applied in the field, which had different conditions than that of the indoor. In the creek, a plastic box of 58.5 cm (length) x 39.5 cm (width) x 39 cm (depth) holds the 20 experimental fishes brought from the lab. Inside the box, rocks were placed to prevent the box being flushed away by creek's discharge (Fig. 2.12). Loaches were places inside the box with rocks 24hrs before the experiment started for acclimatization to new environment. When experiment starts, the top of the box was sealed to prevent fishes jumping out and other disturbances such as predation. On the upstream site, a fish trap (Fig. 2.13) was attached to the corrugated pipe and fish food was placed inside. The total length of the fishway was of 4.11m. The diameter of the pipe was of 11.94 cm and the gap of corrugation was 2 cm which is a bit bigger than that of the indoor experiment. The L shape connector diameter was of 8.4cm.

Fig 2.10. Downstream of field experiment.

Fig 2.11. Upstream of field experiment.

Fig 2.12. Fish trap. Dimensions: 36.5cm (length) x 14.4cm (diameter).

Fig 2.13. Top view of the fish trap. The hole in the middle is the entrance to the trap which has a diameter of 3cm.

The field experiment procedure was the same as those applied in the indoor experiment without video recording as the pipe in the field experiment was not split into half. Conditions in the field experiment were tried to be kept as those in the indoor experiment except following factors: water quality (Table 2.1), temperature, pipe size, water discharge, distance travel to upstream and a 90° turn separating section 1 and section 2 (Fig 2.14.) Migrating fishes had to face two different discharges before migration, the one from the creek and the one from the pipe.

One angle with 2 replicates was tested on the field were carried out (2015/4/19~2015/4/20). The angle tested in the field experiment was of 3° and 1.07m of length, called section1. After section1, the fish had to travel section2 which had a distance of 3.04m with an elevation of 1°~2 ° to get into the fish trap (fig 2.14). Only fishes caught in the fish trap were considered succeed ones and then measured, weighted, and sexually defined. The DO, pH, EC, temperature and discharge rate were measured before and after the 6 hours experiment. The inside of the fishway was checked at the very end of each experiment to prevent leaving any loaches inside the fish ladder before next experiment starts.

Table 2.1. Water quality from field experiment site, 2015/4/18

	In	Out
pH	6.58	6.52
DO (mg/L)	6.07	7.07
EC (us/cm)	99.90	89.40
Temperature (˚ C)	24.8	24.6
Turbidity (NTU)	16.00	13.00
SS(mg/L)	0.03	0.05
TP(mg/L)	0.01	0.03
PO_4^{3-}-P(mg/L)	0.67	0.40
NO_3^--N(mg/L)	0.09	0.03
NH_4^--N(mg/L)	0.44	0.32

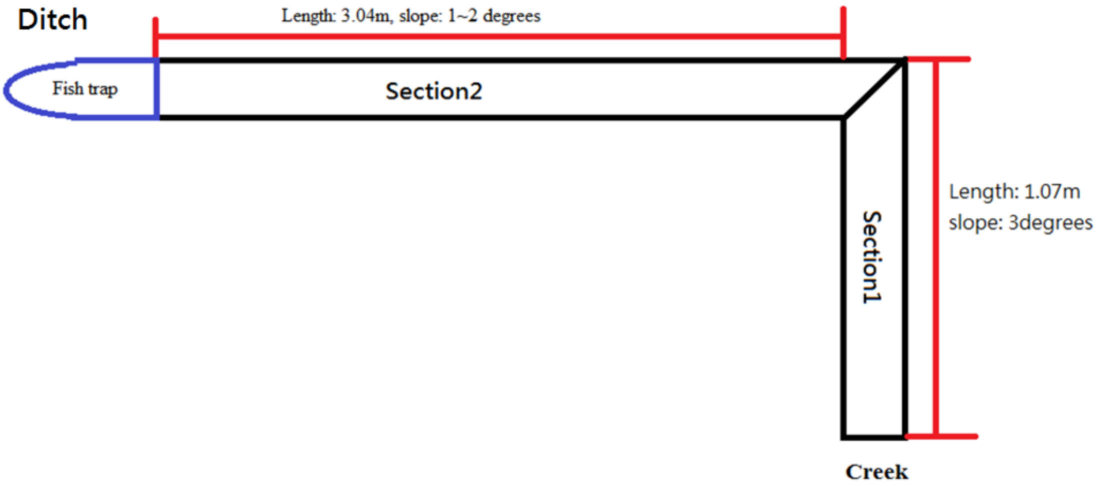

Fig 2.14. Length and slope of each section of the fishway on the field.

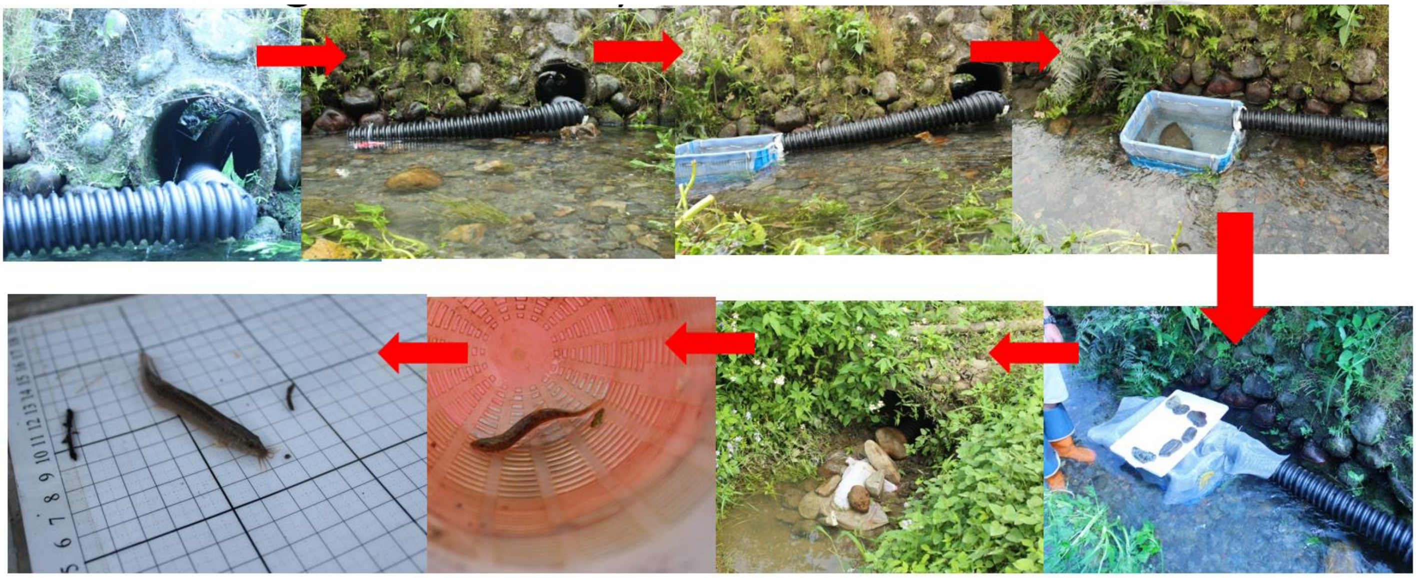

Fig 2.15. Building of the field experiment. Arrows show building sequence. First, fish ladder is introduced into the concrete pipe connected to the ditch. Afterwards, plastic box containing the 20 randomly loaches is located at the end of the fish ladder; rocks will be used to prevent box being flushed away by creek's current. The plastic box is covered to prevent any disturbances and finally fishes who successfully migrated are measured.

2.5 Statistical analysis and other analysis

Statistical analysis was only used in indoor experiment to see which factor (discharge, slope, gender or age class) affected the success percentage of fish during their migration. After finding the factor affecting the success percentage via General Linear Model (GLM), a Duncan's New Multiple Range Test was done to compare the means of the affecting factors (α=0.05). This analysis was done through IBM SPSS Statistics 22 software. Finally, for the indoor experiment, the analysis will be divided into two result sections:

1. 3 hour analysis: fish swimming velocity and migrating period.
2. 6 hours analysis, which is the result at the very end of the experiment. The definition of success in this research is the following: Only fishes which have completely moved to the upper tank of the system and stayed there after 6 hours of experiment will be considered successful migrating fishes. Factors affecting the success percentage analyzed are: discharge, slope, fish age class and gender. Slope are categorized into small (0° and 3°), mild (6° and 10°) and high (12° and 15°); discharges are categorized into slow ($100cm^3/s$), mild ($316cm^3/s$) and fast ($653cm^3/s$).

3. Results and discussion

3.1 Indoor experiment analysis

Table 3.1. Fishes tested for experiment of 3° to 15°.

age class and gender	length (cm)	width (cm)	weight (g)
ADM1	11	1.2	7.12
ADM2	11.5	1.4	5.39
ADM3	11.6	1.3	8.03
ADM4	11	1.5	6.33
ADM5	11	1.1	6.38
ADF1	11.5	1	6.98
ADF2	10	1.5	8.06
ADF3	10.5	1.2	6.62
ADF4	10	1.2	6.2
ADF5	10.5	1.1	5.83
JVM1	8	1	3.47
JVM2	8	1	3.39
JVM3	8	1	3.79
JVM4	8.5	1	3.07
JVM5	8	1	2.7
JVF1	8.5	1	3.97
JVF2	8	1	3.76
JVF3	8.5	1.1	4.11
JVF4	8.5	1	3.73
JVF5	8.5	1	4.18

Notes: AD: adult fishes, JV: juvenile fishes, M: male fishes and F: female fishes.

Table 3.2. Fishes tested for experiment of 0°.

age class and gender	length (cm)	width (cm)	weight (g)
ADM1	11	1.2	6.23
ADM2	11	1.3	7.56
ADM3	11	1.1	4.98
ADM4	10.5	1.2	4.88
ADM5	11.5	1.3	7.6
ADF1	10	1.1	5.59
ADF2	12	1.4	9.92
ADF3	10.5	1.1	5.08
ADF4	10.5	1.4	6.83
ADF5	10.5	1.1	6.91
JVM1	9	1	2.9
JVM2	9.5	1.1	4.7
JVM3	8	1	2.84
JVM4	9	1.1	4.63
JVM5	8.5	0.9	2.6
JVF1	9	1.1	3.62
JVF2	7	1	2.46
JVF3	9	0.9	2.49
JVF4	8	1	3.54
JVF5	8.5	0.9	3.35

Notes: AD: adult fishes, JV: juvenile fishes, M: male fishes and F: female fishes.

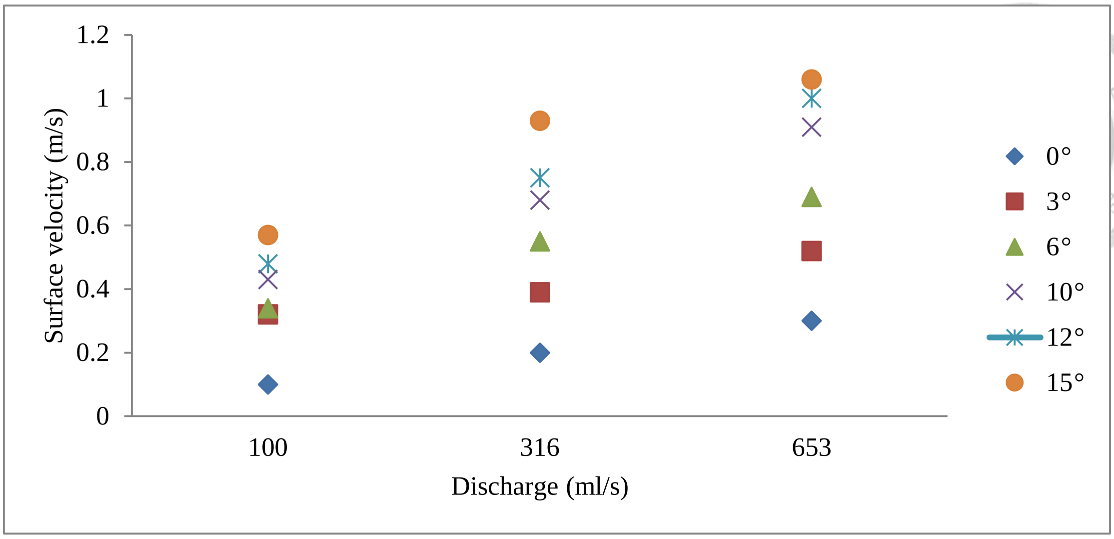

Fig 3.1a. Water surface velocity for different angles as discharge increases.

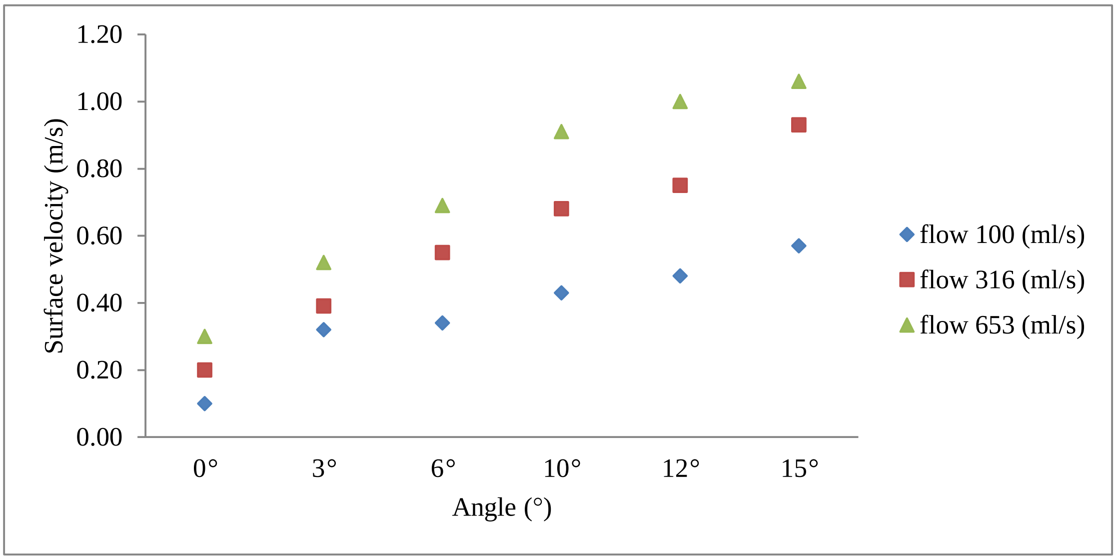

Fig 3.1b. Water surface velocity for different discharges as angle increases.

From figures 3.1a and 3.1b, we can see that water velocity increases due to an increase in angle or discharge, as a result my water velocity depends on the angle and the discharge combination. Same tendency results were seen in Suzuki (2001) fishway experiment. Numerical values can be seen appendix section.

3.1.1 Three hours analysis

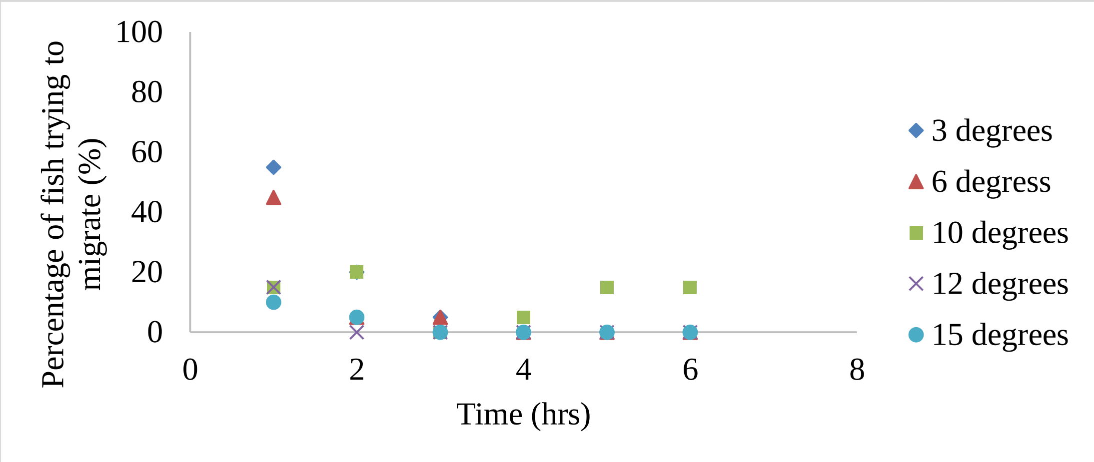

Fig 3.2a Migration period of fishes experiment for discharge 100 cm^3/s.

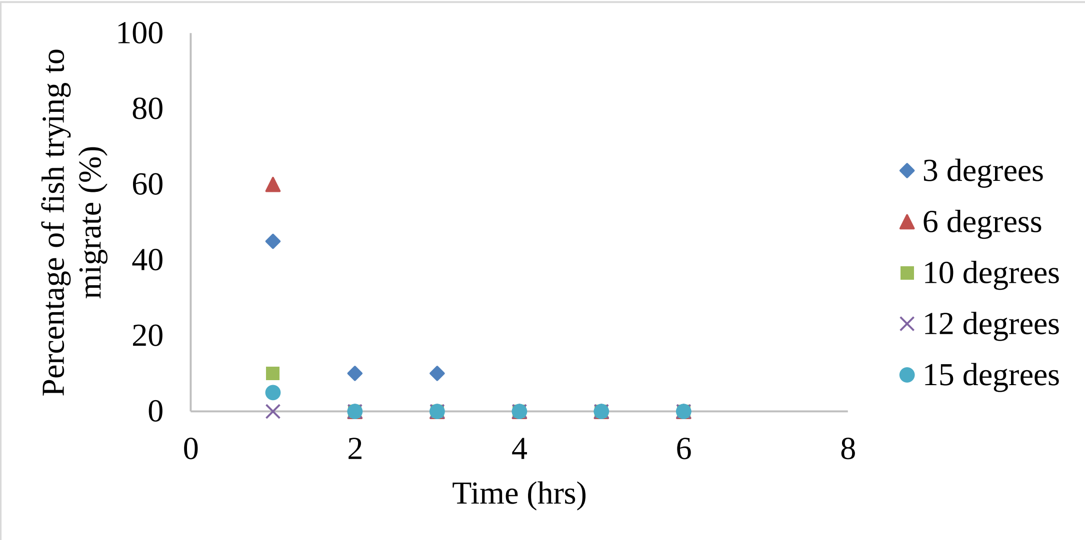

Fig 3.2b. Migration period of fishes experiment for discharge 316 cm^3/s.

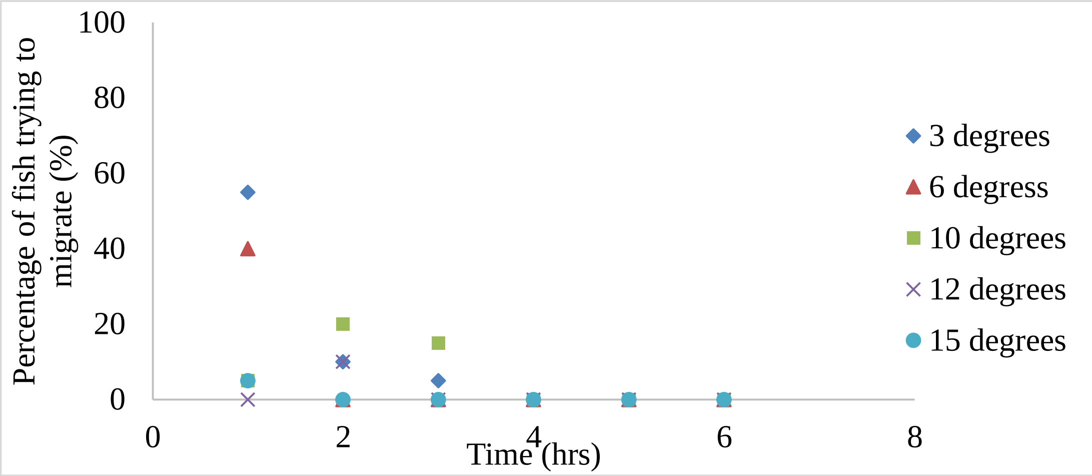

Fig 3.2c. Migration period of fishes experiment for discharge 653 cm^3/s.

Fig 3.1a, fig 3.1b and fig 3.1c shows that loaches tend to be more active during the first three hours of the experiment. After the three hours, loaches activity has the tendency of lowering to 0 meaning that they are not trying to migrate anymore. The reasons for this tendency may be due to giving up or due to fatigue after three hours of trying. In fig 3.1a, an outlier can be seen, when the angle is of 10° and the discharge is of 100cm^3/s, loaches migration continues along the six hours. This result may be because loaches are more attracted to this kind of slope and discharge combination. Japanese researchers such as Suzuki (2001), used the angle of 10° as the lowest trial slope, which may be due to the fact that loaches are more attracted to this kind of slope. In regards to the discharge, discussion will be made during the six hours analysis.

Fish swimming velocity may also affect the success percentage during migration of fishes in corrugated HDPE pipe fishways. Analysis for this assumption will be seen on fig 3.3. Swimming velocities was adjusted by adding the actual fish swimming velocity to the water discharge velocity as this should be the real fish swimming velocity of the fishes during migration.

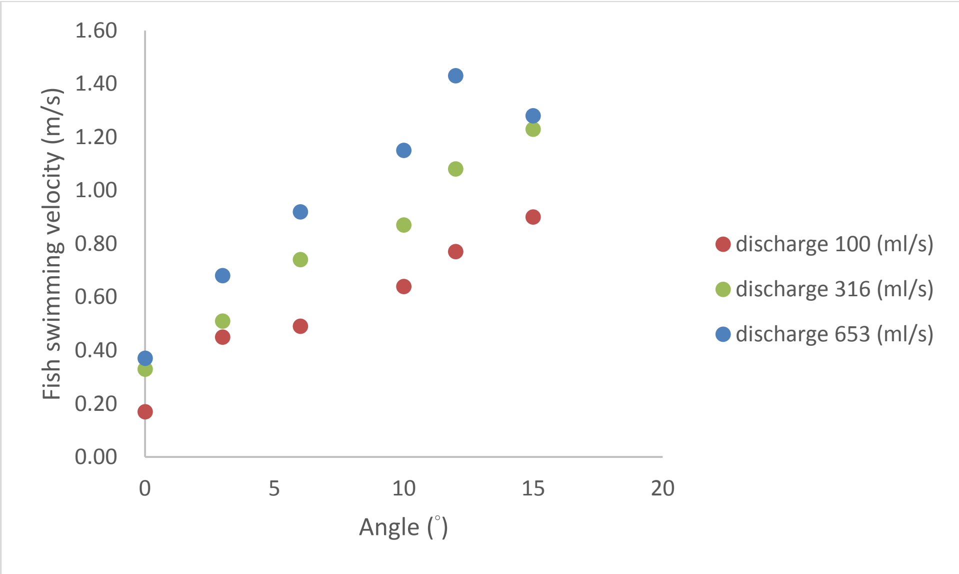

Fig 3.3. Change of fish average swimming velocity for different discharges as angle increases during 3 hours analysis.

From the figure 3.3, a limit swimming velocity for the fishes can be seen. According to the graph, fishes swimming velocity increases as slope and discharge increases. This tendency is the result of fish having to increase their swimming velocity to overcome faster water velocities. As said before (fig 3.1a and 3.1b), as angle increases and discharge increases, the water velocity increases; so fishes have to swim faster than the water velocity in order successfully migrate.

3.1.2 Six hours analysis

Table 3.3 GLM analysis for successfully migrated fishes after 6 hours experiment

Source	Type III sum of squares	df	Mean square	F	Significance
slope	19.589	5	3.918	22.566	.000
discharge	1.839	2	.919	5.296	.006
gender	.900	1	.900	5.184	.024
age class	3.211	1	3.211	18.496	.000
slope * discharge	1.394	10	.139	.803	.626
slope * gender	.367	5	.073	.422	.833
slope * age class	1.256	5	.251	1.446	.208
discharge * gender	.650	2	.325	1.872	.156
discharge * age class	.039	2	.019	.112	.894
gender * age class	.544	1	.544	3.136	.078
slope * discharge * gender	.983	10	.098	.566	.841
slope * discharge * age class	1.594	10	.159	.918	.516
slope * gender * age class	.389	5	.078	.448	.815
discharge * gender * age class	.539	2	.269	1.552	.214
slope * discharge * gender * age class	.828	10	.083	.477	.904
error	50.000	288	.174		
total	134.000	360			

From table 3.3, the results of GLM analysis for successfully migrated fishes after 6 hours experiment can be seen. The factors which are affecting the migration of fishes in this experiment are slope, discharge, gender and age class. These factors have no interaction between each other so it is believed that the factors affect the success percentage of fishes separately. This result may be due to the fact that the slopes and discharge experiment were done sequentially and not randomly selected.

As a result of this experiment design, fishes may adapt easily to the experiment as they do not face any kind of abrupt changes. Furthermore, the fishes tested throughout the experiment were the same so this could also support the idea of fishes adapting easily to the experiment changes. As mentioned before, the factors slope, discharge, gender and age class seems to affect the success percentage separately so a Duncan's New Multiple range test was carried out to see how these factors influence the success percentage.

Angle(°)	Discharge 100cm^3/s	Discharge 316cm^3/s	Discharge 653cm^3/s
0	50.00±16.68 ^{abc}	50.00±16.67 ^{ab}	50.00±16.67 ^{a}
3	90.00±10.00 ^{a}	80.00±13.33 ^{a}	80.00±13.33 ^{a}
6	70.00±15.28 ^{ab}	40.00±16.33 ^{ab}	80.00±13.33 ^{a}
10	80.00±13.33 ^{a}	50.00±16.67 ^{ab}	10.00±10.00 ^{b}
12	20.00±13.33 ^{c}	10.00±10.00 ^{b}	0.00±0.00 ^{b}
15	30.00±15.28 ^{bc}	10.00±10.00 ^{b}	0.00±0.00 ^{b}

Table 3.5a Duncan test for adult fishes success percentage.

Angle(°)	Discharge 100cm^3/s	Discharge 316cm^3/s	Discharge 653cm^3/s
0	60.00±16.33 ^{a}	40.00±16.33 ^{ab}	20.00±13.33 ^{ab}
3	70.00±15.28 ^{a}	60.00±16.33 ^{a}	40.00±16.33 ^{a}
6	40.00±16.33 ^{ab}	40.00±16.33 ^{ab}	40.00±16.33 ^{a}
10	30.00±15.28 ^{ab}	20.00±13.33 ^{ab}	10.00±10.00 ^{ab}
12	10.00±10.00 ^{b}	10.00±10.00 ^{ab}	0.00±0.00 ^{b}
15	0.00±0.00 ^{b}	0.00±0.00 ^{b}	10.00±10.00 ^{ab}

Table 3.5b Duncan test for juvenile fishes success percentage.

Table 3.5a and 3.5b shows the Duncan test for age class success percentage. The results shows the following: Adult fishes can migrate in a slope of 10° during slow discharges, 12° during mild discharges and during high discharges, 12° is the only angle they cannot. On the other hand, juvenile fishes can migrate through a slope of 10 ° during slow and mild flows but during fast flows, they can only do until the angle of 6°. As a result, adult fishes seem to be able to migrate in a greater variety of slopes, which may be due to the need of reproduction; they need to adapt themselves to more variety of slopes to migrate in order to have better chances to reproduce. In the case of juvenile fishes, they tend to have higher success percentage than adults in their migration slopes. This may have been influenced by the turbulent flow, size of fish and tail beat angle. As water velocity increases, the gaps inside the HDPE fish ladder produces higher turbulences (Clark, 2011, Ead, 2000) which may produce difficulties for migration of fishes. Furthermore, as adult fishes have bigger size of body, leading to bigger tail beat angle (from observations of the video analysis) which results in higher surface area exposed to the turbulent flow. To sum up, adult fishes have more difficulties to succeed during migration. Finally, the slopes and discharges are changed sequentially and not randomly selected; the same goes for the group of fishes tested, which are the same throughout the whole experiment.

Table 3.5a Duncan test for male fishes success percentage

Angle(°)	Discharge 100cm3/s	Discharge 316cm3/s	Discharge 653cm3/s
0	60.00±16.33ab	60.00±16.33ab	40.00±16.33ab
3	70.00±15.28a	90.00±10.00a	70.00±15.28a
6	80.00±13.33a	30.00±12.28ab	70.00±15.28a
10	60.00±16.33ab	40.00±16.33bc	0.00±0.00c
12	10.00±10.00c	20.00±13.33bc	0.00±0.00c
15	20.00±13.33bc	10.00±10.00c	10.00±10.00bc

Table 3.6b Duncan test for female fishes success percentage

Angle(°)	Discharge 100cm3/s	Discharge 316cm3/s	Discharge 653cm3/s
0	50.00±16.67ab	30.00±15.28ab	30.00±15.28ab
3	90.00±10.00a	60.00±16.33a	50.00±16.67a
6	30.00±15.28b	50.00±16.67a	50.00±16.67a
10	50.00±16.67ab	30.00±15.28ab	20.00±13.33ab
12	20.00±13.33b	0.00±0.00b	0.00±0,00b
15	10.00±10.00b	0.00±0.00b	0.00±0.00b

Table 3.6a and 3.6b shows the Duncan test for age class success percentage. The results shows the following: Males can migrate till the angle of 10° in slow flows, but afterwards, during mild and fast flows, males can only migrate till the angle of 6°. On the other hand, females can migrate through the angle of 10° throughout all the discharges. This shows females have higher migrating slopes than males; but from the results, we can see that males tend to have higher success percentage than the females. This tendencies are believed to be the results of females having heavier weight than males. By being heavier, the energy needed to successfully migrate is much higher as more force is needed to fight against gravity. In addition to this, as Seriously-Fish says, females are those who lead males to the reproduction site so females need to adapt themselves to more varieties of slopes to migrate. Finally, as said before, the experiment order for the combinations of slopes and discharges can have influenced the results in this experiment.

All of above results should be further tested to provide a more reliable conclusion. Furthermore, another set of experiments with randomly chosen combination of fishes, slopes and discharges should be done also to provide more reliable results. The new results should be used to compare with the one already obtained to see if randomness of the experiment affect or not the migration of fishes. In addition, making the experiment result random can prevent the fact of fishes adapting quickly to the next combination of slopes and discharges. Furthermore, more repetitions of the same combination should be carry out randomly as during this experiment, only one replicate of the same experiment was done resulting in not very reliable results. Finally, not only the experiment should be randomized but also longer lengths of HDPE fishways with different diameter which affects the gap distance should and different types of pipes should be tested to provide the most suitable length and diameter to build the fish ladder for the Chinese loach.

3.2 Field experiment

Biological survey

Water conditions are shown in table 3.7 and the results of the survey are shown on table 3.8a, 3.8b, 3.8c, 3.8d, and 3.8e. From the biological survey, we were able to know that there were loaches in the study site so building this kind of fishway here would be a good choice as those loaches found in the creek could migrate back the paddy fields after the fish passage was left there.

Table 3.7. Water condition results, 2015/1/27.

	P1		**P2**		**Creek**
	In	**Out**	**In**	**Out**	
pH	6.53	6.48	6.70	6.55	6.91
DO (mg/L)	6.53	6.70	8.60	7.90	9.60
EC (us/cm)	107.90	162.20	112.00	103.40	139.80
Temperature (° C)	19.7	18.7	19.1	18.9	19.5
Turbidity (NTU)	6.20	12.50	10.80	28.80	20.00
SS(mg/L)	10.50	14.00	8.00	11.00	13.00
TP(mg/L)	0.05	0.08	0.10	0.09	0.08
PO_4^{3-}-P(mg/L)	0.05	0.08	0.11	0.06	0.09
NO_3^--N(mg/L)	0.36	0.06	0.35	0.07	0.06
NH_4^--N(mg/L)	0.08	0.04	0.07	0.18	0.19
TKN(mg/L)	0.24	0.40	0.44	0.56	0.32

Table 3.8a. Da-hu field 1 results.

P	Species	Number	Length (cm)	Width (cm)	Weight (g)
1	No species				
2	*Paramisgurnus dabryanus*	1	6	0.5	1.53
	Cybister japonicus sharp	4			
	Procambarus clarkii	2	3.4	0.6	0.85
			3	0.6	0.77
	Tadpole	3			
3	*Procambarus clarkii*	2	5.5	1.5	3.83
			4	1	1.83
	Hirudo medicinalis	2			
	Cybister japonicus sharp	2			

Table 3.8b. Da-hu field 2 results.

P	Species	Number	Length (cm)	Width (cm)	Weight (g)
1	*Misgurnus anguillicaudatus*	3	4.5	0.5	0.48
	Caridina	4			
2	*Caridina*	1			
	Cybister japonicus sharp	1			
	Nymph of dragonfly	1			
3	*Hirudo medicinalis*	2			
4	Nymph of dragonfly	1			
	Nymph of damselflyfly	1			
	Cybister japonicus sharp	2			

Table 3.8c. Da-hu field 3 results.

P	Species	Number	Length (cm)	Width (cm)	Weight (g)
1	*Cybister japonicus sharp*	1			
2	*Cobitis sinensis*	4	5.5	0.5	0.99
			4.8	0.5	0.54
			4.5	0.5	0.62
			4.5	0.5	0.68
	Cybister japonicus sharp	1			
	Tadpole	8			
3	*Cybister japonicus sharp*	1			
	Tadpole	20			

Table 3.8d. Da-hu field 4 results.

P	Species	Number	Length (cm)	Width (cm)	Weight (g)
1	*Gambusia affinis*	3			
	Nymph of the dragonfly	2			
2	*Procambarus clarkii*	1	7.5	1.6	0.66
	Gambusia affinis	1			
	Tadpole	1			
3	*Gambusia affinis*	1			
	Cybister japonicus sharp	1			

Table 3.8e. Chuantsaitou creek results.

P	Species	Number	Length (cm)	Width (cm)	Weight (g)
right	*Caridina*	23			
left	*Tilapia nilotica*	9	4.3	1.5	2.03
			5	1.5	2.14
			4.5	1.9	3.42
			6	2	3.45
			5	1.5	2.31
			6	2	3.72
			7	2.3	5.1
			6	2	3.9
			5.2	1.5	2.12
	Cobitis sinensis	3	6.5	0.5	1.73
			5.8	0.5	1.26
			5.2	0.5	0.93

From table 3.8a, presence of the Chinese loach was proven to exist in this study site which means than this species inhabits paddy fields so building a fish ladder here would be a good choice.

Table 3.9 Fishes tested for experiment field experiment.

age class and gender	length (cm)	width (cm)	weight (g)
ADM1	11.5	1.3	4.31
ADM2	10.5	1.3	5.21
ADM3	11	1.3	5.17
ADM4	10	1.2	5.85
ADM5	12	1.1	8.34
ADF1	10.5	1.4	5.74
ADF2	10.5	1.3	7.28
ADF3	12.5	1.2	10.41
ADF4	10.5	1	6.72
ADF5	11	1.1	7.33
JVM1	8	1	3.24
JVM2	8	1	3.28
JVM3	8.5	1	3.12
JVM4	9	1	2.52
JVM5	8.5	1	3.32
JVF1	8	1.2	3.54
JVF2	8.5	1.3	3.98
JVF3	9.5	1.1	3.83
JVF4	8.5	1	5.25
JVF5	7.5	1	2.25

Notes: AD: adult fishes, JV: juvenile fishes, M: male fishes and F: female fishes.

Fig 3.4 Field experiment downstream.

Fig 3.5 Field experiment downstream, slope for experiment 3°.

Fig 3.6. Field experiment upstream showing fish trap.

The field experiment was carried out on 2015/4/19 and 2015/4/20. Both experiments have each only one succeeding migrating fish.

Fig 3.7. 2015/4/19 successfully migrated fish.

Fig 3.7 shows a female juvenile fish of length 9cm, width 1cm and 3.47g of weight.

Fig 3.8. 2015/4/20 successfully migrated fish.

Fig 3.8 shows a male juvenile fish of length 8.5cm, width 1cm and 4.24g of weight.

Due to the many differences with the indoor experiment, the field experiment's results are not able to be compared with the indoor experiment. During field experiment, both days result showed that juvenile fishes have better chance to succeed than adult fishes. Field experiment results for success percentage were much lower than that of indoor experiment. Chen's (2014) experiment shows that the success percentage of upstream migrating loaches in field is of 25 out of 400 loaches, 6.25% (no angle and length of the fishway was given) which is near to this research, 1 out of 20 (5%).

Some of the difference introduced in the field experiment, for example the diameter of the tube was bigger than that of the indoor experiment leading to greater gaps distance could lead to this drop in success percentage. Grater gaps distance may have influence the migration of the fishes. Furthermore, if the fish passage is to long for the fish to use, this one should have a resting area. In the case of corrugated HDPE pipes, the resting area is provided by the gaps don by the undulations; so if fishes are not able to use this gaps for resting, then there won't be able to rest. Gerstner (1998) demonstrates that the gap's wavelength will decide if the fish will use it to rest. At the same time, the space provided at the downstream area was much bigger than that of the indoor experiment giving more space to move through. Furthermore, rocks were used to stabilize the downstream box, may have provided shelter for loaches leading them to not wanting to move out from bellow rocks. This result was also shown by Chen (2014) who observes that loaches tend to hide under rocks. Another issue was the length of the whole fishway, the indoor experiment was of 1m but the one on the field was of 4.11m (1.07m at angle 3° and 3.04m at an angle between 1° to 2°. *Paramisgurnus dabryanus* may not be able to travel such a distance without resting. In addition to length problem, longer lengths could have reduce the chemical stimuli provided by the food, making loaches unaware of food presence. All these factors may have affected success percentage of migrating fished during field experiment.

Environmental factors such as water quality, light intensity and discharge may have also affected the success for migration as these factors were not possible to control. Loaches are said to be nocturne (Chen *et al*., 2014) and these experiments were carried out during day time. The measurement of the discharge during field experiment shows that in the field, discharge may change throughout the day. Furthermore, probably the experiment time period was not during mating seasons for loaches in Taiwan. As a result of not being mating season, adult loaches are not attracted to paddy fields. Finally, the environment provided by the creek and box containing the loaches may have provided a suitable living environment for the fishes leading to no migration of these ones. In regards to physical factors. All these factors may have affected success percentage of migrating fished during field experiment.

4. Conclusions

- Biological survey showed that there are presence of Chinese loaches in Dahu (study site), which is a reason for choosing this field as the experiment site.
- 3 hour analysis shows that loaches activity tend to lower after 3 hours of experiment.
- Fishes swimming velocity increases as water surface velocity increases as they need to overcome the water surface velocity to successfully migrate.
- From six hours analysis, we can conclude that males have better chance to succeed in high angles and high discharges than females.
- Adult fishes have a wider range of migrating slopes but juveniles have higher success percentage.
- Females have a wider range of migrating slopes but males have higher success percentage.
- Field experiment shows that length, gaps distances and natural factors may affect success percentage.
- Field and indoor experiment shows that HDPE fishway works for loaches.

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Appendix

Data of indoor experiment. AD: adult, JV: juvenile, M: male, F: female.

0°-100ml/s experiment

date:	2015/5/10	water changed	16:37	
Combination	0°-100ml/s	fed	16:58	
starting time:	10:08			
ending time:	16:08			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	0	time for measurement		time for measurement
pH:	7.011	10:01	7.063	16:16
DO (mg/l):	7.86	10:01	6.85	16:16
EC (us/cm):	106.4	10:01	113.2	16:16
temperature (℃):	25.2	10:01	31.6	16:16
discharge (ml/s):	100.5			
velocity measured(m/s)	0.1			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5163.75	10:05		
water depth (cm):	13.5	10:05		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5546.25	10:05		
water depth (cm):	14.5	10:05		
tube condition				
lower tube water depth (cm):	1.5	10:05		
upper tube water depth (cm):	1.5	10:05		
middle section depth				

highest water depth (cm):	1.5	10:05
lowest water depth (cm):	3	10:05

0°-100ml/s, 6 hours analysis successful fishes

successful: 11	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	9	1.1	4.82
2	F	AD	12	1.2	9.1
3	M	JV	8	1	2.42
4	M	JV	8	1	3.01
5	F	JV	8.5	1	3.51
6	M	AD	10.5	1.1	5.26
7	M	AD	11	1.4	7.44
8	F	AD	11.5	1.3	7.63
9	M	AD	11	1	5.98
10	F	JV	8.5	1	4.45
11	F	AD	10	1	5.27

0°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	10	2.39	2.49	10	0.10
2	8.5	3.36	3.51	14	0.07
3	11	5.31	6.01	30	0.03
4	11.5	34.50	35'07	17	0.09
5	12	101.10	101.39	29	0.04

0°-100ml/s, 3 hours analysis successful fishes continued.

fish	observations
1	
2	
3	
4	34.52min to 34.56min stays at rest at 20cm
5	reaches to 90cm at 47.51min and stays at rest and swimming till 47.56min

0°-100ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	12	6.07	6.23	16	0.11	100
2	11.5	10.02	10.25	23	0.1	95
3	10.5	24.56	28.54	238	0.06	60
4	11.5	28.09	28.54	45	0.1	30
5	12	28.46	29.05	19	0.05	40
6	11	29.32	30.30	58	0.07	60
7	11.5	29.50	30.38	48	0.04	70
8	10.5	31.06	31.32	26	0.2	20
9	11	32.19	32.47	28	0.03	60
10	11	32.32	32.34	2	0.2	90
11	11.5	33.07	34.12	65	0.03	95
12	8.5	33.07	34.19	72	0.03	70
13	9	34.25	35.00	35	0.1	35
14	11	44.13	45.14	61	0.03	70
15	8.5	81.41	81.46	5	0.1	15
16	10	116.33	117.11	38	0.15	25

0°-100ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	fights at 70cm from 10.09min to 10.17min
3	25.21min to 25.23min swims at 40cm
4	28.09min to 28.45min fights at 10cm. 28.45min swims up to 30cm(28.47min)
5	28.49min to 28.54min fights at 20cm. 28.56min to 29.03min fights at 30cm~40cm.
6	29.35min to 29.37min, stays at rest at 20cm. 29.37min to 29.57min swims to 60cm. 29.59min to 30.10min fights at 30cm. 30.16min stays to 30.29min at rest at 10cm after hitting bottom.
7	30.01min to 30.07min fights at 40cm. 30.15min is pushed from 70cm to 50cm and then swims to 65cm. 30.23min reaches 0cm and at 30.31 reaches 40cm. 30.34 is pushed back down to 0cm and at 30.37 swims to 20cm and is then pushed back down
8	stays at rest at 20cm from 31.07min to 31.29min
9	Stays at rest at 10cm from 32.20min to 32.23min then swims up.
10	
11	33.30min to 33.44min stays swimming at 95cm. 33.51min to 34.09min swims from 20cm to 50cm
12	33.30min to 34.19min stays swimming at 70cm
13	34.27min to 34.48 stays swimming at 25cm to 35cm. 34.50min to 34.57min stays swimming at 20~25cm
14	reaches 35cm at 44.29 but is then push back to 5cm(44.36).44.37min to 44.51min stays at rest and swimming at 20cm
15	burst back down
16	Stays at rest at 10cm from 9.10min to 9.15min. 9.16min stays at rest at 25cm to 9.46min.

0°-316ml/s experiment

date:	2015/5/16	water changed	18:00	
Combination	0°-316ml/s	fed	18:20	
starting time:	11:55			
ending time:	17:55			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	0	time for measurement		time for measurement
pH:	7.013	11:49	7.157	18:04
DO (mg/l):	7.79	11:49	6.83	18:04
EC (us/cm):	98.8	11:49	106.4	18:04
temperature (℃):	25.2	11:49	32.3	18:04
discharge (ml/s):	100.5			
velocity measured(m/s)	0.2			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5546.25	11:50		
water depth (cm):	14.5	11:50		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6196.5	11:50		
water depth (cm):	16.2	11:50		
tube condition				
lower tube water depth (cm):	3.5	11:50		
upper tube water depth (cm):	3.5	11:50		
middle section depth				
highest water depth (cm):	3.5	11:50		
lowest water depth (cm):	4	11:50		

0°-316ml/s, 6 hours analysis successful fishes-

migrated fishes 6 hours successful: 9	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	8.5	1.1	5.15
2	M	AD	10.5	1.1	5.99
3	M	AD	10	1	4.91
4	F	JV	9	1	4.08
5	M	AD	11	1.1	7.57
6	F	AD	11.5	1.1	8.2
7	M	JV	7	0.6	3.12
8	F	JV	9.5	1	6.36
9	M	JV	8	1	2.83

0°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	8	0.56	2.02	66	0.06
2	11.5	3.23	3.34	11	0.09
3	8.5	5.19	5.24	5	0.20
4	12	6.10	6.19	9	0.18
5	9.5	8.04	9.15	71	0.04
6	9	16.05	16.44	39	0.02
7	11.5	25.03	25.15	12	0.13
8	11	26.08	27.19	71	0.40
9	10.5	27.11	27.17	6	0.20
10	10	142.55	144.47	112	0.02
11	7	146.39	147.15	36	0.04

0°-316ml/s, 3 hours analysis successful fishes continued.

fish	observations
1	Swims to 40cm (0.59m) is then pushed back to 30cm at 1.01m where it swims till 1.05m. 1.07 is pushed to 0 cm but stays there and at 1.08 swims back to 20 cm, 1.11 is pushed back to 0 cm 1.16 reaches 30cm where it stays till 1.24m and is then pushed back to 0cm at 1.26. At 1.31m swims to 40cm where it stays till 1.35 and at 1.36 is pushed back to 0 cm. 1.40m swims to 30cmwhere it stays till 1.43min and at 1.45min is pushed back to 0cm and then slowly swims to op at 2.02 min
2	
3	
4	reaches 30cm at 6.15 and is push back a bit but then swims to top
5	At 90cm it bursts to 100cm but is then pushed back down to 0cm at 8.17cm. Sims to 80cm at 8.32min and is then pushed back down, 8.37min. Reaches 90cm at 8.47min but is pushed back down to 40cm at 8.49min, here it start to swim to the top and reaches at 9.09min where it fights(hanged to the tube) till 9.15min
6	16.12min slowly swims up to top from 20cm
7	swims to 30cm and is push back to 20cm ay 25.06min
8	26.18min is push back to 60cm and then swims to top again at 26.21min but is push back down again. 26.27min swims back to top and fights there from 26.33min to 27.09min. 27.14min swims up again. 27.15min bursts from 20cm to 60cm, stops and swims up again to top.
9	Swims to 20cm at slow speed, burst to 60cm, stops and then burst again to top.
10	fights at 20cm till 41.50 min, swims to 30cm and fights from 41.52min till 42.03 min. 42.11min swims to 40cm and reaches 100cm at 42.40min and stays resting and swimming till 43.21min
11	Stays at 30cm from 45.15min till 45.21min. Reaches top at 45.37min

0°-316ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	11	0.32	0.33	1	0.10	10
2	11	0.34	0.37	3	0.25	25
3	11.5	0.37	0.49	12	0.70	70
4	10.5	0.56	1.02	6	0.13	40
5	10	0.59	1.02	3	0.25	25
6	9	2.08	2.15	7	0.06	35
7	11	2.13	2.15	3	-	5
8	10	2.23	2.35	12	0.10	20
9	11	2.27	2.28	1	-	5
10	10.5	2.47	2.58	11	0.14	100
11	11	3.05	3.09	4	0.10	20
12	11.5	3.25	3.31	6	0.09	35
13	9	6.23	6.52	29	0.06	95
14	9	7.03	7.08	5	0.08	15
15	11.5	7.19	7.22	3	0.20	20
16	8.5	7.25	8.05	40	0.05	100
17	8.5	7.36	7.59	23	0.15	60
18	10	8.44	9.15	30	0.06	95
19	10	15.05	15.16	11	0.10	20
20	11	16.06	16.17	11	0.13	40
21	10	16.20	16.50	30	0.04	95
22	11.5	16.37	16.50	23	0.10	90
23	11	19.06	19.33	27	0.04	60
24	10	22.10	22.45	35	0.05	100
25	10.5	23.08	23.23	15	0.07	65
26	8.5	53.25	53.37	12	0.04	20
27	8.5	63.50	64.09	19	0.05	60
28	10	92.33	92.39	6	0.10	20
29	11	112.30	113.37	64	0.07	100
30	11	131.09	132.06	57	0.15	80
31	10	142.09	143.35	86	0.04	100
32	11	151.17	152.07	50	0.07	100

0°-316ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	swims to 70cm at 0.38 but slowly pushed back down
4	
5	
6	
7	
8	swims at 20cm from 2.23 till 2.34
9	
10	
11	
12	
13	
14	
15	swims at 50cm from 7.32 to 7.40min then swims to 90cm and stays there from 7.47min to 7.55min where it swims to 100cm and is then slowly pushed back down
16	
17	Swims to 30cm with high speed but then slows down but continues sleeping to 60 cm and is then pushed to 0cm at 7.53min but swims to 10 cm at 7.57min. Is then pushed back down
18	fights at 95cm from 9.01min to 9.09
19	fights at 20 cm from 15.07min till 15.15min
20	fights at 40cm from 16.09 till 16.13
21	
22	
23	19.22 is push back to 20cm and then swims back to 40 cm at19.27 where it rests a bit and is then pushed back down
24	22.29min to 22.33 rests at top,
25	
26	2.47min to 2.53 swims at 20cm
27	swims very slowly till 60cm
28	swims at 20cm from 41.52min to 41.55min
29	From 11.07min to 11.24min rests at 20cm. 11.47min swims to 100cm and stays there till 11.50min and is then push to 70cm at 11.53min. 11.56min

	reaches top and stays till 12.00min
30	stays swimming at 30cm from 29.45min to 30.10min then slowly reaches 80cm at 30.32min and is then push back down
31	Reaches 20cm at 40.44min and stays swimming till 40.50min. 41.12min reaches 70cm and swims there till 41.19 min. 41.27 reaches bottom and swims to top at 41.52min and stays at rest here till 42.04min and is then push back down
32	49.52min till 49.59min stays at 20cm then reaches 100cm at 50.11min; stays there till 50.14min and is then push back 20cm at 50.24min till 50.26min which then swims to 80cm at 50.37min

0°-653ml/s experiment

date:	2015/5/14	water changed	18.35	
Combination	0°-653ml/s	fed	18:55	
starting time:	12:11			
ending time:	18:11			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	0	time for measurement		time for measurement
pH:	6.58	12:08	7.123	18:25
DO (mg/l):	7.75	12:08	6.96	18:25
EC (us/cm):	95.6	12:08	100.4	18:25
temperature (℃):	24.7	12:08	31	18:25
discharge (ml/s):	100.5			
velocity measured(m/s)	0.3			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5737.5	12:10		
water depth (cm):	15	12:10		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6693.75	12:10		
water depth (cm):	17.5	12:10		
tube condition				
lower tube water depth (cm):	4	12:10		
upper tube water depth (cm):	4	12:10		
middle section depth				
highest water depth (cm):	4	12:10		
lowest water depth (cm):	5.1	12:10		

0°-653ml/s, 6 hours analysis successful fishes

successful: 7	sex	age class	length (cm)	width (cm)	weight (g)
1	M	AD	10.5	1.0	5.10
2	M	JV	8.5	1.1	4.78
3	M	JV	8.0	1.0	2.94
4	F	JV	8.0	1.0	3.82
5	M	JV	8.0	0.5	3.32
6	F	JV	8.0	1.0	3.38
7	F	AD	11.0	1.2	7.70

0°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	10.5	2.26	2.47	21	0.09
2	11	2.47	3.03	16	0.06
3	8.5	5.23	5.36	13	0.09
4	8	7.04	7.31	27	0.06
5	8	8.37	9.04	27	0.04
6	8	33.29	33.48	19	0.05
7	11	38.21	38.36	15	0.10
8	11	55.10	56.03	53	0.10
9	8	121.17	121.43	26	0.04

0°-653ml/s, 3 hours analysis successful fishes continued

fish	observations
1	2.38min to 2.47min swims at top
2	
3	5.34min~5.36min swims at top
4	7.20~7.24min is push back to 70cm
5	
6	
7	38.32min reaches top and stays at rest till 38.35min
8	7.22min reaches 20cm where it swims till 7.27min.7.29min reaches 50cm and fights till 7.37min where it is push back to 30cm. 7.53min reaches top, but is push back to 40cm at 7.57mim. 8.03min reaches top and is push back to 80cm but swims back to the top
9	26.17min reaches top and stays there till 26.21min

0°-316ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	11	0.10	0.14	4	0.15	15
2	10.5	1.42	1.55	13	0.20	50
3	10.5	2.18	2.49	31	0.05	100
4	10	3.37	4.15	38	0.06	100
5	11	5.03	5.37	34	0.07	100
6	10.5	7.12	7.41	29	0.07	100
7	9	8.44	9.09	24	0.06	85
8	8.5	18.10	18.14	4	0.15	15
9	10	38.04	38.08	4	0.05	5

0°-316ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	
4	
5	7.27min to 7.36min swims at top
6	
7	9.02~9.06min swims at 50cm
8	
9	

3°-100ml/s experiment

date:	2015/3/7	water changed	18.35	
Combination	3°-100ml/s	fed	18:55	
starting time:	12:00			
ending time:	18:00			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	3	time for measurement		time for measurement
pH:	7.055	11:45	7.07	18:20
DO (mg/l):	6.5	11:45	6	18:20
EC (us/cm):	114	11:45	115	18:20
temperature (℃):	19.1	11:45	24.5	18:20
discharge (ml/s):	100			
velocity measured(m/s)	0.32			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5125.5	11:50		
water depth (cm):	13.4	11:50		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5890.5	11:50		
water depth (cm):	15.4	11:50		
tube condition				
lower tube water depth (cm):	1	11:50		
upper tube water depth (cm):	1	11:50		
middle section depth				
highest water depth (cm):	1	11:50		
lowest water depth (cm):	2	11:50		

3°-100ml/s, 6 hours analysis successful fishes

successful: 16	sex	age class	length (cm)	width (cm)	weight (g)
1	f	JV	8.5	1	3.91
2	m	JV	8.5	1	3.7
3	m	JV	8	1	3.43
4	m	JV	8.5	1.1	3.85
5	f	AD	11.5	1	6.77
6	f	JV	8.5	1.1	4.29
7	f	AD	11	1.2	5.86
8	m	AD	11	1.3	6.24
9	f	JV	8.5	1.1	4.05
10	f	AD	10.5	1.1	5.41
11	f	AD	10	1.3	7.58
12	f	AD	10	1.1	5.83
13	f	JV	8.5	1	4.36
14	m	JV	8	1	2.68
15	m	AD	11	1.1	5.66
16	m	JV	8.5	1	3.18

3°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	8	0.29	0.36	7	0.14
2	8	1.03	1.15	12	0.08
3	8.5	2.50	2.62	12	0.08
4	8.5	4.45	4.55	10	0.10
5	10	5.40	5.50	10	0.10
6	11.5	9.41	9.48	7	0.14
7	8.5	9.44	9.53	9	0.11
8	10	16.49	16.59	10	0.10
9	10.5	17.51	17.58	7	0.14
10	11	25.40	25.45	5	0.20
11	8.5	51.01	51.17	16	0.06
12	8.5	76.23	76.31	8	0.13
13	8.5	80.47	80.51	4	0.25
14	8.5	99.33	99.41	8	0.13
15	11	116.41	116.49	8	0.13
16	11	155.54	155.63	9	0.11

3°-100ml/s, 3 hours analysis successful fishes continued

fish	observations
1	
2	stayed on from 1:15 to 1:26 on the top part of the tube and then succeeded
3	
4	
5	
6	
7	
8	
9	
10	stayed on from 25:45 to 22:56 on the top part of the tube and then succeeded
11	
12	
13	
14	stayed on from 48:35 to 48:38 on the top part of the tube and then succeeded
15	
16	

3°-100ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	0.08	0.21	13	0.05	35
2	8.5	0.11	0.21	10	0.21	85
3	8.5	0.11	0.17	6	0.05	20
4	11	0.22	0.28	6	0.04	20
5	10	0.26	0.40	14	0.06	50
6	11	0.30	0.45	15	0.04	50
7	8	0.31	0.42	11	0.10	20
8	10.5	0.32	0.48	16	0.10	20
9	10	0.34	0.49	15	0.10	35
10	8	0.43	0.53	10	0.07	50
11	10	0.53	0.58	5	0.03	20
12	10	1.11	1.14	3	0.05	10
13	10	1.22	1.33	11	0.06	50
14	11	1.22	1.30	8	0.02	10
15	10.5	1.23	1.30	7	0.03	15
16	9.5	1.34	1.41	7	0.05	15
17	10	1.37	1.41	4	0.05	5
18	11.5	1.45	1.52	7	0.10	40
19	10.5	1.47	1.58	11	0.07	20
20	11	2.16	2.21	5	0.08	15
21	11	2.32	2.44	12	0.13	25
22	8	2.53	2.73	20	0.10	100
23	10	2.56	2.58	2	0.10	10
24	10.5	3.02	3.09	7	0.08	30
25	10	3.21	3.33	12	0.08	70
26	10	4.11	4.15	4	0.08	15
27	10	5.20	5.25	5	0.05	20
28	11.5	5.30	5.35	5	0.05	10
29	10	7.07	7.11	4	0.07	20
30	9.5	27.13	27.22	9	0.05	25
31	9	27.46	27.57	11	0.04	30
32	8.5	61.30	61.38	8	0.07	50
33	8	74.18	74.34	16	0.06	50
34	10.5	78.33	78.52	19	0.02	35
35	10	80.58	80.66	8	0.07	20

36	10	85.43	85.63	20	0.03	20
37	11	93.01	93.21	20	0.04	40

3°-100ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	fights in the bottom(5cm) from 0.16s to 0.21s
2	
3	stays at 15cm fighting for 4 s
4	
5	
6	
7	fights at 20cm for 7s
8	fights at 20cm for 9s
9	fights at 20cm for 9s
10	
11	
12	
13	
14	
15	
16	
17	fights at 5cm from 1.38s to 1.40s
18	
19	fights at 20cm from 1.50 to 1.53, then fights at 5 cm from 1.54s to 1.57s
20	
21	is push back to 5 cm where it fights from 2.34s to 2.39s where it swims to 30 cm
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	swims to 40cm and is then pushed at 23.19 down a bit to swim up to 50cm at 23.21

34	
35	stays at 5cm for a few seconds
36	stays fighting at 5cm from 34.45s to 34.57s
37	fights at 40cm from 42.05 to 42.07 at 42.08 is pushed to 30cm, swims a bit but is then pushed back down

3°-316ml/s experiment

date:	2015/3/5	water changed	18:50	
Combination	3°-316ml/s	fed	19:00	
starting time:	11:35			
ending time:	17:35			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	3	time for measurement		time for measurement
pH:	6.962	11:20	6.97	17:40
DO (mg/l):	7.1	11:20	6.8	17:40
EC (us/cm):	121.1	11:20	122	17:40
temperature (℃):	20.4	11:20	25.2	17:40
discharge (ml/s):	316			
velocity measured(m/s)	0.39			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	11:26		
water depth (cm):	14	11:26		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	11:26		
water depth (cm):	14	11:26		
tube condition				
lower tube water depth (cm):	2	11:26		
upper tube water depth (cm):	2	11:26		
middle section depth				
highest water depth (cm):	1.5	11:26		
lowest water depth (cm):	3	11:26		

successful: 14	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	8	1.1	2.82
2	F	JV	8.5	1.2	4.19
3	F	AD	10	1.5	7.35
4	F	JV	8.5	1.1	4.59
5	F	JV	8.5	1.1	3.79
6	M	JV	8.5	1.1	3.67
7	M	AD	10.5	1.2	5.38
8	M	JV	8.5	1.1	3.98
9	M	JV	8.5	1.1	3.45
10	M	AD	11.5	1.1	6.72
11	M	AD	11	1.2	6.46
12	M	JV	8.5	1.2	3.69
13	F	AD	10	1.3	6.13
14	M	AD	11	1.2	5.77

3°-316ml/s, 6 hours analysis successful fishes

3°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	8	7.55	7.59	4	0.25
2	10.5	8.54	8.64	10	0.10
3	10	15.46	15.61	15	0.07
4	8.5	23.05	23.1	5	0.20
5	8.5	28.08	28.22	14	0.07
6	11.5	33.44	33.49	5	0.20
7	8.5	36.17	36.32	15	0.07
8	8.5	39.22	39.33	11	0.09
9	11	40.00	40.09	9	0.11
10	10	41.24	41.47	23	0.04
11	10	49.26	49.32	6	0.17
12	8	70.17	70.28	11	0.09
13	10	73.25	73.33	8	0.13
14	10	127.32	127.47	15	0.07
15	8.5	295.04	295.07	3	0.33
16	11	334.26	334.33	7	0.14

17	8.5	335.08	335.12	4	0.25

3°-316ml/s, 3 hours analysis successful fishes continued

fish	observations
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	49.30pushed back a bit
12	
13	
14	
15	add 50.47(24)
16	
17	

3°-316ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	11	0.01	0.03	2	0.15	15
2	10	0.23	0.27	4	0.10	20
3	10	0.23	0.28	5	0.10	10
4	8	0.39	0.43	4	0.05	10
5	8.5	0.52	0.57	5	0.10	10
6	9	3.59	3.63	4	0.10	20
7	8.5	4.24	4.27	3	0.20	20
8	9.5	7.26	7.30	4	0.17	50
9	8	9.16	9.26	10	0.10	70
10	10.5	15.13	15.21	8	0.13	90
11	11	18.50	18.61	11	0.08	60
12	8	20.06	20.22	16	0.02	20
13	9.5	20.21	20.44	23	0.09	100
14	10	24.24	24.31	7	0.08	40
15	9	25.05	25.11	6	0.14	55
16	11.5	25.11	25.18	7	0.04	25
17	8.5	25.33	25.38	5	0.20	60
18	11.6	31.27	31.36	9	0.07	40
19	10	31.52	31.62	10	0.09	60
20	11	34.18	34.25	7	0.18	55
21	9	37.46	37.53	7	0.08	40
22	10	51.42	51.50	8	0.09	35
23	11	52.02	52.06	4	-	5
24	9	80.02	80.23	21	0.06	95
25	8	80.16	80.23	7	0.03	10
26	11	86.18	86.31	13	0.02	10
27	11	90.31	90.36	5	0.05	10
28	10	93.10	93.14	4	0.05	10
29	10.5	119.35	119.41	6	-	5
30	10	328.56	328.65	9	0.14	95

3°-316ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	
4	
5	stays at rest there
6	
7	
8	
9	
10	
11	
12	
13	swims to 100cm but is then push down to 30cm and swims back to 100cm at 20.37s but is then push back down to 0cm tries to swim back reaching30 cm at 20.42s but is then completely push back down
14	
15	
16	
17	
18	
19	
20	
21	
22	swims for 2 sec at 5cm before falling down
23	stays swimming at 5 cm from the start to the end
24	
25	
26	stays swimming at 10cm for 12s
27	
28	
29	stays swimming at 5cm
30	

date:	2015/3/9	water changed	18:00	
Combination	3°-653ml/s	fed	18:20	
starting time:	11:36			
ending time:	17:36			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	3	time for measurement		time for measurement
pH:	7.038	11:30	7.04	17:45
DO (mg/l):	6.2	11:30	5.8	17:45
EC (us/cm):	123.6	11:30	124.2	17:45
temperature (℃):	20.4	11:30	25.4	17:45
discharge (ml/s):	653			
velocity measured(m/s)	0.52			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6120	11:32		
water depth (cm):	16	11:32		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6732	11:32		
water depth (cm):	17.6	11:32		
tube condition				
lower tube water depth (cm):	3.5	11:32		
upper tube water depth (cm):	3	11:32		
middle section depth				
highest water depth (cm):	2	11:32		
lowest water depth (cm):	4	11:32		

3°-653 ml/s experiment

3°-653ml/s, 6 hours analysis successful fishes

successful: 12	sex	age class	length (cm)	width (cm)	weight (g)
1	M	AD	11.5	1.3	6.85
2	F	JV	8.5	1.1	3.85
3	M	JV	8	1.1	3.93
4	F	AD	10	1.4	7.66
5	M	JV	8	1.2	3.55
6	F	JV	8.5	1.1	4.04
7	M	AD	10.5	1.2	5.93
8	M	JV	8.5	1.1	3.6
9	M	JV	8	1.1	3.17
10	F	AD	10	1.3	6.02
11	M	JV	8	1.1	2.56
12	F	JV	8.5	1.1	3.9

3°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	8	2.53	2.63	10	0.10	
2	10	8.08	8.17	9	0.11	
3	8	8.26	8.34	8	0.13	
4	10	10.04	10.07	3	0.33	
5	11.5	13.43	13.49	6	0.17	
6	8	13.51	13.57	6	0.17	
7	10.5	14.17	14.23	6	0.17	
8	8	44.26	44.31	5	0.20	
9	8.5	44.48	44.55	7	0.14	
10	8.5	66.23	66.33	10	0.10	
11	8.5	103.37	103.44	7	0.14	
12	8.5	166.06	166.21	15	0.07	

3°-653 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	10	5.16	5.26	10	0.10	70	
2	11	5.52	5.59	7	0.11	55	
3	9	6.12	6.23	11	0.20	100	
4	9.5	8.02	8.07	5	0.07	20	
5	9	40.59	40.69	10	0.10	50	
6	10	98.48	98.57	9	0.17	100	
7	10	99.52	99.60	8	0.20	90	
8	11.5	103.05	103.16	11	0.04	30	
9	10	104.47	104.52	5	0.17	50	

6°-100ml/s experiment

date:	2015/3/17	water changed	17:40	
Combination	6°-100ml/s	fed	17:41	
starting time:	11:08			
ending time:	17:08			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	6	time for measurement		time for measurement
pH:	7.38	10:56	7.288	17:40
DO (mg/l):	6.2	10:56	5.8	17:40
EC (us/cm):	122.4	10:56	125.5	17:40
temperature (℃):	23.3	10:56	27.6	17:40
discharge (ml/s):	100			
velocity measured(m/s)	0.34			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5163.75	10:55		
water depth (cm):	13.5	10:55		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5737.5	10:55		
water depth (cm):	15	10:55		
tube condition				
lower tube water depth (cm):	1.5	10:55		
upper tube water depth (cm):	1	10:55		
middle section depth				
highest water depth (cm):	1	10:55		
lowest water depth (cm):	2	10:55		

6°-100ml/s, 6 hours analysis successful fishes

successful: 11	sex	age class	length (cm)	width (cm)	weight (g)
1	F	JV	8.5	1.2	3.93
2	M	JV	9.5	1.4	7.58
3	M	AD	11	1.3	5.90
4	M	AD	11.5	1.1	4.88
5	F	JV	8.5	1.2	3.85
6	M	AD	11.5	1.3	6.07
7	M	JV	8.5	1.1	2.66
8	F	JV	8.5	1.1	3.79
9	M	JV	9	1.1	3.42
10	M	JV	8.5	1.2	3.85
11	M	AD	10.5	1.3	5.82

6°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	8.5	2.25	2.28	3	0.33
2	9.5	2.57	2.73	16	0.06
3	11.5	4.00	4.07	7	0.14
4	11.5	7.32	7.37	5	0.20
5	10.5	10.07	10.21	14	0.07
6	8.5	12.34	12.48	14	0.07
7	8.5	16.17	16.27	10	0.10
8	11	23.28	23.38	10	0.10
9	11	47.13	47.22	9	0.25
10	10	93.17	93.22	5	0.20
11	9.5	150.30	150.4	10	0.10
12	8.5	180.17	180.2	6	0.17
13	9	204.39	204.4	4	0.25

6°-100ml/s, 3 hours analysis successful fishes continued

fish	observations
1	
2	
3	
4	
5	fights in the top for 2s
6	fights in the top for 5s
7	fights in the top for 2s
8	
9	12.25 is pushed back down to 60cm(12.28) but then swims up again
10	
11	fights a bit in the top for 3s
12	
13	

6°-100 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	1.23	1.28	5	0.30	60
2	8	6.31	6.37	6	0.02	10
3	11.5	7.18	7.34	16	0.09	95
4	8	9.08	9.16	8	0.05	10
5	9	9.48	9.57	9	0.05	10
6	10	10.23	10.29	6	0.05	20
7	11.5	10.47	10.56	9	0.06	40
8	8.5	11.28	11.36	8	0.03	20
9	11.6	24.39	24.64	25	0.05	20
10	8	26.51	26.66	15	0.13	80
11	11	31.11	31.21	10	0.10	30
12	10	47.10	47.23	13	0.07	50
13	8	64.03	64.13	10	0.04	30
14	10.5	95.13	95.27	14	0.48	95
15	10	99.11	99.21	10	0.27	80
16	11	104.29	104.35	6	0.38	75
17	8	126.28	126.34	6	0.28	85
18	11.5	128.48	128.55	7	0.30	90
19	9	131.47	131.54	7	0.40	80
20	10	139.18	139.25	7	0.43	85
21	10.5	140.52	140.63	11	0.02	10
22	11.5	143.17	143.23	6	0.35	70
23	11.5	165.00	165.13	13	0.08	50
24	10.5	192.40	192.51	11	0.18	95
25	10	199.30	199.37	7	0.45	90

6°-100 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	
4	stays resting at 10cm and then is pushed back 9.14
5	stays resting at 10cm and then is pushed back 9.55
6	
7	
8	
9	
10	
11	
12	
13	
14	reaches top at 8.02 and is push back to 30 cm, swims to 60 cm and is then push back down
15	
16	
17	
18	
19	
20	
21	stays at rest at 10cm till 1.32 and then is push down
22	
23	
24	fights for 1 s at 15cm and swims to 40cm where it fights for another second and then finally swims to the 95cm but is then pushed back down
25	

6°-316 ml/s experiment

date:	2015/3/11	water changed	18:40	
Combination	6°-316ml/s	fed	18:42	
starting time:	12:36			
ending time:	18:36			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	6	time for measurement		time for measurement
pH:	7.141	12:26	7.171	18:50
DO (mg/l):	7.8	12:26	5.7	18:50
EC (us/cm):	109	12:26	115.3	18:50
temperature (℃):	18.7	12:26	25.6	18:50
discharge (ml/s):	316			
velocity measured(m/s)	0.55			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5546.25	12:29		
water depth (cm):	14.5	12:29		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6120	12:29		
water depth (cm):	16	12:29		
tube condition				
lower tube water depth (cm):	3	12:29		
upper tube water depth (cm):	2	12:29		
middle section depth				
highest water depth (cm):	1.5	12:29		
lowest water depth (cm):	3	12:29		

6°-316ml/s, 6 hours analysis successful fishes

successful: 8	sex	age class	length (cm)	width (cm)	weight (g)
1	F	AD	10.5	1.4	5.42
2	F	JV	9	1.2	3.86
3	M	AD	11	1.5	6.35
4	F	JV	9	1.2	3.92
5	M	AD	12	1.5	6.89
6	F	JV	9	1.1	4.01
7	F	AD	10	1.2	5.66
8	M	JV	8.5	1	3.62

6°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	10	0.50	1.06	16	0.13
2	12	2.03	2.09	6	0.17
3	8.5	6.47	6.52	5	0.20
4	9	13.09	13.14	5	0.20
5	10.5	14.19	14.26	7	0.14
6	9	16.29	16.32	3	0.33
7	11	17.34	17.38	4	0.25
8	9	30.34	30.38	4	0.25
9	8	38.32	38.37	5	0.20
10	9	43.22	43.32	10	0.10
11	10	52.45	52.53	8	0.13

6°-316ml/s, 3 hours analysis successful fishes continued

fish	observations
1	swims to 80 cm at 0.56s but is then pushed back to 70 cm at 0.57 then swims up to 100cm at 1.01, is then pushed back to 60 cm at 1.02 and then swims up again entering at 1.06
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

6°-316 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	1.36	1.42	6	0.2	85
2	11.5	2.15	2.20	5	0.16	70
3	8.5	2.33	2.36	3	0.33	100
4	11	3.01	3.09	8	0.12	70
5	10	3.57	3.62	5	0.12	35
6	10	4.45	4.54	9	0.04	30
7	11.5	5.06	5.10	4	0.09	35
8	9.5	5.47	5.52	5	0.03	10
9	10	6.17	6.22	5	0.16	65
10	9	6.20	6.27	7	0.25	100
11	9.5	7.11	7.18	7	0.25	100
12	8	8.56	8.62	6	0.15	30
13	10	8.56	8.74	18	0.16	80
14	10	9.19	9.24	5	0.2	60
15	10	9.24	9.28	4	0.25	50
16	8	10.44	10.54	10	0.06	50
17	8	12.04	12.09	5	0.1	30
18	11.5	12.39	12.44	5	0.2	55

19	9	13.39	13.44	5	0.25	75
20	8.5	16.46	16.54	8	0.14	70
21	8.5	16.46	16.54	8	0.07	40
22	10	18.21	18.23	2	0.10	15
23	10	19.05	19.09	4	0.20	40
24	11.5	19.40	19.43	3	0.20	40
25	10	20.39	20.44	5	0.23	70
26	10	24.01	24.05	4	0.15	30
27	10.5	24.40	24.46	6	0.07	35
28	9.5	24.45	24.50	5	0.22	65
29	8	26.46	26.51	5	0.23	70
30	8	30.52	30.58	6	0.33	100
31	9	31.00	31.06	6	0.35	70
32	8	33.42	33.65	23	0.09	100
33	10	38.19	38.25	6	0.25	50
34	10	38.43	38.49	6	0.17	50
35	9	39.39	39.47	8	0.12	60
36	10	44.12	44.21	9	0.12	70
37	10.5	45.13	45.24	11	0.30	60
38	9.5	45.57	45.64	7	0.23	70
39	9	52.27	52.32	5	0.27	80

6°-316 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	succeeds at 2.36 but is immediately push back down, it fights at the top at 2.37 till 2.42 and is then pushed back down
4	fights at the bottom from 3.09to 3.15
5	
6	
7	
8	
9	
10	reaches the top and is then pushed back to 80cm at 6.24, swims back to top at 6.25 and is then pushed back down
11	
12	
13	Swims to 80 cm at 9.01 is then push back to 0 at 9.04 and then swims to 80cm at 9.07. Is pushed back to 10 cm at 9.10 but swims to 50 cm at 9.12 but is then pushed back down at 9.14
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	

31	
32	fights in the top from 33.53 to 34.01 and then falls back down
33	
34	reaches to 50cm at 38.46 and then is push down to 20cm where it fights for 2s and then is push back down
35	
36	reaches 60cm in 6s where it fights for 2 s and then swims to 70cm and is then pushed back down
37	at 45.16 it is at 10cm where it fights a bit and then swims to 50cm at 45.19s is then pushed back down but swims up again to 30cm at 45.22, then it is finally pushed back down
38	
39	

6°-653ml/s experiment

date:	2015/3/21	water changed	19:15	
Combination	6°-653ml/s	fed	19:20	
starting time:	12:18			
ending time:	18:18			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	6	time for measurement		time for measurement
pH:	7.604	12:10	7.617	18:39
DO (mg/l):	8.23	12:10	7.33	18:39
EC (us/cm):	117.6	12:10	122.2	18:39
temperature (℃):	24.2	12:10	30.7	18:39
discharge (ml/s):	653			
velocity measured(m/s)	0.69			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5622.75	11:56		
water depth (cm):	14.7	11:56		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6502.5	11:56		
water depth (cm):	17	11:56		
tube condition				
lower tube water depth (cm):	3	11:56		
upper tube water depth (cm):	3	11:56		
middle section depth				
highest water depth (cm):	2	11:56		
lowest water depth (cm):	4	11:56		

6°-653ml/s, 3 hours analysis successful fishes

successful: 12	sex	age class	length (cm)	width (cm)	weight (g)
1	F	JV	8.5	1	3.76
2	F	JV	8.5	1.1	3.59
3	M	AD	11.5	1.1	6.3
4	M	AD	11	1.2	5.7
5	M	JV	8.5	1.1	3.82
6	M	AD	10.5	1.2	5.53
7	F	JV	8.5	1.1	3.55
8	M	JV	8.5	1	3.35
9	M	JV	8	1	2.95
10	F	JV	9	1	3.76
11	F	AD	10.5	1.3	7.19
12	M	JV	8.5	1	3.24

6°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	10.5	1.41	1.47	6	0.17	
2	11.5	2.49	2.52	3	0.33	
3	10.5	4.23	4.29	6	0.17	
4	8	4.50	4.58	8	0.13	
5	11	9.27	9.3	3	0.33	
6	8.5	12.54	12.59	5	0.20	
7	8.5	15.50	15.53	3	0.33	
8	11	16.02	16.05	3	0.50	
9	8.5	32.26	32.38	12	0.08	
10	11	34.51	34.56	5	0.20	
11	12	49.21	49.26	5	0.20	
12	8.5	53.44	53.49	5	0.20	
13	9	57.39	57.46	7	0.14	
14	11.5	70.30	70.34	4	0.25	
15	8.5	88.13	88.17	4	0.25	
16	8.5	89.33	89.39	6	0.17	

6°-653 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min) (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	10	3.06	3.10	4	0.50	100	
2	10	3.30	3.35	5	0.15	30	
3	-	4.48	4.51	3	0.08	15	
4	10	38.57	38.61	4	0.07	20	
5	10	46.20	46.24	4	0.25	50	
6	11	52.05	52.11	6	0.18	70	

date:	2015/3/25	water changed	18:20	
Combination	10°-100ml/s	fed	18:12	
starting time:	11:17	use new pH DO and EC		
ending time:	17:17			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	10	time for measurement		time for measurement
pH:	7.277	11:15	7.416	17:30
DO (mg/l):	9.3	11:15	7.69	17:30
EC (us/cm):	117.3	11:15	121.9	17:30
temperature (℃):	19	11:15	28.1	17:30
discharge (ml/s):	100			
velocity measured(m/s)	0.43			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	11:17		
water depth (cm):	14	11:17		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5737.5	11:17		
water depth (cm):	15	11:17		
tube condition				
lower tube water depth (cm):	1.5	11:17		
upper tube water depth (cm):	1.5	11:17		
middle section depth				
highest water depth (cm):	1	11:17		
lowest water depth (cm):	2	11:17		

10°-100ml/s experiment

10°-100ml/s, 3 hours analysis successful fishes

successful: 11	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	8.5	1	3.36
2	M	JV	9	1	3.32
3	M	JV	8	1	2.25
4	M	AD	11	1.1	5.66
5	F	JV	8.5	1	3.75
6	F	JV	8.5	1	3.65
7	M	JV	8.5	1.1	3.18
8	F	AD	10.5	1.3	7.43
9	F	JV	8.5	1	3.61
10	F	AD	11	1	5.5
11	M	JV	8.5	1	4.12

10°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)
1	8	7.25	7.29	4	0.25
2	10.5	51.48	51.52	4	0.25
3	8.5	58.23	58.31	8	0.17
4	10.5	91.23	91.28	5	0.25
5	10	93.22	93.27	5	0.20
6	11	95.12	95.21	9	0.15
7	8.5	104.42	104.49	7	0.14
8	11	229.1	229.16	6	0.50
9	9	264.35	264.47	12	0.10
10	8.5	265.54	265.63	9	0.25
11	8.5	289.57	289.60	3	0.33
12	10	307.58	307.60	2	0.33
13	8	321.33	321.36	3	0.33
14	9	340.34	340.37	3	0.33

10°-100ml/s, 3 hours analysis successful fishes continued

fish	observations
1	
2	
3	fights in the top from 12.54 to 12.56
4	fights in the top from 0.17 till 0.19
5	
6	40.02 is push back down but 40.04 climbs a bit and stays at rest at 40.06. At 40.09 it climbs up again succeeding
7	
8	Is push back down at 1.18 to 90cm at 1.19 but climbs up again
9	fights in the top from 11.15 till 11.18
10	12.28 is push down to 80cm and swims up again at 12.31
11	
12	
13	
14	

10°-100 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	8	0.10	0.15	5	0.18	70
2	11	0.54	0.57	3	0.10	10
3	10	1.00	1.03	3	0.15	30
4	8.5	1.36	1.52	16	0.13	100
5	-	2.02	2.04	2	-	10
6	10.5	5.57	5.63	6	0.25	50
7	9	7.47	7.57	10	0.1	70
8	11	8.06	8.11	5	0.25	50
9	11.5	12.56	12.64	8	0.17	50
10	11	17.44	17.59	15	0.2	20
11	10.5	17.47	17.55	8	0.3	30
12	10	17.47	17.58	11	0.17	30
13	11.6	20.15	20.25	10	0.2	70
14	-	23.46	23.55	9	-	5
15	11	24.15	24.26	11	0.12	90
16	10	27.06	27.15	9	0.33	100
17	9.5	36.21	36.26	5	0.2	40
18	11.5	38.28	38.38	10	0.13	80
19	9.5	42.56	42.65	9	0.17	100
20	9	48.59	48.69	10	0.19	85
21	10	64.53	64.61	8	0.13	50
22	10.5	79.14	79.21	7	0.25	50
23	9	94.48	94.51	3	0.10	95
24	10	95.26	95.34	8	0.30	30
25	11	102.42	102.5	10	0.40	100
26	8	117.32	117.4	3	0.15	30
27	10	120.11	120.2	5	0.15	20
28	10	124.09	124.2	10	0.20	70
29	8.5	135.55	135.6	4	0.20	20
30	10.5	150.21	150.2	2	0.20	20
31	9.5	165.47	165.5	5	0.23	70
32	11	191.32	191.4	6	0.17	50
33	10	208.10	208.2	12	0.08	60
34	10.5	214.22	214.3	5	0.25	50

35	9	228.28	228.3	3	0.25	50
36	8.5	261.33	261.4	4	0.25	50
37	10.5	265.12	265.1	2	0.40	40
38	10	281.58	281.6	3	0.30	60
39	10.5	282.30	282.4	12	0.09	60
40	11.5	284.44	284.5	5	0.20	60
41	10	286.43	286.5	4	0.40	40

10°-100 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	17.54 swims back to 30 cm but is then push back again
12	
13	20.17 stays resting at 40 cm and at 20.19 swims to 70 cm
14	
15	
16	
17	
18	
19	
20	3.30 fights at 60cm till 3.32
21	fights at 50 cm from 19.22 till 19.25 and is then push back down
22	fights at 50cm from 33.41 till 33.45
23	
24	it's push back at 4.19 and swims back to 30cm at 4.21
25	at 11.33 it stops for a bit at 40cm, continues swimming until 60cm where it stops a gain for a bit and then swims to the top where it fights from 11.37 till 11.38
26	
27	
28	33.01 fights at 20 cm till 33.03 and then swims to 60cm where it fights from 33.04 till 33.06, after that it is pushed back down
29	
30	13.38 starts to fight in the bottom then climbs back to 20cm at 13.41 and is then pushed back down
31	
32	

33	fights at 60cm from 25.58 to 26.00 then falls down
34	
35	
36	
37	
38	
39	fights at 60cm from 9.07 till 9.10, is then pushed back down
40	
41	

10°-316 ml/s experiment

date:	2015/3/23	water changed	18:40	
Combination	10°-316ml/s	fed	18:40	
starting time:	12:07	use new pH DO and EC		
ending time:	18:07			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	10	time for measurement		time for measurement
pH:	7.84	12:00	7.95	18:20
DO (mg/l):	8.82	12:00	7.3	18:20
EC (us/cm):	105.8	12:00	109.9	18:20
temperature (℃):	21.4	12:00	28.3	18:20
discharge (ml/s):	316			
velocity measured(m/s)	0.68			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	12:05		
water depth (cm):	14	12:05		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6120	12:05		
water depth (cm):	16	12:05		
tube condition				
lower tube water depth (cm):	2	12:05		
upper tube water depth (cm):	2	12:05		
middle section depth				
highest water depth (cm):	1.5	12:05		
lowest water depth (cm):	3	12:05		

successful: 7	sex	age class	length (cm)	width (cm)	weight (g)

10°-316ml/s, 6 hours analysis successful fishes

1	F	JV	9	1.1	3.65
2	F	AD	11	1	5.44
3	F	JV	8.5	1	3.66
4	M	JV	8	1	3.85
5	M	JV	8.5	1	3.45
6	M	AD	11	1.1	5.59
7	M	JV	8.5	1	3.3

10°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	10	1.34	1.39	5	0.20	
2	9	100.39	100.44	5	0.20	
3	11	100.39	100.46	7	0.14	
4	9	101.42	101.46	4	0.25	
5	8	109.21	109.28	7	0.14	
6	11	126.55	126.60	5	0.20	
7	11	152.37	152.41	4	0.25	
8	8.5	155.39	155.43	4	0.25	
9	11.5	179.44	179.48	4	0.33	
10	10.5	185.20	185.28	8	0.33	40.05~40.09 fights at the top
11	10	211.18	211.21	3	0.33	
12	8.5	232.38	232.45	7	0.14	
13	8.5	266.44	266.50	6	0.17	

10°-316 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	9.5	1.46	1.51	5	0.35	70	
2	10	3.01	3.05	4	0.35	70	
3	12	3.23	3.26	3	0.50	50	
4	10	96.56	96.64	8	0.16	95	
5	10	99.24	99.26	2	0.30	30	
6	10.5	104.15	104.17	2	0.60	60	
7	11.5	111.36	111.41	5	0.50	50	
8	11	112.02	112.07	5	0.13	40	
9	11.5	113.16	113.19	3	0.40	40	
10	10.5	115.36	115.38	2	0.50	50	
11	11	117.18	117.24	6	0.33	100	
12	10	117.28	117.32	4	0.40	40	
13	11	120.21	120.29	8	0.13	85	
14	10.5	124.24	124.31	7	0.21	85	
15	11.5	124.35	124.39	4	0.35	70	
16	11	131.52	131.54	2	0.40	40	
17	11.5	136.29	136.31	2	0.50	50	
18	11	147.36	147.38	2	0.60	60	
19	10.5	148.27	148.31	4	0.12	35	
20	8	150.15	150.17	2	0.20	20	
21	11.5	151.49	151.51	2	0.40	40	
22	11	152.15	152.18	3	0.30	60	
23	10	158.28	158.30	2	0.25	25	
24	10	158.44	158.47	3	0.35	70	
25	10	175.46	175.49	3	0.30	30	
26	11	179.00	179.03	3	0.30	60	
27	10.5	186.42	186.45	3	0.60	60	
28	11	193.48	193.51	3	0.30	60	
29	10.5	207.14	207.17	3	0.38	75	
30	11	218.49	218.51	2	0.50	50	
31	11.5	238.07	238.16	9	0.17	85	
32	11	265.08	265.11	3	0.60	60	

10°-653ml/s experiment

date:	2015/3/27	water changed	18:00	
Combination	10°-653ml/s	fed	18:05	
starting time:	10:58	use new pH DO and EC		
ending time:	16:58			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	10	time for measurement		time for measurement
pH:	7.145	10:50	7.529	17:19
DO (mg/l):	9.12	10:50	7.88	17:19
EC (us/cm):	113.2	10:50	116.2	17:19
temperature (℃):	19.3	10:50	29	17:19
discharge (ml/s):	653			
velocity measured(m/s)	0.91			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5737.5	10:58		
water depth (cm):	15	10:58		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6693.75	10:58		
water depth (cm):	17.5	10:58		
tube condition				
lower tube water depth (cm):	3	10:58		
upper tube water depth (cm):	3	10:58		
middle section depth				
highest water depth (cm):	2	10:58		
lowest water depth (cm):	4	10:58		

10°-653ml/s, 6 hours analysis successful fishes

successful: 2	sex	age class	length (cm)	width (cm)	weight (g)
1	F	AD	10.5	1.3	7.57
2	F	JV	9	1	3.64

10°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	11	4.00	4.04	5	0.20	
2	12	4.54	5.00	6	0.17	
3	9.5	5.59	6.03	4	0.25	
4	11.5	19.57	20.01	4	0.25	
5	9	28.06	28.15	9	0.11	
6	9	31.02	31.07	5	0.33	
7	11	31.27	31.33	6	0.17	
8	11.5	43.39	43.44	5	0.20	
9	12	49.17	49.19	2	0.50	

10°-653 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	11	15.17	15.22	5	0.30	90	
2	10.5	34.21	34.25	2	0.60	60	
3	11.5	42.08	42.13	5	0.50	95	
4	8	43.23	43.26	3	0.50	50	

12°-100ml/s experiment

date:	2015/3/31	water changed	18:10
Combination	12°-100ml/s	fed	18:10
starting time:	11:18	use new pH DO and EC	
ending time:	17:18		
number of ad males:	5		
number of ad females:	5		
number of jv males:	5		
number of jv females:	5		
total number of fishes:	20		
angle (°):	12	time for measurement	
pH:	7.251	11:12	7.137
DO (mg/l):	8.08	11:12	6.84
EC (us/cm):	105.5	11:12	114
temperature (℃):	23.1	11:12	33.6
discharge (ml/s):	100		
velocity measured(m/s)	0.48		
lower box			
length (cm):	45		
width (cm):	8.5		
volume (cm^3)	5316.75	11:14	
water depth (cm):	13.9	11:14	
upper box			
length (cm):	45		
width (cm):	8.5		
volume (cm^3)	5928.75	11:14	
water depth (cm):	15.5	11:14	
tube condition			
lower tube water depth (cm):	1.5	11:14	
upper tube water depth (cm):	1.5	11:14	
middle section depth			
highest water depth (cm):	1	11:14	
lowest water depth (cm):	2	11:14	

successful: 3	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	8	1.1	2.61
2	F	AD	10.5	1.4	7.28
3	F	JV	8.5	1.1	3.52

12°-100ml/s, 6 hours analysis successful fishes

12°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	8	7.02	7.06	4	0.25	
2	10.5	29.02	29.10	8	0.13	
3	8.5	45.17	45.20	3	0.33	
4	11.5	87.45	87.49	4	0.33	31.37~31.39 fights in the top
5	11.5	133.09	133.13	4	0.25	20.52 fights in the top till 20.53
6	11.5	148.17	148.31	14	0.50	35.58~35.60 fights at 60cm, 36.04 reaches bottom, 36.06 swims to 60cm and is pushed down again/36.09 swims up to the top

12°-100 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	11	3.29	3.32	3	0.40	40
2	11.5	5.19	5.22	3	0.45	45
3	10	5.32	5.45	13	0.14	85
4	10	7.56	7.64	8	0.35	70
5	12	8.00	8.02	2	0.10	10
6	10	11.13	11.17	4	0.23	70
7	11.5	12.02	12.06	4	0.50	100
8	10	13.18	13.24	6	0.13	50
9	10.5	19.24	19.32	8	0.33	100
10	10	19.32	19.40	8	0.15	90
11	8	20.16	20.29	13	0.25	100
12	10	20.30	20.33	3	0.30	90
13	12	23.45	23.53	8	0.19	75
14	10	26.35	26.43	8	0.14	70
15	11	27.21	27.32	11	0.45	90
16	10	27.40	27.46	6	0.15	60
17	10.5	29.09	29.14	5	0.35	70
18	11.5	29.45	29.53	8	0.30	60
19	11	32.16	32.20	4	0.30	30
20	11	35.34	35.37	3	0.25	25
21	11	37.09	37.11	2	0.18	90
22	11.5	37.34	37.41	7	0.25	100
23	10.5	38.59	38.64	5	0.33	100
24	10	39.07	39.09	2	0.30	30
25	11	55.20	55.34	14	0.15	100
26	10	64.18	64.22	4	0.30	60
27	11	67.38	67.46	8	0.33	100
28	10	68.06	68.18	12	0.50	100
29	10.5	72.48	72.51	3	0.30	30
30	10	78.14	78.23	9	0.10	70
31	11	82.40	82.43	3	0.25	25
32	9	86.34	86.36	2	0.25	50

33	10	87.30	87.36	6	0.13	50
34	10	89.56	89.68	12	0.20	100
35	10	91.45	91.52	7	0.23	70
36	11.5	96.12	96.18	6	0.20	70
37	10	105.05	105.13	8	0.20	100
38	11	105.52	105.65	13	0.40	100
39	10	121.40	121.46	6	0.33	100
40	9.5	124.23	124.29	6	0.35	70
41	10	125.27	125.31	4	0.10	20
42	10	126.23	126.30	7	0.23	70
43	10	158.49	158.55	6	0.50	50
44	9	193.31	193.40	9	0.20	100

12°-100 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	
3	5.39~5.40 falls to 70cm, 5.42 swims to 80cm
4	
5	reaches 10cm but is hit by coming down fish and goes back to lower tank
6	
7	12.02 fights a bit in the top
8	
9	
10	
11	20.20 is pushed back to 70cm where it fights from 20.22~20.23/20.28~20.30 rests at 10cm
12	
13	
14	
15	27.23~27.25 fights at 80cm, 27.26 swims back to 90cm
16	
17	
18	29.47 fights at 30cm,29.49 falls to 0cm , 29.49~29.51 swims to 60cm
19	
20	
21	
22	
23	
24	
25	55.24 reaches 40cm and is push down a bit,55.24~55.28 swims to 100cm/55.28~55.29 fights in the top
26	
27	11.31~11.33 fish fights at the top
28	12.01 falls to bottom and then swims to 80cm at 12.05 and then falls down
29	
30	20.06 fights a bit at 30cm, 20.10 fights a bit at 70cm
31	
32	

33	
34	33.51~33.53 fights at the top
35	
36	40.04 makes a short stop at 30cm, then swims to 70cm at 40.06
37	
38	3.34 stops at 80cm and then swims to 100cm/3.35~3.40 fights at 100cm/3.40~3.43 fights at 85cm
39	
40	
41	
42	
43	
44	

date:	2015/3/29	water changed	17:35	
Combination	12°-316ml/s	fed	17:37	
starting time:	11:10	use new pH DO and EC		
ending time:	17:10			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	12	time for measurement		time for measurement
pH:	7.213	11:05	7.368	17:19
DO (mg/l):	9.08	11:05	7.33	17:19
EC (us/cm):	110.5	11:05	113.2	17:19
temperature (℃):	19.1	11:05	30.6	17:19
discharge (ml/s):	316			
velocity measured(m/s)	0.75			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	11:06		
water depth (cm):	14	11:06		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6311.25	11:06		
water depth (cm):	16.5	11:06		
tube condition				
lower tube water depth (cm):	2	11:06		
upper tube water depth (cm):	2	11:06		
middle section depth				
highest water depth (cm):	1.5	11:06		
lowest water depth (cm):	3	11:06		

successful: 2	sex	age class	length (cm)	width (cm)	weight (g)
1	M	AD	11	1.4	5.69
2	M	JV	9	1.2	3.29

12°-316ml/s, 6 hours analysis successful fishes

12°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	11	101.28	101.32	4	0.25	
2	11.5	110.47	110.52	5	0.25	
3	9	153.48	153.51	3	0.5	3.3~3.36 fights at the top

12°-316 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	7.03	7.06	3	0.15	30
2	9	10.32	10.39	7	0.25	50
3	9	12.26	12.28	2	0.10	20
4	11	12.43	12.45	2	0.10	15
5	10.5	14.55	14.61	6	0.50	50
6	11	15.37	15.40	3	0.25	25
7	11.5	17.15	17.18	3	0.45	45
8	10.5	20.41	20.44	3	0.30	30
9	10	22.07	22.13	6	0.20	20
10	10	22.35	22.38	3	0.20	40
11	11	24.29	24.33	4	0.30	30
12	10.5	25.21	25.23	2	0.05	5
13	11	25.25	25.31	6	0.20	20
14	11	26.34	26.36	2	0.30	30
15	10.5	28.25	28.34	9	0.24	95
16	11	28.40	28.42	2	0.15	15
17	10	28.45	28.51	6	0.30	30
18	11	29.21	29.23	2	0.35	35
19	10	32.39	32.42	3	0.25	25
20	8	33.30	33.37	7	0.14	70
21	11	36.05	36.12	7	0.14	70
22	11.5	37.56	37.59	3	0.23	45
23	10	38.43	38.48	5	0.23	70
24	11	44.20	44.22	2	0.40	40
25	10	45.11	45.15	4	0.20	60
26	9	46.09	46.14	5	0.23	70
27	10	48.39	48.41	2	0.30	30
28	10	55.17	55.19	2	0.20	20
29	10.5	156.24	156.29	5	0.20	60
30	11	161.27	161.30	3	0.30	30
31	10.5	163.31	163.35	4	0.17	50
32	11	164.34	164.39	5	0.33	65
33	11	182.27	182.29	2	0.20	20
34	11.5	182.27	182.32	5	0.25	75

35	10	185.07	185.09	2	0.15	15
36	11	196.37	196.44	7	0.30	40
37	10.5	198.05	198.07	2	0.60	60
38	11	211.56	211.59	3	0.35	70
39	10	211.56	211.63	7	0.23	90

12°-316 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	10.35~10.38 fights at 50cm
3	
4	
5	14.56~14.58~fights at 50cm
6	
7	
8	
9	22.08~22.12 fights at 20cm
10	
11	22.30~22.32 fights at 30cm
12	
13	25.29 reaches 20cm but is then pushed back down/swims back to 20cm at 25.31
14	
15	28.30~28.31 fights at 95cm
16	
17	28.46~28.51 fights at 5cm
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	6.12~6.13 fights at 60cm
30	
31	
32	14.21~14.23 fights at 65cm
33	
34	

35	
36	46.23~46.24 is pushed from 30cm to 0cm/45.25~45.26 swims to 30cm
37	
38	
39	11.39~11.42 fights at 90cm

12°-653ml/s experiment

date:	2015/4/2	water changed	20:00	
Combination	12°-653ml/s	fed	20:06	
starting time:	13:30	use new pH DO and EC		
ending time:	19:30			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	12	time for measurement		time for measurement
pH:	7.155	13:25	7.254	19:36
DO (mg/l):	8.15	13:25	7.59	19:36
EC (us/cm):	109.4	13:25	114.9	19:36
temperature (℃):	25.3	13:25	31	19:36
discharge (ml/s):	653			
velocity measured(m/s)	1			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5737.5	13:23		
water depth (cm):	15	13:23		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6885	13:23		
water depth (cm):	18	13:23		
tube condition				
lower tube water depth (cm):	3	13:23		
upper tube water depth (cm):	3	13:23		
middle section depth				
highest water depth (cm):	2	13:23		
lowest water depth (cm):	4	13:23		

12°-653ml/s, 6 hours analysis successful fishes

successful: 0	sex	age class	length (cm)	width (cm)	weight (g)

12°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	11	3.30	3.34	4	0.33	3.33~3.34 fights at the top
2	12	5.38	5.41	3	0.50	5.40~5.41 fights at the top
3	9	13.44	13.47	3	0.50	
4	9.5	15.35	15.38	3	0.50	
5	10	73.34	73.37	3	0.33	

12°-316 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	10	2.06	2.11	5	0.4	80	
2	11.5	116.37	116.42	5	0.1	40	

15°-100ml/s experiment

date:	2015/4/6	water changed	19:53	
Combination	15°-100ml/s	fed	19:52	
starting time:	13:17	use new pH DO and EC		
ending time:	19:17			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	15	time for measurement		time for measurement
pH:	7.039	13:10	7.213	19:28
DO (mg/l):	7.69	13:10	6.9	19:28
EC (us/cm):	112.4	13:10	118.9	19:28
temperature (℃):	27.1	13:10	32.8	19:28
discharge (ml/s):	100			
velocity measured(m/s)	0.57			
Froude's number (Fr)	0.00000			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	13:11		
water depth (cm):	14	13:11		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5890.5	13:11		
water depth (cm):	15.4	13:11		
tube condition				
lower tube water depth (cm):	1.5	13:11		
upper tube water depth (cm):	1.5	13:11		
middle section depth				
highest water depth (cm):	1	13:11		
lowest water depth (cm):	2	13:11		

15°-100ml/s, 6 hours analysis successful fishes

successful: 3	sex	age class	length (cm)	width (cm)	weight (g)
1	F	JV	9	1	3.33
2	M	JV	8.5	1	3.24
3	M	JV	8.5	1	2.44

15°-100ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	8.5	3.57	3.60	3	0.33	
2	8.5	26.16	26.19	3	0.33	
3	10	67.29	67.32	3	0.33	
4	9	129.10	129.13	3	0.33	

15°-100 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	5.55	5.58	3	0.10	20
2	10.5	6.42	6.58	16	0.23	70
3	9	6.45	6.47	2	0.10	10
4	8	7.11	7.14	3	0.05	10
5	11.5	9.02	9.10	8	0.20	60
6	8.5	10.10	10.16	6	0.50	100
7	8.5	11.06	11.14	8	0.25	70
8	8.5	11.58	11.65	7	0.30	70
9	9	15.12	15.19	7	0.33	100
10	8	16.56	16.59	3	0.10	10
11	10	18.57	18.64	7	0.27	80
12	11	19.31	19.34	3	0.20	40
13	10.5	20.55	20.57	2	0.05	10
14	10	21.52	21.58	6	0.27	80
15	11.5	23.45	23.56	11	0.27	80
16	9	24.00	24.08	8	0.25	100
17	9.5	26.18	26.25	7	0.33	100
18	10	28.34	28.50	16	0.33	100
19	11.5	30.17	30.53	36	0.20	80
20	9	31.04	31.08	4	0.23	70
21	9.5	35.16	35.22	6	0.33	100
22	10	37.05	37.09	4	0.40	80
23	8.5	38.29	38.38	9	0.25	50
24	10	40.56	40.64	8	0.33	100
25	9.5	48.05	48.12	7	0.20	100
26	11.5	49.25	49.30	5	0.27	80
27	10	52.58	52.63	5	0.07	20
28	11	55.03	55.09	6	0.40	80
29	10.5	55.12	55.15	3	0.20	40
30	11	66.11	66.24	13	0.07	35
31	10	74.13	74.19	6	0.15	60
32	8.5	75.44	75.47	3	0.35	35
33	11	87.10	87.18	8	0.23	90
34	10.5	92.10	92.14	4	0.18	55

35	10	94.20	94.25	5	0.40	80
36	10	94.37	94.41	4	0.30	30
37	11	94.53	94.57	4	0.35	70
38	11.5	97.27	97.43	16	0.50	100
39	9.5	103.39	103.46	7	0.25	100
40	12	108.44	108.49	5	0.45	90
41	9.5	120.46	120.54	8	0.13	65
42	10	122.24	122.27	3	0.40	40
43	10.5	129.90	129.94	4	0.40	40

15°-100 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	
2	falls to the bottom at 6.48 but then swims to 30cm at 6.52/fights at the bottom from 6.53 till 6.58
3	
4	
5	9.06 reaches bottom but swims up to 35cm at 9.08 and then falls down
6	10.15 is push back down exiting at 10.17
7	11.08-11.09 fights at 50cm
8	12.00~12.01 fights at 60cm and then swims to 70cm
9	15.06 is push back down exiting at 15.09
10	
11	
12	
13	
14	
15	23.53~23.56 fights at the bottom
16	
17	
18	
19	30.25~30.53 fights at the bottom
20	
21	
22	
23	38.35is push to bottom and swims up to 25cm at 38.36
24	
25	
26	
27	
28	
29	
30	8.59~9.05 fights at the bottom
31	
32	
33	
34	

35	
36	
37	
38	40.15~40.18 fights at the bottom/40.18~40.21 swims to top and is then pushed back down
39	46.23 is push back down exiting at 46.27
40	
41	
42	
43	

15°-316ml/s experiment

date:	2015/4/4	water changed	18:00	
Combination	15°-316ml/s	fed	18:01	
starting time:	11:32	use new pH DO and EC		
ending time:	17:32			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	15	time for measurement		time for measurement
pH:	7.123	11:32	7.199	17:42
DO (mg/l):	8.03	11:32	7.27	17:42
EC (us/cm):	113.3	11:32	116.5	17:42
temperature (°C):	26.4	11:32	32.6	17:42
discharge (ml/s):	316	11:32		
velocity measured(m/s)	0.93			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	5355	11:31		
water depth (cm):	14	11:31		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6311.25	11:31		
water depth (cm):	16.5	11:31		
tube condition				
lower tube water depth (cm):	2	11:31		
upper tube water depth (cm):	2	11:31		
middle section depth				
highest water depth (cm):	1.5	11:31		
lowest water depth (cm):	3	11:31		

15°-316ml/s, 6 hours analysis successful fishes

successful: 1	sex	age class	length (cm)	width (cm)	weight (g)
1	M	JV	8.5	1	3.82

15°-316ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	8.5	3.43	3.46	3	0.33	
2	10	32.22	32.25	3	0.33	
3	11.5	33.07	33.11	4	0.25	

15°-316 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)	observations
1	10.5	0.37	0.39	2	0.40	40	
2	10	3.48	3.53	5	0.23	90	
3	10	6.44	6.46	2	0.30	60	
4	10	9.02	9.09	7	0.27	80	
5	11	11.51	11.57	6	0.25	100	
6	11.5	15.31	15.37	6	0.50	100	
7	10.5	15.42	15.45	3	0.20	40	
8	11	16.51	16.54	3	0.60	60	
9	9.5	26.11	26.14	3	0.50	50	
10	11	31.17	31.19	2	0.15	30	
11	11.5	35.54	35.56	2	0.20	20	
12	11	37.08	37.09	1	0.13	25	
13	11	37.14	37.23	9	0.20	60	
14	10.5	43.11	43.13	2	0.30	30	
15	10	58.19	58.23	4	0.13	40	
16	10	58.30	58.33	3	0.25	50	
17	12	60.56	60.60	4	0.27	80	

15°-653ml/s experiment

date:	2015/4/8	water changed	18:36	
Combination	15°-653ml/s	fed	18:37	
starting time:	12:06			
ending time:	18:06			
number of ad males:	5			
number of ad females:	5			
number of jv males:	5			
number of jv females:	5			
total number of fishes:	20			
angle (°):	15	time for measurement		time for measurement
pH:	7.231	12:01	7.357	18:15
DO (mg/l):	8.8	12:01	7.91	18:15
EC (us/cm):	114.6	12:01	118.1	18:15
temperature (℃):	21.6	12:01	28.6	18:15
discharge (ml/s):	653			
velocity measured(m/s)	1.06			
lower box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6120	12:03		
water depth (cm):	16	12:03		
upper box				
length (cm):	45			
width (cm):	8.5			
volume (cm^3)	6885	12:03		
water depth (cm):	18	12:03		
tube condition				
lower tube water depth (cm):	3.5	12:03		
upper tube water depth (cm):	3.5	12:03		
middle section depth				
highest water depth (cm):	2	12:03		
lowest water depth (cm):	4	12:03		

15°653ml/s, 6 hours analysis successful fishes

successful: 1	sex	age class	length (cm)	width (cm)	weight (g)
1	M	AD	10.5	1	5.35

15°-653ml/s, 3 hours analysis successful fishes

fish	length (cm)	time entered (min)	time for success (min)	time used (min)	velocity(m/s)	observations
1	8	35.43	35.47	4	0.25	
2	10.5	83.1	83.14	4	0.25	

15°-653 ml/s, 3 hours analysis failing fishes

try but failed	length (cm)	time entered (min)	time exit (min)	time used (min)	velocity(m/s)	distance travel before failure (cm)
1	10	8.05	8.08	3	0.20	15
2	11	11.59	11.67	8	0.23	70
3	12	12.43	12.44	1	0.30	40
4	11.5	14.46	14.47	1	0.10	10
5	11	18.33	18.35	2	0.40	40
6	10.5	18.46	18.5	4	0.30	60
7	10	20.00	20.05	5	0.10	10
8	11	20.33	20.35	2	0.20	40
9	11.5	22.56	22.57	1	0.30	30
10	11.5	24.47	24.49	2	0.35	35
11	11	30.41	30.42	1	0.70	35
12	10.5	31.51	31.56	5	0.30	60
13	11	34.16	34.17	1	0.20	20
14	10	38.16	38.18	2	0.10	10
15	10	44.35	44.4	5	0.20	80
16	10.5	49.80	49.82	2	0.35	35
17	11.5	56.51	56.53	2	0.60	60
18	10	85.54	85.55	1	0.40	40
19	10	90.10	90.16	6	0.08	40
20	11	91.53	91.55	2	0.35	35

15°-653 ml/s, 3 hours analysis failing fishes continued

try but failed	observations
1	fights at 15cm from 8.06 till 8.08
2	
3	
4	
5	
6	
7	20.01~20.05 fights at the bottom
8	
9	
10	
11	
12	31.53~31.55 fights at 60cm
13	
14	
15	
16	
17	
18	
19	
20	

Water velocity (m/s) for the combination of angles and discharges.

Angle (°)	discharge 100 (ml/s)	discharge 316 (ml/s)	discharge 653 (ml/s)
0°	0.10	0.20	0.30
3°	0.32	0.39	0.52
6°	0.34	0.55	0.69
10°	0.43	0.68	0.91
12°	0.48	0.75	1.00
15°	0.57	0.93	1.06

Success percentage and average velocity of migrating fishes.

Angle (°)	discharge	velocity m/s	max success percentage	Percentage of success AD (%):	Percentage of success JV (%):	fish real swimming velocity (m/s)	Fish velocity (m/s)	AD fish velocity (m/s)	JV fish velocity (m/s)
0	100	0.10	55	40	10	0.17	0.07	0.07	0.17
3	100	0.32	80	70	90	0.45	0.13	0.13	0.12
6	100	0.34	45	50	40	0.49	0.15	0.15	0.14
10	100	0.43	30	40	20	0.64	0.21	0.21	0.21
12	100	0.48	15	40	20	0.77	0.29	0.30	0.29
15	100	0.57	20	10	30	0.90	0.33	0.33	0.33
0	316	0.20	25	60	50	0.33	0.13	0.17	0.07
3	316	0.39	70	80	60	0.51	0.12	0.11	0.13
6	316	0.55	50	50	60	0.74	0.19	0.16	0.21
10	316	0.68	30	30	30	0.87	0.19	0.18	0.20
12	316	0.75	30	20	10	1.08	0.33	0.25	0.50
15	316	0.93	15	20	10	1.23	0.30	0.29	0.33
0	653	0.30	45	40	50	0.37	0.07	0.09	0.06
3	653	0.52	55	40	80	0.68	0.16	0.19	0.14
6	653	0.69	80	80	80	0.92	0.23	0.27	0.19
10	653	0.91	45	60	30	1.15	0.24	0.25	0.23
12	653	1.00	25	30	20	1.43	0.43	0.39	0.50
15	653	1.03	10	10	10	1.28	0.25	0.25	0.25

Fish swimming velocity

Angle (°)	Discharge (ml/s)	Fish swimming velocity (m/s)	Success percentage (%)
0	100	0.17	55
0	316	0.33	25
0	653	0.37	45
3	100	0.45	80
3	316	0.51	70
3	653	0.68	55
6	100	0.49	45
6	316	0.74	50
6	653	0.92	80
10	100	0.64	30
10	316	0.87	30
10	653	1.15	45
12	100	0.77	15
12	316	1.08	30
12	653	1.43	25
15	100	0.90	20
15	316	1.23	15
15	653	1.28	10

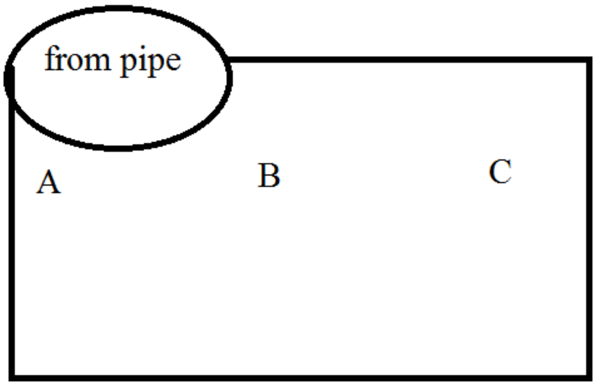
Average length and standard deviation (S.D) of migrating fishes during first 3 hours.

slope	discharge(ml/s)		successful (cm)	failed (cm)
0	100	mean	10.60	10.69
		S.D. ±	1.39	1.14
	316	mean	9.86	10.27
		S.D. ±	1.61	0.98
	653	mean	9.33	10.11
		S.D. ±	1.48	0.86
3	100	mean	9.41	9.92
		S.D. ±	1.25	1.00
	316	mean	9.50	9.72
		S.D. ±	1.14	1.16
	653	mean	10.00	9.17
		S.D. ±	0.83	1.35
6	100	mean	10.06	9.76
		S.D. ±	1.31	1.43
	316	mean	9.64	9.60
		S.D. ±	1.19	1.04
	653	mean	9.81	10.20
		S.D. ±	1.41	0.45
10	100	mean	9.75	10.00
		S.D. ±	1.21	1.05
	316	mean	9.67	10.76
		S.D. ±	1.21	0.71
	653	mean	10.72	10.25
		S.D. ±	1.23	1.55
12	100	mean	10.25	10.44
		S.D. ±	1.60	0.79
	316	mean	10.50	10.44
		S.D. ±	1.32	0.76
	653	mean	10.30	10.75
		S.D. ±	1.20	1.06
15	100	mean	9.00	9.98
		S.D. ±	0.71	1.05
	316	mean	10.00	10.65
		S.D. ±	1.50	0.68
	653	mean	9.25	10.78
		S.D. ±	1.77	0.64

Average length and standard deviation (S.D) of migrating fishes during first 6 hours.

slope	discharge(ml/s)		successful
0	100	mean	9.82
		S.D. ±	1.47
	316	mean	9.44
		S.D. ±	1.47
	653	mean	8.86
		S.D. ±	1.31
3	100	mean	9.41
		S.D. ±	1.25
	316	mean	9.39
		S.D. ±	1.21
	653	mean	9.00
		S.D. ±	1.19
6	100	mean	9.59
		S.D. ±	1.28
	316	mean	9.88
		S.D. ±	1.22
	653	mean	9.29
		S.D. ±	1.21
10	100	mean	9.14
		S.D. ±	1.12
	316	mean	9.21
		S.D. ±	1.25
	653	mean	9.75
		S.D. ±	1.06
12	100	mean	9.00
		S.D. ±	1.32
	316	mean	10.00
		S.D. ±	1.41
	653	mean	0.00
		S.D. ±	-
15	100	mean	8.67
		S.D. ±	0.29
	316	mean	8.50
		S.D. ±	-
	653	mean	10.5
		S.D. ±	-

Drawing of the downstream container demonstrating the measuring points of velocity.



Measurements done for field experiment

	Day one start		
Date	4/19		
Time	10:15		
Morning			
Discharge (ml/s)	286.7		
Water depth pipe entrance (cm)	2		
Water depth in box (cm)	21		
	Up	Down	09:30
pH	6.481	6.34	
DO	5.76	6.25	
EC	89.3	89.7	
Temperature	22.7	22.6	
Angle	3	3	
velocity(m/s)			
from pipe		0.2	
middle section counting from left to right(looking at the pipe)			
A	B	C	
0.1	0	0	

Day one finish

Time	16:15		
Afternoon			
Discharge	355.52		
Water depth pipe entrance (cm)	2		
Water depth in box (cm)	21		
	Up	Down	16:20
pH	6.237	6.407	
DO	5.06	5.72	
EC	89.9	88.1	
Temperature	22.2	22.1	
Angle	3	3	
velocity(m/s)			
from pipe		0.2	
middle section counting from left to right(looking at the pipe)			
A	B	C	
0.1	0	0	

Day two start			
Date	4 月 20 日		
Time	10:03		
Morning			
Discharge (ml/s)	407.45		
Water depth pipe entrance (cm)	2		
Water depth in box (cm)	21		
	Up	Down	09:30
pH	6.359	6.428	
DO	4.84	6.79	
EC	91.4	88.6	
Temperature	22.2	22	
Angle	3	3	
velocity(m/s)			
from pipe		0.2	
middle section counting from left to right(looking at the pipe)			
A	B	C	
0.1	0	0	

Day two finish

Time	16:03		
Afternoon			
Discharge	497.24		
Water depth pipe entrance (cm)	2		
Water depth in box (cm)	21		
	Up	Down	16:05
pH	6.306	6.421	
DO	4.2	8.41	
EC	89.8	112.5	
Temperature	22.8	22	
Angle	3	3	
velocity(m/s)			
from pipe		0.2	
middle section counting from left to right(looking at the pipe)			
A	B	C	
0.1	0	0	