International Journal of Education and Knowledge Management (IJEKM) 4(5): 1-15 (2021)
Print ISSN: 2616-5198
Online ISSN: 2616-4698

Research Publishing Academy (RPA)
London, United Kingdom (UK)

IJEKM
International Journal of Education and Knowledge Management (IJEKM)
Journal Homepage: https://rpajournals.com/ijekm

Preserve the Diversity of Freshwater Fish Species at Son La Hydroelectric Dam after Nearly a Decade of Operation

Thuy Yen Dang[1]
Le Thi Thu Hoa[2*]
Northwestern University, Vietnam[1,2]

Abstract

Son La Hydroelectric dam is the largest hydroelectric work in the South East in the upstream of Da River at It Ong Commune, Muong La District, Son La, Vietnam. This is the multi-objective work with great role for national power production and economic development, water regulation for Red River Delta. However, the construction of Son La Hydroelectric dam has drastically reduced the diversity of fish species here. Pursuant to the data comparison and analysis from previous researches and result of field surveys in 2019 and 2020, the research indicated clearly the effects of the construction and operation of hydroelectric dam to the diversity of fresh - water fishes in Son La Hydroelectric dam. The result showed that the composition of fresh-water fishes here has decreased by 30% compared to before the construction of hydroelectric dam. The current composition of fish species in this area is identified as 69 species and 1 subspecies belonging to 20 families, 9 orders and showing a high degree of diversity in both order and family level. In this area, 53 species are listed in IUCN Red List, 6 species in VU Vulnerable, 2 species in NT Near-threatened, 26 species in LC Least Concern, 19 species in DD Data Deficient. In particular, the research added Truong Giang Drift fish (Prochilodus argenteus Spix & Agassiz, 829) and channel catfish (Ictalurus punctatus Rafinesque, 1818) to the list of Da River fish in Son La area. This is the first research on the composition of fish species in Son La Hydroelectric dam after the construction and coming into operation in 2012. Through the research, we proposed measures to preserve the diversity of composition of fresh-water fish species in the research area.

Keywords: Son La Hydroelectric Dam, Da River, Composition of Fish Species

*Corresponding author: Le Thi Thu Hoa; Email: hanguyenedu1277@gmail.com
DOI: https://doi.org/10.37227/IJEKM-2021-05-928

Introduction

Hydroelectricity is one of the most important electric supplies in the world, the construction of reservoirs, prevention of flow to create dam is one of the conditions to construct large hydroelectric plants. There are more than 47,000 dams that are constructed higher than 15m in the world, in which, the most of large dams are concentrated in China, India and the USA ("Dams, Rivers and Responsibilities - Rights of People | VUFO - Vietnam NGO Resource Center.," n.d.). In addition to the benefits of dams in terms of water storage, flood control, and waterway transport support, especially the economic benefits derived from hydroelectricity, the dam construction also transforms natural rivers

into river and lake sections leading to changes in flow; preventing the migration of aquatic organisms; this is one of the main reasons affecting their habitat, which has a great influence on the change in fish species diversity(Liermann, Nilsson, Robertson, & Ng, 2012; Vörösmarty et al., 2010; Antonov et at., 2019).

The research have shown that dams have less impact on common fish species and pose a greater threat to local endemic species (Anderson, Freeman, & Pringle, 2006; Cerny, Copp, Kovac, Gozlan, & Vilizzi, 2003; Cheng et at.,2018; Eugene et at.,2019). In particular, Poff et al. (2007) studied the effects of reservoirs construction and flow variability on fish species diversity of 317 rivers in the United States, or Begoss et al. (2020) in tropical regions such as the Amazon and have shown that changes in river and lake habitat caused by dams are closely related to the difference in the composition and structure of fish communities (Begossi et al., 2019); Recently, Freyhol et al. (2020) with a project funded by the European Union's research and innovation program reported that in the biodiversity hotspot of the Mediterranean basin, 63% of all fresh-water fish species are presently threatened with near extinction by existing hydroelectric plants, and up to 55% of all critically endangered species are severely affected ("Threatened Freshwater Fishes of the Mediterranean Basin Biodiversity Hotspot," n.d.). Recognizing from a solution perspective, Moran et at., 2018; Simanov (2019) analyzed the negative impacts of hydroelectricity on freshwater ecosystems in the transboundary Amur River basin shared by Russia, China and Mongolia and recommends the application of various assessment and conservation tools at the appropriate time from production preparation to operation which is a key factor in minimizing the environmental impact of dams on fresh water ecosystems (Simonov, Nikitina, & Egidarev, 2019).

Flowing on the steepest terrain in Vietnam, the Da River is considered the place with the largest hydroelectricity reserves in Vietnam. Currently, there are 7 different large and small hydroelectric projects on the Da River. Especially, Son La hydroelectric dam is the largest hydroelectric dam in Vietnam and Southeast Asia which was built in 2005 and put into operation since 2012.

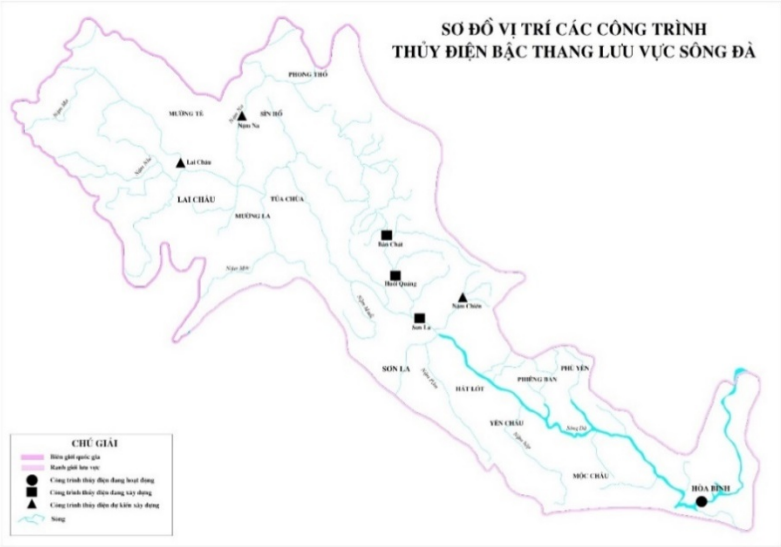

Figure 1. Location map of hydropower projects on the Da River

Source: (Vietnam Electricity Corporation, 2007)

The ichthyologic research in the Northwest region and the Da River has been conducted quite early. French scientists were the pioneers. The first person to conduct research and classify fish in the Northwest and Da River was Vaillant (1891) who collected 10 species, including 6 new species. After that, many other authors also conducted research such as: P. Chevey and J. Lemasson (1937) publishing a comprehensive work on freshwater fish in the North, including 23 species of fish in the Northwest, particularly, the collection from sites in the Da River basin: Phong Tho, Lai Chau Town, Nam Lay (Lai Chau Province), Muong Bu, Moc Chau (Son La Province) were 19 species (Chevey & Lemasson, 1937).

Since the restoration of peace, Mai Dinh Yen has been the scientist with the most research on freshwater fish species in the Da River. In 1978, the research "Fishes identification in the northern provinces of Vietnam" obtained 82 species at the following sites: Muong Lay, Muong Tung, Phong Tho, Pa Ham, Nam Na river, Nam Muc (Lai Chau pProvince), Chieng Pac (Son La Province)(Mai Dinh Yen, 1978). After many years of surveying the composition of the Da River fish fauna at three locations: Ta Khoa (1963), Hoa Binh (1969), Lai Chau (1970), he et al. have collected 80 species, especially 50 species in Lai Chau Town. However, these works have been conducted for quite a long time and have not been published (Mai Dinh Yen, 1985). In addition, the researches of Nguyen Van Hao (1996-1998) surveyed, collected fish samples at 9 sites in Lai Chau Province, including 4 sites in the Da River basin; 128 species in Da River basin, 104 species in Nam Rom river and 38 species in Ma river. Nguyen Huu Duc and Nguyen Van Hao (2000-2001) discovered and announced 4 new species of fish in the Northwest region. Most recently, Nguyen Thi Hoa, 2011, in the work "Contributing to the research of fish in the Da River basin in Vietnam", published 242 species and subspecies belonging to 109 genera, 24 families, 9 orders, in which, 98 species are recorded in the study area (Nguyen Thi Hoa, 2011). This can be considered the most complete and large-scale study of fish fauna in the Da River basin so far. The studies are the basis for assessing the fish species diversity of the Da River before the impact of the hydroelectric dam. Create a basis to compare the volatility in fish species composition under the impact of Son La hydroelectric project.

Location and Time of Research

Location: The research area is a hydroelectric reservoir basin on the Da River, the section flowing through Son La province, with an area of 13,000 hectares, flowing through 2 districts, Quynh Nhai and Muong La. Foot of the dam is located in It Ong commune, Muong La district, Son La. Sampling collecting above the dam is mainly in Quynh Nhai district and Muong La district.

Figure 2. Location map of hydropower projects on the Da River

(Source: Google earth)

Time: The time for document collection, field investigation is 2 years from January 2019 to December, 2020, including dry and rainy seasons.

Research Methodology

Method of Document Synthesis and Analysis

The research was compiled from 26 documents related to the research problem, specifically:

- The impact of hydroelectricity to the diversity of fish species composition in the world and in the country
- Documents of research on freshwater fish, fish group distribution, natural conditions, socio-economy and the actual situation of fish exploitation in research area
- Documents, projects of research in the research area so far.
- Documents on fish composition identification

Systematize the information collected from the documents. Analyze to make clear the novelty of the research problem; inheritance, development and supplement compared to previous research.

Field Method and Sample Collection

During the fieldwork of 2 years, the research team collected sample twice a month at the beginning and middle of the month, from 1 to 3 days per period along the length of Son La hydroelectric reservoir in the research area:

- Collecting fish samples at riverside and lakeside fish markets; purchasing fish caught randomly by fishermen, local people; Collecting all species encountered and collecting samples in different seasons. The number of samples depends on each species. Less common species, strange fish species, and special morphological species are prioritized to collect more than common fish species. Collected specimens are morphologically intact, without desquamation, broken fins.
- Fish samples were shaped, made specimen and fixed at 8 - 10% formaldehyde; Take a picture of the fish specimen and label the sample with information such as the local

name of the fish (if any), location, time of fishing... Collected fish samples will be kept at the laboratory of Tay Bac University, Son La and Museum of Biology, Faculty of Biology, University of Science - Vietnam National University, Hanoi.

Interview Method

Monthly, the research team conducts interviews with people in combination with sample collection:

- Investigate and interview people (fishermen, fishmongers) actively by listing the names of fish species encountered by local names; use pictures and specimens of fish species to help the interviewees determine whether the fish species are local or not or ask negative questions to determine information.

The Method of Identification by External Morphology

The method of identification by external morphology followed the guidance of Pravdin and the documents of Mai Dinh Yen, Nguyen Van Hao et al., Kottelat. After identification, the fish is arranged according to the Van Der Laan fish taxonomy and an updated electronic version of this document (Kottelat, 2001; Mai Dinh Yen, 1978; Pravdin. I. F, 1973). At the same time, the research team also used the FishBase standard - a global database of fish species as a taxonomic reference, to complete the list of fish species ("FishBase," n.d.).

Results

The environmental effects of Son La hydroelectric dam construction and operation to fish species

The construction of hydroelectric dams greatly affects the habitat of fish species both during construction and operation.

The greatest impact of hydroelectric dams on fish species is the impediment of fish migration routes. Dams prevent fish from moving along their natural path between feeding and spawning grounds, causing disruptions in their life cycles that limit their ability to reproduce. In addition, there are species that, if moving through gas turbines, can be injured or cause death in young fish due to hydraulic shear, pressure changes (Gracey & Verones, 2016; Nguyen et al., 2018)

Second, when the water storage reservoirs increase the depth, area and the change in conditions from the flow form to the perching regime (static) will change the structure of the dominant species with the new environment (Bunn & Arthington, 2002). The exposure and limited reproductive habitat may occur in the shallower areas at the foot of the dam for many riverine fish species (Hirst, 1991).

Third, when the water surface of the water storage reservoirs increases, which means that the exposure to sunlight is expanded causing the lake water temperature to increase, coastal erosion also increases causing the water environment to change and the turbidity to increase which changes the reproductive habitat of fish species and cause death. The heat regime is considered to be the most important factor affecting the rate of metabolism, growth, development and survival as well as the distribution and richness of fish species, attenuating the delay in migration and reproduction, reducing native fish production, even the extinction of native fish species and the intrusion of exotic fish species causing extinction of native species (Hari, Livingstone, Siber, Burkhardt-Holm, & Güttinger, 2006; Zhang et al., 2021)

Fourth, the increase in concentration of dissolved oxygen, nitrogen and water temperature when passing through the turbine affects the movement of fish species, with many species disappearing or changing their distribution area (Risley, Constantz, Essaid, & Rounds, 2010)

Specifically for Son La hydroelectricity area, Vietnam Electricity Corporation and the Ministry of Industry and Trade have assessed the environmental impact on the freshwater ecosystem of Son La hydroelectric project during and after the completion of the project.

The Impact of Plant Construction on Water Environment

During the period of four years from 2005 to 2009, on an area of 1742 hectares, the activities of plant construction that affect the water environment include:

Construction of auxiliary infrastructure works, construction materials receipt, raw materials exploitation, materials transportation, leveling and stone dumping activities... These activities have had a great impact on the regime and natural river water environment, the processes of rock movement from the surface to the river-bed and the flow of sand and mud in the river-bed.

Table 1. Volume of Soil and Rock Excavated when Constructing Son La Hydroelectric Dam

Activities	Volume of soil and rock
Leveling, digging soil and rock	16.350.700 m^3
Excavating soil and rock for dyke	1.757.000 m^3
Exploiting construction materials	9.000.000 m^3

Source: Ministry of Industry and Trade,(Vietnam Electricity Corporation, 2007)

Second, domestic waste, domestic wastewater and substances of a large number of workers are concentrated in high density (about 14.000 people and an additional 14.000 accompanying people) on 118 hectares in Chien Stream valley. Total domestic wastewater is 2380 m3/day. These are mainly organic wastes.

The third is to affect the natural river water environment, which will inundate some land areas, increase the flow of sand and mud in the river-bed, water pollution due to waste oil and the decomposition of organic matters in flooded areas. During the construction process, some amount of biomass will be flooded in the lake, decomposed over time reducing the dissolved oxygen content in the water; the total volume of flooded plant organic matter can reach over 590 thousand tons. According to the calculation, by October 2010, when the lake water level was at an altitude of 190m to 215m, the DO content just reached 5,33 – 5,7mg/l - the water standard level for aquatic life which has not yet reached the level for domestic use during this period.

The Impact after Completing Son La Hydroelectric Plant

The plant after completion also has a lot of aquatic environment impacts including:

The sedimentation of the lake bed profoundly changes the hydrological-hydraulic regime of the river. Alluvium was deposited much changing the ecology of the lake bed.

On the other hand, the flow rate in the lake decreases, sediment accumulation increases, the invasion process in the upstream river and stream system decreases

changing the ecological environment in general. The inflow downstream causes erosion of the river bed in downstream of the dam.

There is occurrence of phenomenon of temperature and dissolved gases stratification in the vertical depth of the reservoir such as the area near the dam. Changes in water quality in Son La reservoir are predicted: BOD5 content will decrease by 20%, DO index currently from 6,5-8,0 will decrease to 5,5-6,5. In summer, the temperature difference between the surface layer and the bottom layer ranges from 4-7^{0}C, possibly up to 80C. Dissolved oxygen stratification also often occurs in summer.

Changes in water conditions and quality lead to a much higher density of phytoplankton than in water body in the form of river and stream. The density of zooplankton will be higher than before the lake formation. However, the group of mollusks will decrease sharply in number and species composition. Fish also have great changes such as: species that prefer flowing water area greatly decrease in number, species that eat plankton and organic humus develop. The output of natural fish is high in the first years after the formation of the reservoir, then the natural shoal of fish will gradually decrease due to the blocking of the dam to change the flow for migratory fish, causing loss of spawning grounds, etc. Instead, the structure of the farmed fish will gradually increase such as drift fish, grass carp,...

The Change of Freshwater Fish Species Composition in Son La Hydroelectric Lakebed

Fish species composition before the formation of hydroelectric dam

Through analysis, identification of fish samples collected and synthesis of research results of previous authors, the list of Da River fish in the hydroelectric dam area was determined to include 69 species and 1 subspecies belonging to 20 families, 9 orders. (Table 2). In the fish species composition obtained by the research team, no migratory fishes were observed, the reason is that the downstream of Hoa Binh dam has prevented fish species from moving from the coastal estuary to the upstream area for reproduction and vice versa. The diversity of families and species of each fish order is shown in Table 1.

Table 2. Number and percentage of families, genera and species in the Da River fish orders in Son La hydroelectric dam area

NO.	Order		Families		Species	
			n	%	n	%
1	Cypriniformes	Carp	3	15,00	41	58,57
2	Characiformes	Serpae tetra	2	10,00	2	2,86
3	Siluriformes	Catfish	6	30,00	12	17,14
4	Osmeriformes	Smelt	1	5,00	1	1,43
5	Gobiiformes	Goby	1	5,00	4	5,71
6	Synbranchiformes	Synbranchiformes	2	10,00	2	2,86
7	Anabantiformes	Anabas	3	15,00	5	7,14
8	Cichliformes	Peacock Bass	1	5,00	2	2,86
9	Cyprinodontiformes	Silver-head	1	5,00	1	1,43
Total			**20**	**100,00**	**70**	**100,00**

According to the results shown in Tables 1 and 2, the order Siluriformes has the largest number of families with 6 families (30%), followed by the order Anabantiformes and the order Cypriniformes with 3 families (15,00%). Meanwhile, the order Cypriniformes is the order with the richest number of species with 41 species and subspecies (58,57%), followed by the order Siluriformes with 12 species (17,14%), the order Anabas with 5 species (7,14%).

According to the IUCN Red List version 2020-3, 53 species have been identified, accounting for 78,57% of the total number of species identified in the research area named in this list. In which, 6 species at the level of vulnerable (VU) are: Golden Sinilabeo Graffeuilli *Bangana tonkinensis*, Mrigan *Cirrhinus cirhosus*, thin body oily fish *Pseudohemiculter dispar*, common barb *Cranoglanis bouderius*, rock Goby *Rhinogobius albimaculatus*, *Channa orientalis*; 2 species at the near-threatened (NT) level: Drift fish *Cirrhina molitorella*, Chinese Silver Carp *Hypothamichthys molitrix*; 26 species at Least Concern (LC); 19 species at Data Deficient (DD).

Table 3. Fish Species Composition in Son La Hydroelectric Dam

NO.	Scientific name	IUCN ver.2020-3
I.	**CYPRINIFORMES**	
I.1	COBITIDAE	
1	*Misgurnus anguillicaudatus* (Cantor, 1842)	LC
II.2	BALITORIDAE	
2	*Schistura chapaensis* (Rendahl, 1944)	
I.3	CYPRINIDAE	
3	*Acheilognathus tonkinensis* (Vaillant, 1892)	DD
4	*Bangana tonkinensis* (Pellegrin & Chevey, 1934)	VU
5	*Bangana lemassoni* (Pellegrin & Chevey, 1936)	DD
6	*Carassius auratus agenteaphthalmus* Nguyen, 2001	
7	*Carassius auratus* (Linnaeus, 1758)	LC
8	*Cirrhina molitorella* (Cuvier & Valenciennes, 1844)	NT
9	*Cirrhinus cirrhosus* (Bloch, 1975)	VU
10	*Chanodichthys erythropterus* (Basilewsky, 1855)	LC
11	*Culter flavipinnis* Tirant, 1883	DD
12	*Cyprinus carpio* Linnaeus, 1758	
13	*Elopichthys bambusa* (Richardson, 1844)	DD
15	*Garra orientalis* Nichols, 1925	LC
16	*Hemibarbus medius* Yue, 1995	
17	*Hemiculter elongatus* Nguyen & Ngo, 2001	DD
18	*Hemiculter leucisculus* (Basilewsky, 1855)	LC
19	*Hemiculter songhongensis* Nguyen, 2001	DD
20	*Ctenopharyngodon idellus* (Valenciennes, 1844)	LC
21	*Hypophthalmichthys harmandi* Sauvage, 1884	DD
22	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	NT
23	*Hypophthalmichthys nobilis* (Richardson, 1845)	DD
24	*Labeo rohita* (Hamilton, 1822)	LC
25	*Megalobrama terminalis* (Richardson, 1846)	LC
26	*Metzia formosae* Oshima, 1920	LC
27	*Carassioides cantonensis* (Heincke, 1892)	LC

NO.	Scientific name	IUCN ver.2020-3
28	*Mylopharyngodon piceus* (Richardson, 1846)	DD
29	*Onychostoma laticeps* Gunther, 1868	DD
30	*Opsariichthys bidens* Gunther, 1873	LC
31	*Opsariichthys songmaensis* Nguyen & Nguyen, 2000	DD
32	*Osteochilus salsburyi* Nichol & Pope, 1927	LC
33	*Puntioplites falcifer* Smith, 1929	LC
34	*Pseudohemiculter dispar* (Peters, 1880)	VU
35	*Semilabeo obscurus* Lin, 1981	LC
36	*Spinibarbus denticulatus* (Oshima, 1926)	LC
37	*Squaliobarbus curriculus* (Richardson, 1846)	DD
38	*Toxabramis hotayensis* Nguyen, 2001	DD
39	*Toxabramis houdemeri* Pellegrin, 1932	LC
40	*Xenocypris macrolepis* Bleeker, 1871	LC
41	*Xenocypris davidi* Bleeker, 1871	DD
II.	**CHARACIFORMES**	
II.1	PROCHILODONTIDAE	
42	*Prochilodus argenteus* Spix & Agassiz, 829	LC
II.2	CHARACIDAE	
43	*Colossoma branchypomus* (Cuvier, 1818)	LC
III.	**SILURIFORMES**	
III.1	BAGRIDAE	
44	*Tachysurus fulvidraco* (Richardson, 1846)	LC
45	*Hemibagrus guttatus* (Lacépède, 1803)	DD
46	*Hemibagrus microphthalmus* (Day, 1877)	LC
47	*Hemibagrus vietnamicus* (Mai, 1978)	DD
48	*Pelteobagrus tonkinensis* V.H. Nguyen, 2005	LC
49	*Pseudobagrus vachellii* (Richardson, 1846)	DD
III.2	SISORIDAE	
50	*Bagarius rutilus* Ng & Kottelat, 2000	DD
III.3	SILURIDAE	
51	*Silurus asotus* Linnaeus, 1758	LC
III.4	CLARIIDAE	
52	*Clarias gariepinus* (Burchell, 1882)	LC
53	*Clarias fuscus* (Lacépède, 1803)	LC
III.5	CRANOGLANIDIDAE	
54	*Cranoglanis bouderius* (Richardson, 1846)	VU
III.6	ICTALURIDAE	
55	*Ictalurus punctatus* (Rafinesque, 1818)	
IV.	**OSMERIFORMES**	
IV.1	SALANGIDAE	
56	*Neosalanx brevirostris* (Pellegrin, 1923)	DD
V.	**GOBIIFORMES**	
V.1	GOBIIDAE	
57	*Acentrogobius chlorostigmatoides* (Bleeker, 1849)	
58	*Rhinogobius albimaculatus* Chen, Kottelat & Miller, 1999	VU
59	*Rhinogobius boa* Chen & Kottelat, 2005	
60	*Rhinogobius giurinus* (Rutter, 1897)	

NO.	Scientific name	IUCN ver.2020-3
VI.	**SYNBRANCHIFORMES**	
VI.1	MASTACEMBELIDAE	
61	*Mastacembelus armatus* (Lacépède, 1800)	LC
VI.2	SYNBRANCHIDAE	
62	*Monopterus albus* (Zuiew, 1793)	LC
VII.	**ANABANTIFORMES**	
VII.1	ANABANTIDAE	
63	*Anabas testudineus* (Bloch, 1792)	LC
VII.2	OSPHRONEMIDAE	
64	*Trichogaster trichopterus* (Pallas, 1770)	
VII.3	CHANNIDAE	
65	*Channa maculata* (Lacépède, 1802)	LC
66	*Channa orientalis* Bloch & Schneider, 1801	VU
67	*Channa striata* (Bloch, 1797)	
VIII.	**CICHLIFORMES**	
VIII.1	CICHLIDAE	
68	*Oreochromis* sp.	LC
69	*Oreochromis* sp.	
IX.	**CYPRINODONTIFORMES**	
IX.1	POECILIIDAE	
70	*Gambusia affinis* (Gaird & Birard, 1853)	LC

Notes:

IUCN: Named in IUCN Red List ((IUCN Redlist version 2020-3).
EN: Endangered; VU: Vulnerable ; NT : Near Threatened; LC: Least concern;
DD: Data deficient;

Changes of freshwater fish species composition after the construction and operation of hydroelectric dam

According to the research of Nguyen Thi Hoa, 2011, in the research area, 98 species were counted, however, in this research, only 68 species were recorded (except for 02 recently imported species). Thus, the number of species has decreased markedly, up to 30,6%. Domestic and foreign research results on hydroelectric dams to species diversity also show a decrease in fish species composition diversity before and after the hydroelectric dam comes into operation. In the research area, there is the most obvious change in species group, fish species that prefer flowing water replaced by species prefer standing water, bottom-dwelling species replaced by floating species of Culter leucisculus subfamily such as: Brown ditch fish, Netuma thalassina, lake oily fish, river oily fish, Abramis brama and species that prefer deep water such as Mam, Mit, Bagridae. There are a number of species that disappear after the completion of Hoa Binh hydroelectric dam for a year or a few years: milkfish, Ochetobius elongatus, Tru, Cyprinus hyperdorsalis, and Cyprinus multitaeniata.

According to Mai Dinh Yen (1985), the composition of fish species in the Da River before the formation of Hoa Binh Lake was counted to have about 80 species; and after the formation of Hoa Binh Lake, Ho Thanh Hai et al (2001) identified 21 fish species, in which fish species migrating from the sea to spawn are no longer found in the lake area such as *Nematolosa nasus*, *Tenualosa reevesii*, *Clupanodon thrissa* and *Anguilla japonica*.

The appearance of Hoa Binh and Son La hydroelectric dams has prevented the migration routes of these fishes and they will certainly no longer appear in the research area. In the research of the authors' group, through interviews with people and samples collection during the research period, a serious decrease was also found in the species of *Semilabeo obscurus*, *Golden Sinilabeo Graffeuilli*, and *Sinilabeo lemassoni* in Son La lake-bed area. After 2 years of investigation, the research team only caught twice by local people. Three species of fish with high economic value, *Hemibagrus guttalus*, *Bagarius rutilus*, and *Elopichthys bambusa*, are being exploited strongly when being caught at a weight less than 1kg. Therefore, effective protective measures are needed to maintain numbers.

One of the main causes leading to the decline in species is the formation of hydroelectric dams, which completely change the water body. In fact, Hoa Binh river hydroelectric reservoir, Son La hydroelectric reservoir and Lai Chau hydroelectric reservoir will almost turn the entire Da River into a large hydroelectric lake inundating many spawning grounds. Da River lake has different characteristics in terms of physical, chemical and biological properties, so it is no longer a suitable habitat for many pre-inhabited species, and at the same time creates new habitats. In Son La, there is the most obvious change in species groups, fishes that prefer flowing water replaced by fish that prefer standing water, bottom-dwelling species replaced by floating species of Culter leucisculus subfamily such as: Brown ditch fish, Netuma thalassina, lake oily fish, river oily fish, Abramis brama and species that prefer deep water such as Mam, Mit, Bagridae. There are a number of species that disappear after the completion of Hoa Binh hydroelectric dam for a year or a few years: milkfish, Ochetobius elongatus, Tru, Cyprinus hyperdorsalis, and Cyprinus multitaeniata. Hoa Binh hydroelectric dam is a barrier to migration of species from the Red River or from the sea to the Da River, including Tenualosa reevesii and Clupanodon thrissa from the sea to spawning grounds at Bo waterfall, Rut stream (Hoa Binh), Van Yen (Son La).

In addition to reflecting the decrease in fish species composition diversity, the results of the research also add two species of exotic fish: Truong Giang drift fish (*Prochilodus argenteus* Spix & Agassiz, 829) and Channel catfish (*Ictalurus punctatus* Rafinesque, 1818) to the list of Da River fish in Son La area compared to research by Nguyen Thi Hoa in 2011

	
Scientific name: *Prochilodus lineatus* (Valenciennes, 1936) **Common name**: Truong Giang Drift fish **Distribution**: Domestic: Truong Giang drift fish is a species of fish imported from China through unofficial border trade into our country since 2003. World: South	**Scientific name**: *Ictalurus punctatus* (Rafinesque, 1818) **Common name**: Channel catfish, Bagridae **Distribution**: The channel catfish is a native fish of the Americas, distributed in the south of Canada and eastern North America as well as northern Mexico. Fish are imported and

America. Collected in June 2020	farmed in many countries. Channel catfishes were imported from China by unofficial border trade into the country in about 2000. Collected in April 2020

Figure 3. Some fish species on the Da River

The above results show that the impact of hydroelectric construction has changed the fish species composition in Son La hydroelectric lakebed. In addition, the change in the number and species composition is also subject to human impacts in indiscriminate exploitation and fishing, such as the use of bagua net, dredging, etc. and year-round exploitation makes little fish and spawning fish also be thoroughly exploited.

Discussion

The fish species composition in the Da River at Son La hydroelectric dam area was determined to include 69 species and 1 subspecies, belonging to 20 families and 9 orders. The dominant fish family in terms of species composition is the Cyprinidae family with 40 species and 1 subspecies. The predominance of Cypriniformes here shows typical freshwater properties. Out of a total of 69 fish species and subspecies in Son La hydroelectric area, there are 54 species in the IUCN Red List, 6 species at level of vulnerable VU, 2 species at level of near-threatened NT, 26 species at level of Least Concern LC , 19 species at level of Data Deficient DD.

The results showed that compared to the research of Nguyen Thi Hoa (2011)(14), the species composition in Son La hydroelectric lakebed was reduced by 30,6%.

Addition of Truong Giang Drift fish (*Prochilodus argenteus* Spix & Agassiz, 829) and Channel catfish (*Ictalurus punctatus* Refinesque, 1818) belonging to 2 orders and 2 families to the list of Da River fish in Son La area.

The combined impact of many factors after the formation of the Son La dam has led to a profound change in fish species composition in the research area before and after the construction of the hydroelectric dam, so effective long-term measures are needed to protect rare fish species as well as to build a legal framework for sustainable exploitation of aquatic resources on the Son La hydroelectric lakebed. Based on the natural - social characteristics, the current status of resources, especially the causes affecting fish resources in the research area, it is necessary to take some measures to protect biodiversity and fish resources as follows:

Develop a collection and treatment system of all kinds of waste, and well perform the cleaning of the hydroelectric lakebed before inundating.

Reorganize the wild fishery, put current fishing laws into social life, and perfect legal sanctions. In the immediate future, it is forbidden to use dredging nets, electric shocks, poisons, mines, etc. and destructive mining measures. Make a commitment to use the mesh size prescribed in the community. Regulate places to wash barrels, sprayers of pesticides and herbicides. Regulate the minimum water retention time in the field after spraying pesticides and herbicides. Regulate specific exploitation time and locations to avoid exploitation in spawning grounds and spawning season.

Promote propaganda and education such as: Providing necessary information about fish species in the Vietnam Red List and rare fish to the people; There are billboards, posters of propaganda on the protection of fish resources; Integrating the content of fish

resource protection in teaching preschool, primary and high school in schools in the research area.

Promote and improve the quality of sustainable development activities, including: Developing eco-tourism and conservation tourism; Forming village conventions, launching emulation and commitment to protect fish resources among villages and communes. Building typical examples of zoning and protecting natural fish resources; Research and strongly develop aquaculture, especially raising natural fish species with high economic value such as: Bagarius bagarius, Bagridae, Spinibarbus denticulatus, etc.; promote commercial farming of *Oncorhynchus mykiss* salmon in areas that have been identified as having suitable aquatic environments such as Bac Yen (Son La); maintain and regularly stock additional fingerlings (Carp, Grass carp, Bighead Carp) with reasonable quantity and rate into Da River lake. It is necessary to have a solution to restore and regenerate some rare and precious fish species such as Cyprinus, Ochetobius elongatus, Bagarius bagarius, Bagridae, Bangana lemassoni, Semilabeo notabilis,etc.; Promote the efficiency of afforestation and rational use of land resources in order to regulate water sources, reduce floods, and increase flow in the dry season; Early make plan of inland water conservation area in upstream of Da River taking the content of conservation of the original as the basic, conservation of displacement as secondary to zoning fish resources: expolitation area, strictly protected area and ecological restoration zone. Regulate fish species that are allowed to be caught, species that need to be protected, ban on fishing in spawning grounds during spawning season, and implement the Ordinance on protection of fish resources.

Conclusion

Overall, this study has clearly shown the influence of hydropower dam construction and operation on freshwater fish diversity at Son La Hydropower Dam. With the objective of studying the composition of fish species present at the hydroelectric dam after it is put into use, by method of document synthesis, analysis and field method and sample collection on the basis of data analysis from recent years, including 2019-2020. Research results have been found that the composition of freshwater fish here has decreased by 30% compared to before the construction of Son La hydropower dam. However, the fish species composition is still extremely diverse, including 69 species and 1 species belonging to 20 families and 9 orders and has a high degree of diversity in both levels and families. In this area, there are 53 species listed in IUCN Red List, 6 species in VU Near Endangered, 2 species in NT Near Threatened, 26 species in LC Least Concern, 19 species in DD Remaining data lack.

Research Limitations & Future Research

The limitation of the paper is that the study mainly focuses on the factors of hydropower plant construction affecting the diversity of fish species in the area. However, the decline in fish species diversity and fish numbers is also strongly influenced by human overexploitation around the Son La hydropower basin (Vörösmarty et al., 2010, Simonov et al., 2019).

Future research efforts may fully explore the factors affecting fish species diversity in the Son La hydropower basin. Besides, it is also possible to base on specific research on the impact of hydropower construction on fish species in this study to expand to other aquatic species. Thereby improving the level of biodiversity and conservation for organisms in the study area.

Acknowledgments

The article is the result of a project at the Ministry of Education and Training, Vietnam; code B2019-TTB; conducted in 02 years (2019, 2020) and I sincerely thank the Ministry of Education and Training for financial support, Northwestern University in supporting material facilities to carry out the study; functional departments of Quynh Nhai district and Muong La district, Son La province, Vietnam.

References

Anderson, E. P., Freeman, M. C., & Pringle, C. M. (2006). Ecological consequences of hydropower development in Central America: Impacts of small dams and water diversion on neotropical stream fish assemblages. *River Research and Applications*, *22*(4), 397–411. https://doi.org/10.1002/rra.899

Antonov, A.L.; Barabanshikov, E.I.; Zolotukhin, S.F.; Mikheev, I.E.; Shapovalov, M.E. (2019), Fishes of the Amur; *World Wide Fund for Nature (WWF)*: Vladivostok, Russia; p. 318.

Begossi, A., Salivonchyk, S. V., Hallwass, G., Hanazaki, N., Lopes, P. F. M., Silvano, R. a. M., … Pittock, J. (2019). Fish consumption on the Amazon: A review of biodiversity, hydropower and food security issues. *Brazilian Journal of Biology*, *79*(2), 345–357. https://doi.org/10.1590/1519-6984.186572

Bunn, S., & Arthington, A. H. (2002). Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management*, *30*(4), 492–507. https://doi.org/10.1007/s00267-002-2737-0

Cerny, J., Copp, G. H., Kovac, V., Gozlan, R. E., & Vilizzi, L. (2003). Initial Impact of the Gabíkovo Hydroelectric Scheme on the Species Richness and Composition of 0+ Fish Assemblages in the Slovak Flood Plain, River Danube. *River Research and Applications*, *19*(7), 749–766. Retrieved from http://www3.interscience.wiley.com/journal/106566740/abstract

Chevey, P., & Lemasson, J. (1937). Contribution à l'étude des poissons des eaux douces tonkinoises [Monographie ou série]. Retrieved May 13, 2021, from http://aquaticcommons.org/20967/

Cheng, L.; Opperman, J.J.; Tickner, D.; Speed, R.; Guo, Q.; Chen, D (2018). Managing the Three Gorges Dam to Implement Environmental Flows in the Yangtze River. *Front. Environ. Sci*, 6, 64.

Dams, rivers and responsibilities—Rights of people | VUFO - Vietnam NGO Resource Center. (n.d.). Retrieved May 13, 2021, from https://ngocentre.org.vnFishBase. (n.d.). Retrieved May 15, 2021, from https://www.fishbase.in/search.php

Eugene A. Simonov, Oxana I. Nikitina,and Eugene G. Egidarev (2019). Freshwater Ecosystems versus Hydropower Development: Environmental Assessments and Conservation Measures in the Transboundary Amur River Basin. *Environmental Science*, 11(8):1570, https:// doi:10.3390/w11081570

Gracey, E. O., & Verones, F. (2016). Impacts from hydropower production on biodiversity in an LCA framework—Review and recommendations. *The International Journal of Life Cycle Assessment*, *21*(3), 412–428.

Hari, R. E., Livingstone, D. M., Siber, R., Burkhardt-Holm, P., & Güttinger, H. (2006). Consequences of climatic change for water temperature and brown trout populations in Alpine rivers and streams. *Global Change Biology*, *12*(1), 10–26. https://doi.org/10.1111/j.1365-2486.2005.001051.x

Hirst, S. M. (1991). *Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia* (No. AEC--97-4/2093E-VOL.2). Applied Ecology Consultants. Retrieved from Applied Ecology Consultants website: http://inis.iaea.org/Search/search.aspx?orig_q=RN:25049709

Huang, Z.; Wang, L (2018). Yangtze Dams Increasingly Threaten the Survival of the Chinese Sturgeon. *Curr. Biol*, 28, 3640–3647

Kottelat, M. (2001). *Freshwater Fishes of Northern Vietnam*.

Liermann, C. R., Nilsson, C., Robertson, J., & Ng, R. Y. (2012). Implications of Dam Obstruction for Global Freshwater Fish Diversity. *BioScience*, *62*(6), 539–548. https://doi.org/10.1525/bio.2012.62.6.5

Moran, E.F.; Lopez, M.C.; Moore, N.; Müller, N.; Hyndman, D.W (2018). Sustainable hydropower in the 21st century. *Proc. Natl. Acad. Sci. USA*, 115, 11891–11898.

Mai Dinh Yen. (1978). *Freshwater fish identification in Northern provinces of Vietnam*. Ha Noi: Science and Technology Publisher.

Mai Dinh Yen. (1985). *List of Da River fish composition*.

Nguyen, T. H. T., Everaert, G., Boets, P., Forio, M. A. E., Bennetsen, E., Volk, M., … Goethals, P. L. (2018). Modelling tools to analyze and assess the ecological impact of hydropower dams. *Water*, *10*(3), 259.

Nguyen Thi Hoa. (2011). *Contributing to the research of fish in the Da river basin in Vietnam*. Hanoi National University of Education.

Pravdin. I. F, B. dịch của P. T. M. G. (1973). *nstruction on fish research. Science*. Ha Noi: Science and Technology Publisher.

Risley, J. C., Constantz, J., Essaid, H. I., & Rounds, S. A. (2010). Effects of upstream dams versus groundwater pumping on stream temperature under varying climate conditions. https://doi.org/10.1029/2009WR008587

Simonov, E. A., Nikitina, O. I., & Egidarev, E. G. (2019). Freshwater Ecosystems versus Hydropower Development: Environmental Assessments and Conservation Measures in the Transboundary Amur River Basin. *Water*, *11*(8), 1570. https://doi.org/10.3390/w11081570

Threatened Freshwater Fishes of the Mediterranean Basin Biodiversity Hotspot: Distribution, extinction risk and the impact of hydropower. Euronatur and Riverwatch. (n.d.). Retrieved May 13, 2021, from https://doi.org/10.7479/c6d4-2f73

Vietnam Electricity Corporation. (2007). *Report on environmental impact assessment on Son La hydroelectric work construction. Ministry of Industry and Trade*. Ha Noi: Vietnam Electricity Corporation.

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., … Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, *467*(7315), 555–561. https://doi.org/10.1038/nature09440

Zhang, P., Qiao, Y., Grenouillet, G., Lek, S., Cai, L., & Chang, J. (2021). Responses of spawning thermal suitability to climate change and hydropower operation for typical fishes below the Three Gorges Dam. *Ecological Indicators*, *121*, 107186. https://doi.org/10.1016/j.ecolind.2020.107186