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- RESEARCH ARTICLE -

Development of an Arduino Based Fish Counter Prototype for European Eel (*Anguilla anguilla* L.)

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Abstract

European eels (*Anguilla anguilla* L.) has a great dispersion from Sargasso Sea to across the Europe and North Africa. Their population have decreased dramatically over the years and listed in IUCN as critically endangered. Stock estimation is one of the important issues in order to sustainable management of this species. Last decades, researchers have focused various studies which based on monitoring of various life stages of eels. Manual counting methods with ladder traps is commonly used based on collection of glass and elver stages of eels from the natural habitats while their migration to upward of streams. During their special migration pattern, a counting device on the eel ladders can be designed so that the eels may be counted while passing through this device. The offered prototype was designed for eel ladders which was briefly, powered by an open-source electronics platform, Light Dependent Resistor (LDR) and 650 nm Laser light were used to count elver eels. Several trials were conducted to test this prototype and results were promising. This study aimed to explain features of prototype and working principle of elver counter. Designed prototype has several advantages such as usable with eel ladders, easy to customisation and affordable characteristics. However, this device needs some improvements in order to effective usages in the field.

Keywords:
Arduino, European Eel, *Anguilla anguilla*, Counter, Monitoring of elvers
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Introduction

The European eel (*Anguilla anguilla* L.) spawns in Sargasso Sea and their population distributed as far as Europe and North Africa (Tesch, 2013). Their life cycle has various metamorphose phases. Larvae (leptocephalus) drifts to coastlines and then they enter transitional waters or go to upstream as glass eel form to processes of recruitment in fresh water habitats. Then they transform into elver stage and migrate to upper sites of streams as continental form of yellow eel stage (Bonhommeau et al., 2009; W. Dekker, 2000; Feunteun, 2002; Jacoby & Gollock, 2014). Finally, the last phase is silver eel stage. In this stage those fishes migrate back to downward of streams in order to reach Sargasso Sea for reproduction (Daverat et al., 2006).

High economic value in all over their distributional area as food and other usages makes this species popular in fishery and industry (Food and Agriculture Organization of the United Nations, 2006; Ringuet, Muto, & Raymakers, 2002). This species is considered as "Critically Endangered" by International Union for Conservation of Nature and Natural Resources (IUCN) due to dramatically declining of eel population (Jacoby & Gollock, 2014). The parasites, predators, increasing migration barriers, pollution, habitat loss and over fishery are some of the responsible factors assumed for declining eel population (Aalto et al., 2016; Bonhommeau et al., 2009; Feunteun, 2002; ICES, 2016; Tesch, 2013). All of these factors were discussed and a new regulation on European Eel Management was created by European Union in 2007 with EC Regulation No. 1100/2007. By this regulation, anthropogenic mortalities must be reduced at least 40% of silver eel at pristine level escape, due to complex life cycle of eels, must be provided. In addition to national regulations, many of institutions are working for to conservation of eel population such as ICES (International Council for the Exploration of the Sea), EIFAAC (European Inland Fisheries and Aquaculture Advisory Commission), GFCM (General Fisheries Commission for the Mediterranean), CMS (Convention and the Conservation of Migratory Species of Wild Animals), CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora), IUCN (The International Union for the Conservation of Nature) were also involved for this regulation (ICES, 2016). Stock assessment and monitoring of eels are very important due to such regulations.

During to monitoring studies quantitative and quality data set on glass, yellow and silver stage European eel is needed for stock assessment of eels while migration (Feunteun, 2002). These datasets must be collected based on the number of eels in glass and elver stages by spatial and temporal in order to estimate recruitment during monitoring studies. Eel ladders are commonly used manual traps for catching and counting eels in various countries. In this system, eels are collected in a box after climbing a ladder system. Then a person must go to this monitoring station to release and count the collected eels. However, data collection using eel ladders during monitoring is hard, needs qualified personnel and also expensive to costs vary from 16 000€ to 33 000€ per site per year (Willem Dekker, 2002). Thanks to technology, recently a company developed new counter system that can take photos and count of fishes, especially they also developed for elvers (VAKI Aquaculture Systems LTD., 2017). Nonetheless, cheaper and also reliable technologies may be designed for present eel ladder systems. The eels collected in that box may be counted and released automatically through the upward of the stream.

Arduino is open-source hardware and software ecosystem. This system has been used since 2005 from first Arduino board. Today, Arduinos are used by professionals, students, programmers and even corporations. This system provides easy to programme with Arduino programming language (based on Wiring), and the Arduino integrated development environment (IDE), based on Processing. By this feature, anyone can use, programme or customize Arduino based prototypes who has no experience about electronics. Another advantage is those components are cheap to acquire (Arduino, 2017; Wishkerman & Wishkerman, 2017). Furthermore, several scientific studies were conducted with Arduino in order to design various devices (Dwiputra, Achmad, Faridah, & Herianto, 2017; Frot, Taccoen, & Baroud, 2016; Jo & Baloch, 2017; Masseroni, Facchi, Depoli, Renga, & Gandolfi, 2016; Wishkerman & Wishkerman, 2017). This study offers a cheap, reliable, easy to use and customizable alternative prototype as a fish counter using Arduino system for counting elvers.

This prototype was designed in laboratory conditions. Counts of the eels were gathered by LDR sensor, 650 nm laser module and the side modules, SD card and date-time modules were used to save gathered data to memory card with date and time information. This study will demonstrate the working principles of the device.

Material and Methods

Eels

Elver eels (12.00 cm ± 2.07) were collected from Yuvarlak Çay, Köyceğiz, Muğla Turkey. 15 of elvers were transferred with oxygen provided fresh waters to our laboratory in Çanakkale, Turkey. This study was conducted by the legal ethical procedures with decision number 2017/02-01 of Local Ethical Committee of the Çanakkale Onsekiz Mart University. Also Republic of Turkey Ministry of Food, Agriculture and Livestock, General Directorate of Fisheries and Aquaculture was permitted to catch these eels with decision number 67852565-140.03.03-E252954. Those fishes were kept in big fish tanks for 3 months with proper food and fresh water supply until experiment term. Even the eels were kept in suitable conditions, 12 of 15 elvers were couldn’t survive at laboratory conditions and 3 elvers (13.00 cm ± 2.82) could be used in trials.

Description of the Prototype

Offered prototype should contain an eel ladder system to lead elvers into “collect box”, and this ladder system should be established as starting from stream water ending to land which should be upward. This system contains water attractant to direct the eels to ladder and collect box. The collect box must be positioned an α angle with soil basement.

The “collect box” which contains continuous limpid and no-bubbles water feed to collect elvers. This flow lead fishes to “counting gate” then they direct “exit ramp”. All the three components should be at same angle according to soil basement (Figure 1). Exit of the collect box and counting gate should have a “V” shaped.

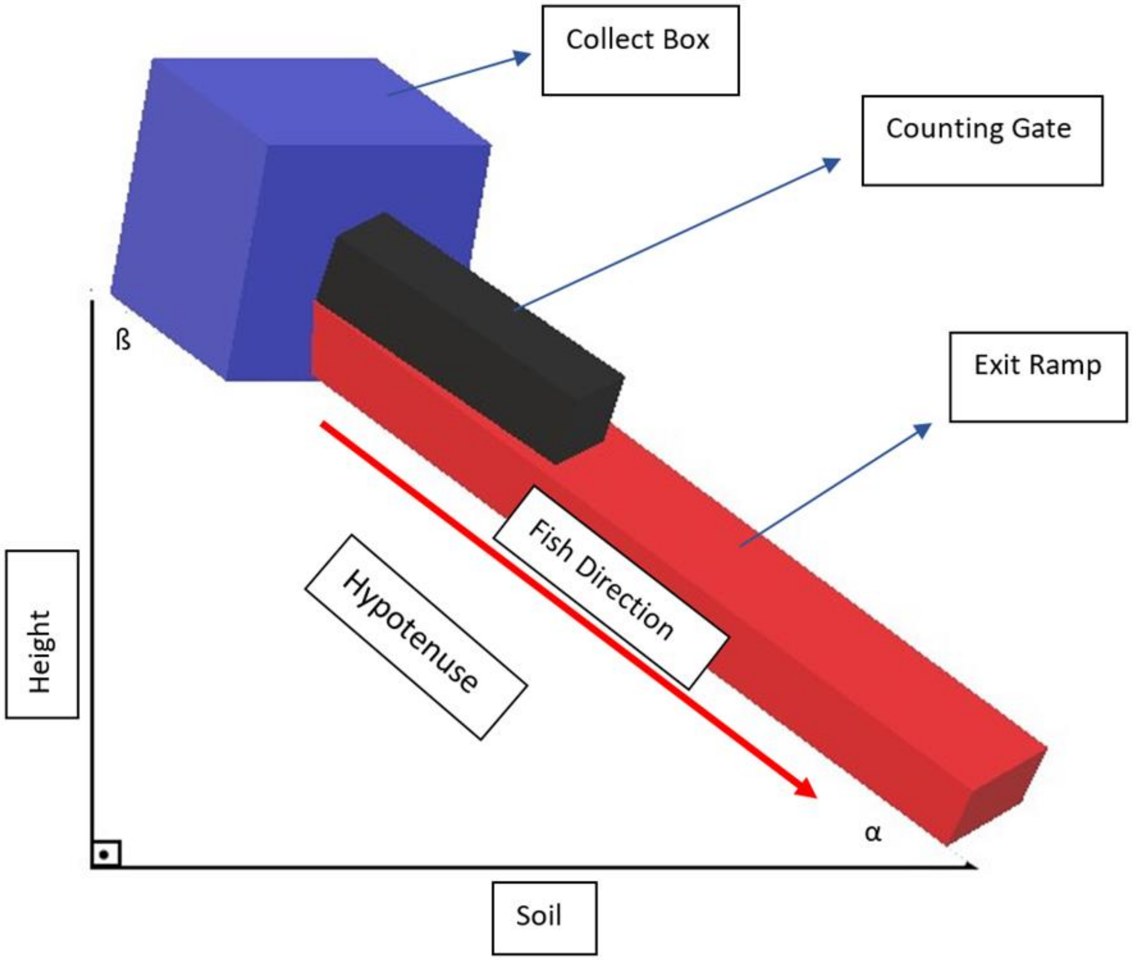

Figure 1. Collect box, exit ramp which has the counting gate mounted on it has the same α angle according to soil. Altogether of those compounds creates roughly a 90° triangle

Counting gate is made up flexi plastic in order to make V shape. The V shape is given by electric heater at 370°C (Cimaarec, Thermo Scientific) and bended while it was hot enough. By the providing of V shape the eels pass through laser beam one by one and also prevents excessive movements of eels. Therefore, multiple counts could be avoided. The flexi plastic also provides slippery surface to help elvers slide over it. This slipper surface also prevents backward movements. A 650nm Laser Module were mounted on the mid-point of bridge as laser beam source. A 2.0 mm diameter dark chamber was placed under counting gate. A Light Dependent Resistor (LDR) sensor was placed into this dark chamber (Figure 2). Dark chamber was mounted the counting gate by a round hole. This hole was covered with transparent, non-lens effect and water-resistant object in order to transmit laser beam.

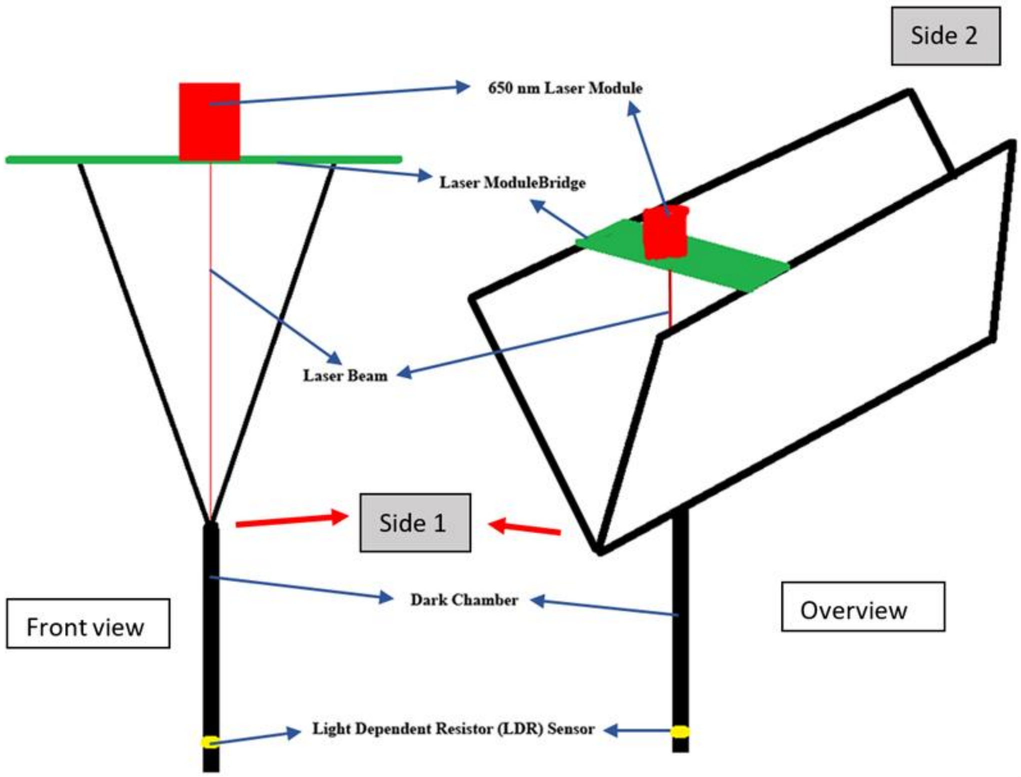

Figure 2. Overview of Counting gate

The offered prototype was developed in Aquatic Ecology Laboratory and trials were conducted in the same place with certain conditions. Several attempts were also conducted to design optimum prototype. We didn't use the ladders in each trial after testing the eels can climb the ladder system (Figure 3). In order to time save and to avoid fatigue of animals the prototype was tested from the beginning of "collect box".

In trial conditions certain values were calculated. From collect box to end of exit ramp, the system was mounted as hypotenuse of a 90° triangle (Figure 1). The hypotenuse length was measured 81.13 cm, height was measured 53.5 cm and basement was measured 61.00 cm according to end to end of the system. By light of these measurements, the angle of α was estimated with the formula,

$$\sin\alpha^{-1} = \frac{Height\ (53.5\ cm)}{Hypotenuse\ (81.13 cm)} \qquad \textit{(eq. 1)}$$

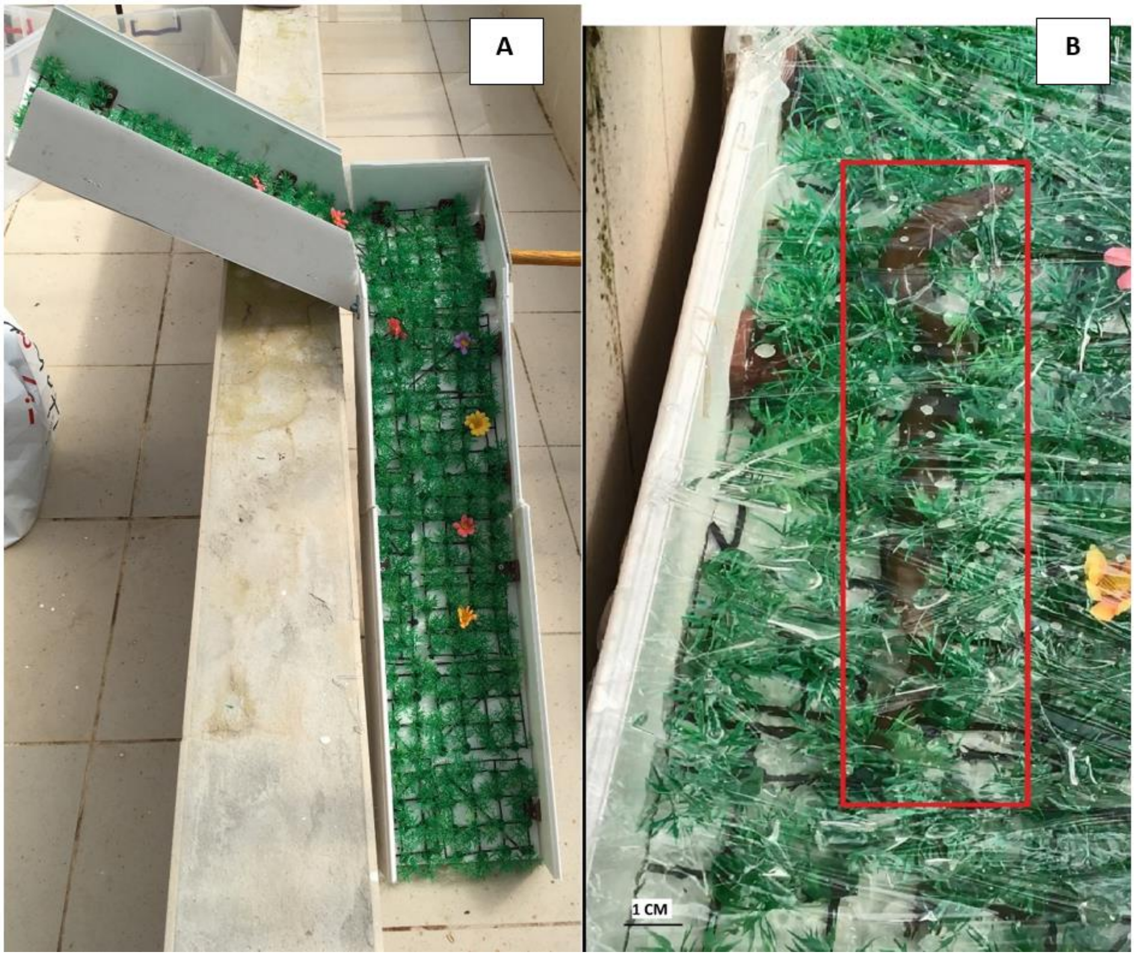

Figure 3. Crafted eel ladder. Side (A), overview of eel ladder. Side (B), a climbing eel fish

Electronic Components

The system powered by Arduino Mega 2560 Clone as electronic platform and supported with Arduino Mega Sensor Shield v2.0 to increase pin numbers. The sensor shield was mounted on to Arduino Mega directly. This shield also has its own SD card pins independently from other pins. SD card module was connected via shield's SD card pins respectively. Commercially available micro SD card adaptor was used to save gathered data to SD card. "DS1307 RTC and 24C32 EEPROM" was purchased in a module and this module was used to save date-time data on SD card with counter values. The pins were defined by vendor on the module as DS, SCL, SDA, VCC and GND. Those pins were connected to sensor shield pins with pin 21 for SCL, pin 22 for SDA, pin V for VCC and pin G for GND. DS pin was not used. Commercially available 650 nm Laser module (Keyes, China) was used for laser beam source. The module pins were defined +, S and -. The + pin was connected to V pin on sensor shield and – pin was connected to G pin on sensor shield therefore the laser beam will be open continusly. 5 mm LDR was used as light sensor. The sensor was mounted in cylindrical dark tube in order to prevent other light sources except laser beam. The sensor was connected with 10k resistor by one side. That cable was divided into two ways, one for signal path (A2 pin) and one for ground path (GND pin) to enhance laser beam sensing. The other side of LDR was connected directly to 5V pin on sensor shield (Figure 4). All components including cables and connections were kept in dry conditions by hot silicone isolation.

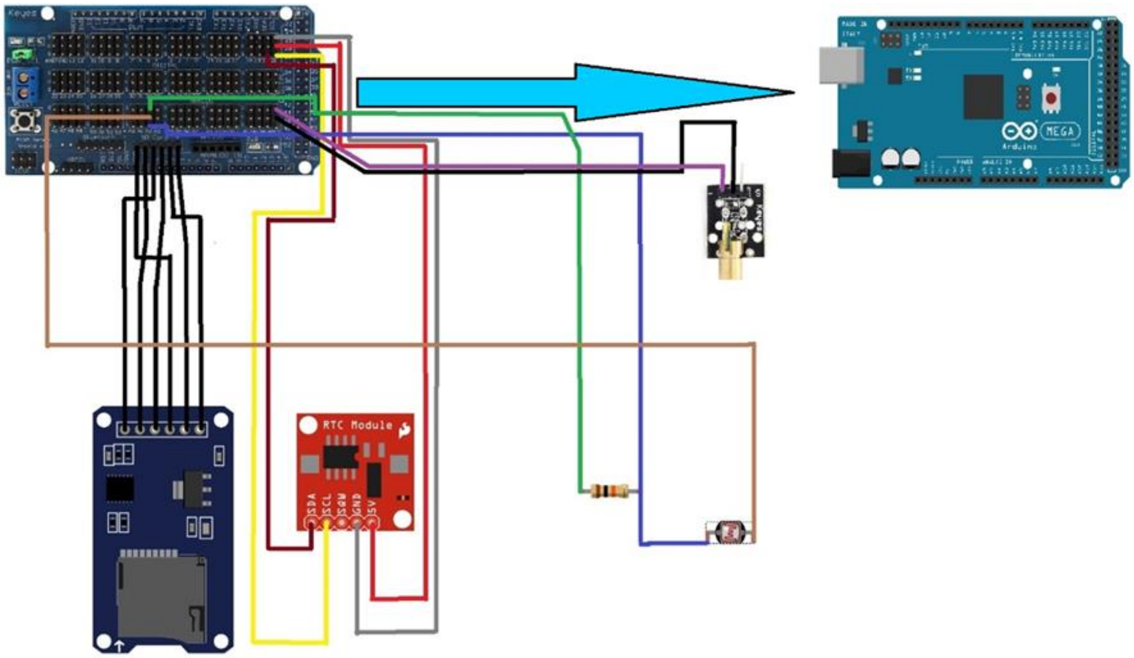

Figure 4. Electronic pin connections for each module, shield and Arduino board

Source Codes

The source codes for Arduino IDE compiler software was written in supplementary material. RTClib library was downloaded and added to the code from github.

Working Principle

The elvers are collected in collect box by standard eel ladders (Figure 1). The eels leave the collect box and enter to V shape counting gate. While sliding through counting gate it passes and cuts the laser beam between LDR sensor and laser beam source. After that the eels can be directed to desired place by exit ramp. In each cut events of the laser beam, LDR sensor input the counts and save this counting to SD card with date and time information. The V shape prevents multiple counting and provides individual entrance to counting gate. The minimum and maximum sensor value has a range of 0 to 1023. When there is no fish in the counting gate, the sensor read values as 1023. If the sensor value is below the threshold, LDR counts the fish. The α angle provides enough slope for the flow rate and also help elver eels slide on counting gate to exit ramp.

Results

This prototype which is consist of Collect box (25cm x 13cm x 20 cm), counting gate (15 cm x 8.5 cm) and exit ramp (64.5 cm x 20 cm) were placed with the α angle of 41.25°. This angle was calculated based on the sizes of three components. In addition to these main components the prototype consists of a laser module on the bridge (8 cm in length) and LDR sensor which is placed at the point of 9 cm in length of totally 11 cm and 2 mm in diameter dark chamber.

When the laser source is closed LDR sensor values were recorded from 0 to 150 according to environmental light sources. LDR sensor threshold was set on value of 200 in order to minimize the possible environmental light contamination.

Table 1 indicates the results of trials of the prototype in various flow rates. In order to slide of eels through counting gate, 16 trials were tested and 20 Ls^{-1} were indicated as the optimum flow rate. While the sensor works properly, less flow rate than 20 Ls^{-1} resulted in multiple counting. In addition, the low flow rate prevented to slide of the eels through counting gate. In the condition of higher than 20 Ls^{-1} flow rate, the LDR sensor counted the bubbles with eels.

Table 1. The trial results of the testing prototype

Trials	Flow rate, Ls-1	Counting reports of fish	Reading	Fish occurrence	Sensor success
1	40	-	no reading	absent	success
2	40	Multiple counting	reading	present	Not success
3	38	-	no reading	absent	success
4	38	Multiple counting	reading	present	Not success
5	36	-	no reading	absent	success
6	36	Multiple counting	reading	present	Not success
7	34	-	no reading	absent	success
8	34	Multiple counting	reading	present	Not success
9	30	-	no reading	absent	success
10	30	Multiple counting	reading	present	Not success
11	24	-	no reading	absent	success
12	24	Multiple counting	reading	present	Not success
13	20	-	No reading	absent	success
14	20	Individual counting	reading	present	success
15	17	-	reading	absent	Not success
16	17	Counting with bubbles	reading	present	Not success

Elver eels were passed through counting gate one time and sensor was counted each of them without error in the optimum flow rate. After all trials no harm or damage were seen on the specimens. The eels on the counting gates is given in Figure 5.

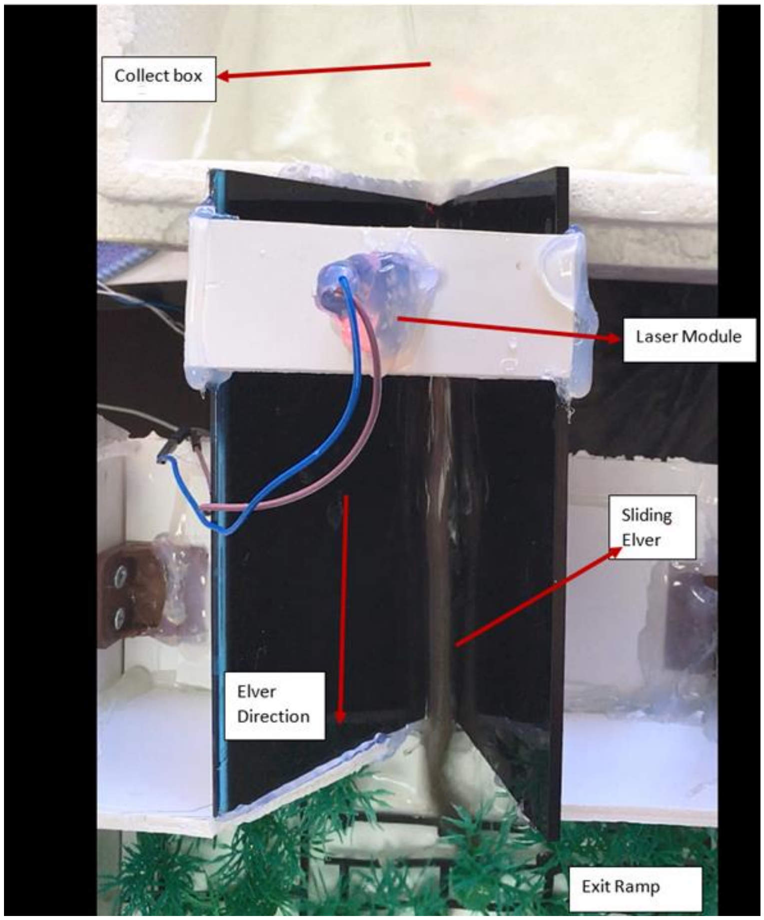

Figure 5. Elver was counted while sliding from collect box to the exit ramp through counting gate

Discussion

The prototype is designed in laboratory conditions and the test results indicated that this device can be used for counting European eels with classical ladder systems. However, it needs some improvements in order to use it in various environmental conditions on the field. The sizes of the equipment, source of laser beam and flow rate might be arranged according to field conditions. This device was arranged for elvers and similarly it can be designed for glass and yellow even silver eels too. The main system that contains electronic components can be established outside of water and also a box can be used to isolate system from direct water interaction and protect fishes from predators while they were in it. In addition, developed prototype needs to turbidity filter for collect box and certain conditions described in this present study in order to optimum running.

Eel fishes can climb ladders and their behaviour characterised to swim upward of stream while they migrate to streams (Tesch, 2013). This behaviour of eels was considered and therefore, standard eel ladder planned as a way to collect box, which is still using method as eel trap (Willem Dekker, 2002). After the exit ramp, fishes could be directed to upward stream. So, these fishes cannot come back to counting gate through exit ramp and also, slippery surface will also help for such purpose to prevent duplicate data for elver counter. Additionally, to reduce miscalculation of eels, due to their large numbers while migration, to prevent agglomeration and lead to passing one by one to the counting system, a size filter may attach to between collect box and counting gate. In future, this system might be developed for eel ladders without collect box and exit ramp.

The system has several advantages because of developed on Arduino. The first advantage is its low cost. Some other studies showed that, Arduino offers low cost and alternative approaches to solutions instead of high industrial offers (Schneidereit, Kraus, Meier, Friedrich, & Gilbert, 2017; Tedeschi, Calcaterra, & Benedetto, 2017). Also, some of the industrial offers expensive and not allowed to customisation. This prototype is open to customisation and the offered system can overcome several data problems about eels. For instance, this system may store temperature of water or other sensor supported values and also with a turbidity meter may implant to the prototype to improve monitoring and control the turbidity value of the collect box water (Weber-Shirk, 2014). Not limited of additional sensors, broken or damaged hardware can be replaced with new, low cost hardware (Schneidereit et al., 2017). This board is also field-serviceable device (Gillanders, Samuel, & Turnbull, 2017). What more, this system can be converted into self-working counter with internet of things (IoT) to send data to institutions and several studies used Arduino for such purpose. Arduino Mega is also compatible with IoT applications. (Mejías et al., 2017; Yeh, Su, Choo, & Chiu, 2017). This system can be also upgraded with solar energy kit and mobile phone (GSM) kit for off-grid electric supply and IoT applications.

Some studies were used Arduino as a data logger and LDR sensors (Leeuw, Boss, & Wright, 2013; Maranhao, Brito, Leal, Fonseca, & Macedo, 2015). Different projects were conducted with this board in various fields like biology, environmental sciences, chemistry, physics and others (Benavides et al., 2015; England et al., 2017; Kanaparthi & Badhulika, 2017; Lockridge, Dzwonkowski, Nelson, & Powers, 2016; Swain & Palai, 2016). These studies are proving the reliability of Arduino and other components.

Today, when we consider expensive monitoring methods, this system can be easy to manage, low cost and efficient new approach to monitor elver eels on their migration. Researches using capture and visual monitoring in field (Bernotas et al., 2015; MacNamara, McCarthy, & Barry, 2016). Studies show that, eel ladders are key instruments that can help monitoring of eel populations (Willem Dekker, 2002; ICES & Acom, 2016; Jacoby & Gollock, 2014). The advanced models of this prototype may be the optimum choice for monitoring of eels by low-cost, efficient, good data logger. In addition, there might be no longer qualified personnel needed for field monitoring by this system.

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