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www.anthonys.ac.in
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Ratchet Effect and Particle Diffusion in an Underdamped Inhomogeneous Periodic Potential System

Shantu Saikia[1*] and Francis Iawphniaw[1,2]

[1] *Department of Physics, St Anthony's College, Shillong, Meghalaya*

[2] *Department of Physics, Assam Don Bosco University, Sonapur, Guwahati, Assam*

**Corresponding author: shantusaikia@anthonys.ac.in*

Abstract: Thermal fluctuations or noise assisted particle dynamics in a driven underdamped inhomogeneous periodic potential system is studied. This forms an archetypal model to study different Physical and Biological processes in the microscopic domain. The particles are shown to exhibit directed transport aided by these fluctuations without the application of any external bias. This phenomenon, also known as ratchet effect, is a counterintuitive phenomenon in which systems in the microscopic domain harnesses the energy of the random fluctuations to do constructive work. Also in the presence of random thermal fluctuations or noise, the particles undergo diffusion, the amount of which can be controlled by controlling the different parameters of the system. This can have important technological applications.

Keywords: *Ratchet effect, Particle Diffusion, Inhomogeneous systems*

1. INTRODUCTION

Any system at a finite temperature experiences minute and random fluctuations in temperature. The energy scales of these fluctuations are negligible in the macroscopic domain. However, in the microscopic domain, they are comparable to the energy scales of the system and play a dominant role in the system dynamics. Though conventionally considered to be unwanted, many systems and processes have been discovered where these fluctuations play a counter- intuitively constructive role. Stochastic Resonance [1 - 2], Noise - induced stability of states [3], Resonant activation [4], Noise - induced transitions [5], energy transport [6], intracellular transport [7], ratchet effect [8] etc. are a few such phenomena.

Noise assisted particle dynamics in periodic potential systems forms an archetypal model in explaining many different Physical and Biological phenomena. Ratchet effect [8] is one such phenomenon in which the system harnesses energy out of the random fluctuations. In the presence of an inherent asymmetry in the system, when driven out of equilibrium, the particles undergo a directed transport, without the application of any obvious external bias. This phenomenon of ratchet effect forms the key to understanding processes like intracellular transport and molecular motors [9], ad-atom

motion on the surface of crystals [10], super-ionic conductors [11], cancer cell metastasis [12], transport of ions through Nano-pores [13], the motion of vortices in superconductors [14] etc. Though initial interest in the study of ratchets was to understand the working of naturally occurring molecular motors [9], presently the study of ratchets have diversified to different other fields [10, 11, 14]. This also is inspired by the possibility of controlling and fabricating Nanodevices which can have tremendous technological applications [8].

Diffusion of Brownian particles in periodic potentials has been a vibrant topic of current research both in theory [16 – 19] and experiments [20 – 23]. Almost all particles in finite temperature systems experience diffusive behaviour. The possibility of controlling this diffusion by controlling the parameters of the system hints at the possibility of technological applications. For example, diffusion plays a major role in shaping the behaviour of different processes and systems including bio-related fields, energy conversion and storage (fuel and solar cells), separation membranes, and microfluidics [15 and references therein]. Surface diffusion also is found to play a major role in varied fields like microelectronics, catalysis, biophysics etc. A recent work found that the diffusion of Brownian particles in a periodic potential system with broken symmetry shows a non-monotonic dependence on temperature [24].

The present work is aimed at studying ratchet effect and diffusion of particles in a model under-damped inhomogeneous periodic potential system. Particle dynamics in such inhomogeneous system forms an important field of study, as many analogies are there in natural systems. This inhomogeneity could be structural, configurational, entropic, temperature-driven non-uniformities, etc. Our model considers inhomogeneity due to a space-dependent friction coefficient. In nature, there are innumerable examples of such inhomogeneous systems having space-dependent friction. For example, motor proteins moving along the periodic structures of microtubules [25], particles undergoing surface diffusion [26], in Josephson junctions, periodically varying frictional coefficients correspond to the term present in interference between the quasi-particle tunnelling and the Cooper pair tunnelling [27], ad-atom motion on the surface of a crystal of identical atoms etc. [28].

Particle transport in such inhomogeneous systems, driven away from equilibrium, therefore, has been an active field of research for the past few decades [29 – 48]. In these systems, the particles experience a non-uniform diffusion which may either be due to a space-dependent temperature [29–31] or due to a space-dependent friction [32–48]. Though over-damped approximation is valid for many systems, the various aspects of which have been reported in existing literature [32 – 35], inertial effects too, play an important role in many other systems [36–48].

Particles moving in a tilted under-damped periodic potential system were shown to exhibit an enhancement in mobility when there is a periodic modulation of the constant tilt [36]. Also in a similar model system, the particle current was found to be dependent on the various system parameters [37, 38]. When driven with a square drive, the system also shows dispersion-less particle

motion at intermediate time regimes [39, 40]. The duration of this regime can be controlled by controlling the different parameters of the system. This result can have important technological implications; for even under the influence of fluctuations particles undergo dispersionless motion. In the deterministic limit, the same system shows particle current with associated multiple current reversals [41]. The nature of the particle dynamics is sensitively dependent on the initial conditions of the system. The ratchet current and the efficiency of transport in this model system can be optimised by optimising the system parameters [42]. Also, the role of damping on the occurrence of Stochastic Resonance in an under-damped inhomogeneous periodic potential was studied [45].

In a recent work [48], the particle current and the quality of transport obtained in the model under-damped inhomogeneous ratchet [43 – 47] was compared to that of the more common ratchet model with an asymmetric potential [8]. A new model combining essential features of both these models was proposed which showed higher efficiency of transport.

The particle diffusion in an underdamped periodic potential is characterised by the diffusion coefficient. The dependence of the diffusion coefficient on the system parameters has been of interest, particularly, the non-monotonic dependence on the system temperature [50]. In this very recent work, this counterintuitive behaviour is explained based on the velocity dynamics.

In the present work, we will try to further study the phenomenon of ratchet effect and particle diffusion in the model underdamped inhomogeneous periodic potential system

2. THE MODEL

We study the motion of a particle in a periodic sinusoidal potential of the form $V(x)=-V_0\ (Sin(kx)+bSin(2kx)$The parameter $\gamma(x)=\gamma_0\ (1-\lambda Sin(kx+\phi)\ )$ of the system is periodic with the same periodicity as the potential and space-dependent, making the system inhomogeneous. The parameter λ determines the degree of inhomogeneity in the system.

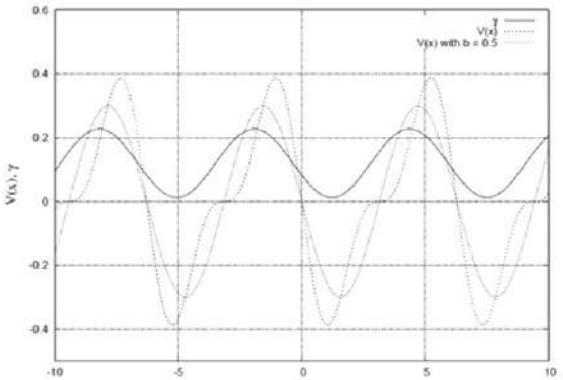

Figure 1: Plot of the potential V(x (with and without asymmetry)) and the friction coefficient γ(x) with a phase difference of

Fig. 1 shows the plot of the potential $V(x)$ (with and without asymmetry) and the space-dependent periodic friction coefficient $\gamma(x)$

An external periodic forcing $F(t)=F_0 \cos(\omega t+\phi_0)$ drives the system out of equilibrium. The net external forcing however, averages out to zero over a period of drive, making the system unbiased. There is a critical value of amplitude, $F_0=1$ at which the barrier to the particle motion in the periodic potential wells vanishes. So the value of F_0 is always kept less than one so that there is always a finite barrier to the particle motion. Any motion of the particle out of the wells, therefore, is a result of the random fluctuations acting on them which arises due to the finite temperature of the system.

The particle motion in such a system can be described by the one dimensional Langevin's equation. For a particle of mass 'm' moving in one dimension, the Langevin's equation can be written as

$$m\frac{d^2x}{dt^2} = -\gamma(x)\frac{dx}{dt} - \frac{\delta V(x)}{\delta x} + F(t) + \sqrt{\gamma(x)T}\xi(t) \quad (1)$$

In the above equation, T is the temperature of the system which is in units of the Boltzmann constant $\mathbf{k_B}$ $\boldsymbol{\xi(t)}$ represents the random fluctuations due to the finite temperature T and are Gaussian distributed. So they obey the statistics: $\langle\xi(t)\rangle=0$, $\langle\xi(t)\xi(t')\rangle=2\delta(t-t')$. To make the equation simpler to solve numerically and also to make it dimensionless, the parameters $(m, V_0, k$ are set equal to 1. With this choice of parameters, the dimensionless form of the equation can be written as

$$\frac{d^2x}{dt^2} = -\gamma(x)\frac{dx}{dt} + cos(x) + 2bcos2x + F(t) + \sqrt{\gamma(x)T}\xi(t) \quad (2)$$

In the dimensionless form too, the random variable $\xi(t)$ obeys the same statistics.

The symmetry of the system needs to be broken for obtaining finite particle current. This can be achieved in this model in two ways: due to inhomogeneity ($\lambda \neq 0$, where $n=0, 1, 2...$) and due to an asymmetric potential and due to an asymmetric potential $b\neq 0$ In this work, we introduce asymmetry in the system by using either of these frameworks or a combination of both.

The occurrence of net directed transport of the particles can be understood physically as follows. The particles trapped at the bottom of the potential well are kicked around by the thermal fluctuations. However, because of the space-dependent friction coefficient, the average friction on the right slope of the potential well is higher compared to the left slope. As a result, the particles will have more probability of escaping in the left direction from a potential well compared to the right leading to a net directed transport. Alternatively, the presence of higher friction means that the particle spends more time on an average on the right slope absorbing more energy from the fluctuations. So the probability of them escaping in the right direction will be more. Being a stochastic process, the final direction of the particle is probabilistic in nature and is determined by a competition between these two processes. Further, the inclusion of an asymmetry in the potential will add to the asymmetry in the probability of particle escape in either direction leading to higher current.

3. NUMERICAL RESULTS

The stochastic dynamics of the particle in the potential is described using the Langevin's equation as mentioned in the previous section. This equation is solved numerically using the Heun's Method [49], which is a second-order method to solve stochastic differential equations. The

particle is allowed to evolve over time from a given set of initial conditions i.e position and velocity (x(0), v(0)) and its trajectory is mapped over a long time to the order of (t $\sim 10)^5$ The dynamics of the particle is sensitively dependent on the initial conditions of the problem. So the initial conditions are chosen randomly from a Gaussian distributed set. The different runs of the particle with different initial conditions constitute an ensemble of trajectories. The average velocity of the particle is defined by the equation

$$V_{avg} = \left\langle \lim_{t\to\infty} \frac{x(t)}{t} \right\rangle$$

where ⟨.....⟩ represents averaging over ensembles and the limit t→∞ represents averaging over time.

Also the diffusion coefficient of the particle is given by the equation

$D=((\langle x^2(t)\rangle^2)/2-\langle t$

For physically relevant results, both ensemble averaging (over 50 ensembles) and time averaging ($t\sim 10^5$) is done.

Fig. 2 is a plot of the trajectory of a particle for the parameters specified for two different temperatures. As can be clearly seen, the particles clearly exhibit two kinds of motion - the locked state and the running state. In the locked state, the particles get trapped in a potential well and are kicked around within the well by the random fluctuations, and the running state when the particle shows extended periods of motion over the potential profile, without getting locked. The particle therefore during its motion, gets trapped in a well of the potential, remains there for some time, only to be kicked out of the well due to the thermal fluctuations. These motions are indeed due to the fluctuations, as in the absence of these fluctuations the particles would have remained trapped in a single well of the potential. If the temperature is very less the particles won't be able to overcome the finite barrier and will remain trapped in a single well. Apparently, with higher system temperature, there is more probability of the particles moving out of

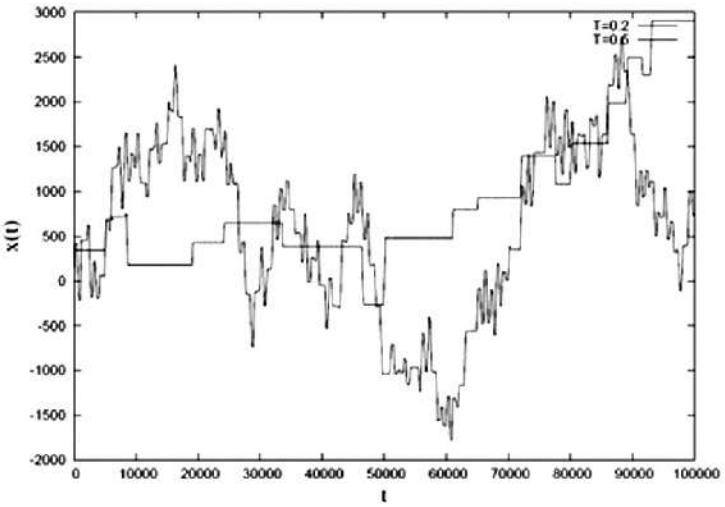

Figure 2: Plot of particle trajectories for T = 0.2, and 0.5; x(0)= -1.57, v(0) = 0, γ_0=0.20, λ = 0.9 ϕ= 0.35

the wells. Hence the duration of the particles being in the locked state reduces drastically as can be seen from the figure.

When the system is driven away from

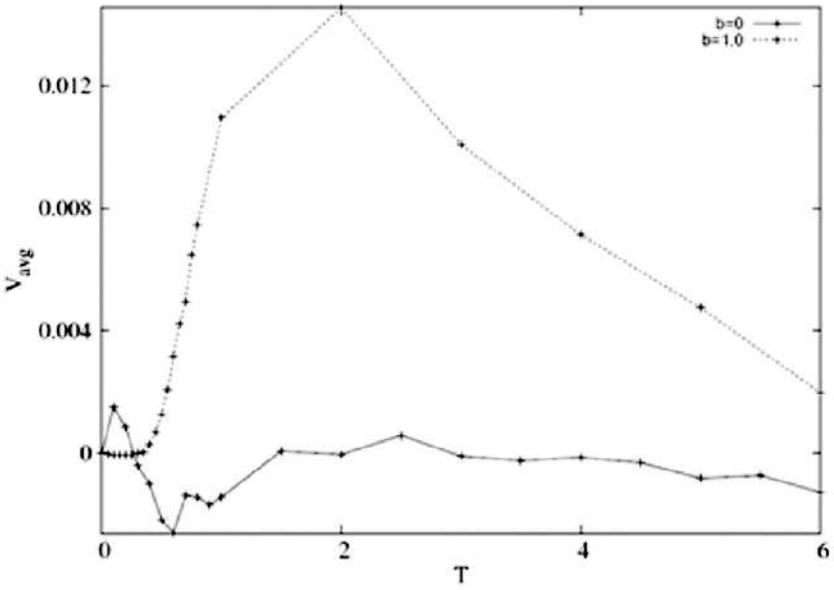

Figure 3: Plot of average particle velocity V_avg versus temperature for two different values of b; F_0 0.2, γ_0 = 0.12 λ0.9, = 0.35

equilibrium, the particles show a net directed transport characterized by the average particle velocity V_{avg} Fig. 3 shows the plot of V_{avg} in our model system as a function of temperature for the values of the parameters as shown. It is seen that even with a symmetric potential (b=0), the system exhibits particle current. This is due to the space dependent friction coefficient in the system which makes the system inhomogeneous. Along with the phase difference with the potential, the symmetry of the system is broken. The cause of asymmetry however being feeble, the velocity is undoubtedly less. Addition of a small asymmetry in the potential (b=1.0) enhances the average velocity of the particles to a great extent as can be clearly seen in the figure. The asymmetry in the potential makes the particle distribution about the bottom of the potential well further skewed, on top of that due to the inhomogeneity.

The plot for b=0 clearly shows a current reversal at T~0.25. This holds important implications to particle separation techniques where different particles move in different directions in a system as a function of the system parameters [51]. Another interesting observation is that for the plot of b=1.0, the plot of V_{avg} *vs* T shows a peaking at an optimal value of temperature. This is because, at lower temperatures, the energy gained by the particles from the fluctuations is less. So lesser number of particles can escape from the well leading to lesser average velocity. As temperature increases, more and more particles escape from the well leading to higher average velocity.

However, at very high temperatures, the effect of asymmetry leading to directed transport gets nullified by the higher amplitude fluctuations. So at an optimal temperature, the average velocity is maximum showing a resonance like behaviour. Importantly the addition of an asymmetry in the underlying potential is shown to enhance the particle transport to a great extent.

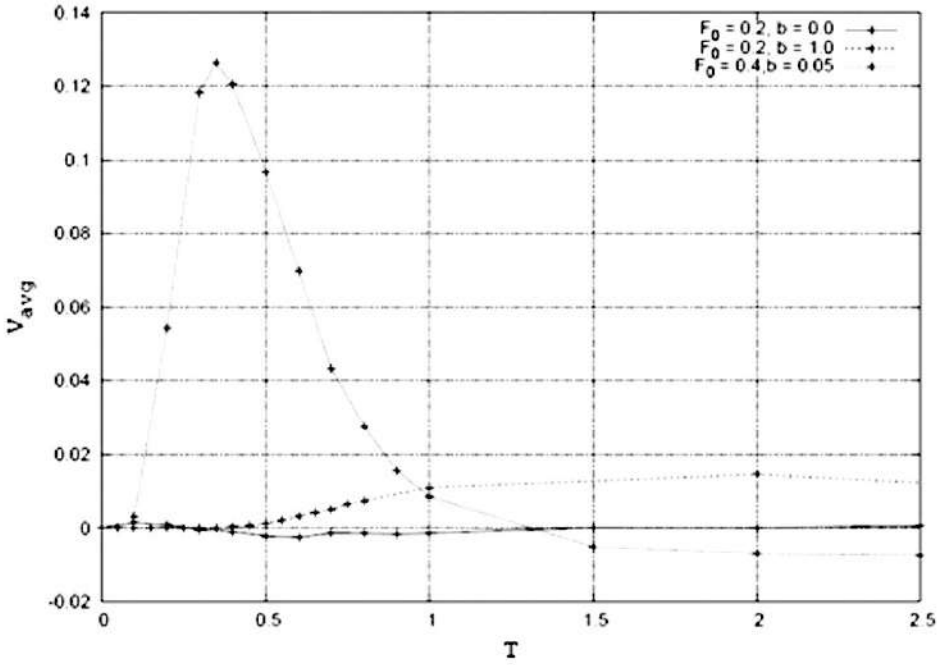

Figure 4: Plot of V_{avg} *vs* Temperature T for F_0=0.2 (b=0 and b=1.0) and F_0= 0.4; γ_0= 0.12, λ0.9, ϕ =0.35

Proper tuning of the system parameters can optimize the performance of this model ratchet leading to higher efficiency of transport. Fig. 4 shows that change of F_0 from 0.2 in the plot of Fig. 3 to 0.4, increases V_{avg} by more than 10 times.

As the particle evolves, the particles undergo diffusion which is characterised by the diffusion coefficient D. The diffusion experienced by the particles and the diffusion coefficient is critically dependent on the parameters of the system. Fig. 5 shows a plot of the diffusion experienced by the particles corresponding to the average velocity of the particles plotted in Fig. 4. The diffusion of the particles is found to vary with the parameters of the system like the amplitude of drive F_0, inherent asymmetry in the potential b and the temperature T This hints to controlling the diffusive behaviour of the particles in the model system by optimizing the system parameters.

4. DISCUSSION AND CONCLUSION

Particle dynamics in a model inhomogeneous periodic potential system has

been studied in this work. Most of the earlier works reported in existing literature have either used an asymmetric potential or an inhomogeneous friction coefficient with a phase difference with the potential. In this work, we have combined both these causes of asymmetry and have been able to enhance the degree of transport of the particles.

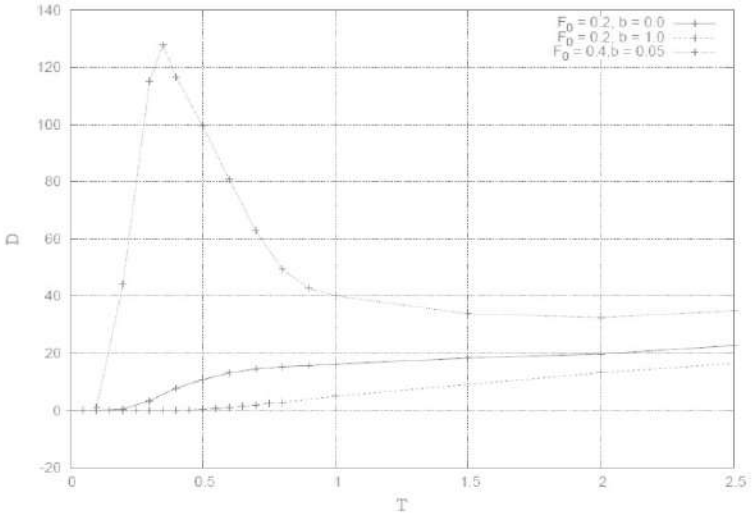

Figure 5: Plot of particle Diffusion (D) vs Temperature T;, $\gamma\_0 = 0.12$, $\lambda = 0.9$, $\phi = 0.35$

The particles undergo diffusion due to the random fluctuations in the system. We show that the degree of diffusion of the particles and their transport can be controlled by controlling the different parameters of the system. This hints to interesting technological applications in the field of particle separation techniques, drug delivery mechanisms, surface film technologies etc. as has been discussed in earlier sections. The parameter regime being vast, finalising an optimal numerical model with directly transferable technological possibilities is an open-ended problem. The present work is an addition to the vast domain of extensive and active research in this field, putting forward another aspect to the multitudes of possibilities.

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Cyprinid Fishes: An Overview on the Present Status in Meghalaya, India

Rupak Nath[1*] and S M Kharbuli[2]

[1,2]Department of Fishery Science, St. Anthony's College
Shillong-793001, Meghalaya, India
**Corresponding author: nathrupak10@gmail.com*

Abstract: Cyprinid fishes of Meghalaya were investigated from twin drainage basins Brahmaputra and Barak-Surma-Meghna. 27 cyprinid fishes under 14 genus and 7 sub families were recorded from rivers and reservoirs of four different gradient zones. The diversity of Cyprinid fishes was highest with 49% representation of Cyprinids at lower elevation Zone IV below 500 m above MSL and bio diversity indices estimated as H: 3.05, 1-D: 0.10. In contrary lowest diversity with 7% representation of fishes was observed at elevation 1501 to 2000 m above MSL in Zone I with bio diversity indices H: 0.25, 1-D: 0.57. Distribution of commercially important cyprinids under genus *Labeo, Systomus* and *Cirrhinus* were found to be restricted to rivers of Barak-Surma-Meghna drainage basin. Catch percentage of cyprinids indicates that 70% of fishes exhibit occasional occurrence and 30% as common occurrence. High percentage of occasional occurrence, low catch composition percentage and with restricted distribution of commercially important fishes to only certain rivers of Barak-Surma-Meghna drainage is an indication of depletion of cyprinid resources in the state and requires taking multi prong conservation measures to protect cyprinid fishes in Meghalaya.

Keywords: *Cyprinids, elevation, drainage basin, Meghalaya*

1. INTRODUCTION

Cyprinids are primary freshwater fishes and have major economic importance in world fisheries belong to order Cypriniformes and sub order Cyprinoidei. Cyprinids are most widely exploited fresh water fishes in the world either by fishing and farming [1, 3]. Hamilton, 1822 [7] described cyprinids under genus *Cyprinus*, with the typical features of the body are one back fin, which has rays, but both this and the pectoral fins are unarmed; with no teeth in either jaw; with the edge of the visceral cavity blunt. McClelland, 1939 [12] portrayed on Cyprinids in India and classified family Cyprinidae into three sub families namely Paenominae (herbivorous Cyprins), Sarcoborinae (Carnivorous Cyprins) and Apalopterinae (Loaches). Beavan,1877 [2] termed fishes under family Cyprinidae as 'Carp family' and opined that large number of fishes of India belong to this family and being confined to fresh waters. A total 1000 cyprinids species are reported from Asia and approximately 265 (27%) number of species described from India, which are exclusively confined to fresh water [9]. In total of 177 Cyprinid species belonging to 2 families, 4 subfamilies and 27 genera are reported from

the inland waters of India. Jhingran *et al* (1988), out of the 177 species 43 species are considered of great economic importance and grouped into three categories, major (500 mm and above), medium (250 mm-450mm) and small-size species with size 250mm [8]. Lakra *et al* 2010 [10] reported 120 fish species from India under threatened category and of which 55 species are cyprinoids. Family Cyprinidae under order Cypriniformes divided into eleven subfamilies: Acheilognathinae, Barbinae, Cyprininae, Danioninae, Gobioninae, Leptobarbinae, Leuciscinae, Paedocypridinae, Sundadanioninae, Tincinae, and Xenocypridinae [25]. In recent time Danioninae up graded to family Danionidae under the sub order Cyprinoidei and divided into sub family Chedrinae, Rasborinae, Danioninae and Esominae [29].

Meghalaya is a hilly state located in North eastern region of India and situated in between 25°02′N - 26°06′ N latitude and 89° 48′E to 92°52′E longitude. Rivers in the state either drained to Barak-Surma-Meghna in the south neighbouring country Bangladesh and Brahmaputra in the north adjoining state Assam of India. The drainage pattern of Meghalaya gives a worthwhile field for ichthyo faunal investigations particularly cyprinid resources. Meghalaya is one of the richest in fish genetic resources in India harbouring with approximately 165 fish species which are distributed at different gradient zones in different aquatic ecosystems of the state [19, 20]. A perusal of literature indicates that Cyprinid fishes are dominant group in Meghalaya representing 41 % in Khasi Hills and 40% in Garo hills [15, 27,15]. Ramanujam *et al* 2010 [17] recorded 68 fish species belonging to 45 genera, 20 families and 6 orders reported from Meghalaya where Cyprinidae was the most dominant group. Though Cyprinid represent economically important fishes but study on this group of fishes in Meghalaya is meagre. There are many problems confronting by the riverine fisheries including cyprinid fishes such as habitat destruction, polluting streams and rivers by sewage, detergents, Acid Mines Drainage (AMD). Use of toxic chemicals and herbal poison for large scale harvesting of fishes are responsible of fast declining of fish population in the state [5, 10, 12]. The main aim of the present study was to assess status of cyprinid fishes in Meghalaya in terms of their altitude wise diversity, distribution and catch composition percentage which will help to formulate conservation planning for these native fish resources.

2. MATERIALS AND METHODS

During the study period, field visits were conducted to collect fish samples from four different gradient zones of the selected rivers and reservoirs namely Myntang, Umiurem, Umiam, Nongmahir reservoir (Umtru) of Brahmaputra basins and Umngot, Umngi, Amlayee and Kynshi rivers of Barak-Surma-Meghna. The four gradient zones with their altitudinal coverage are: Zone I (2000-1501 m), Zone II (1500 – 1001 m MSL), Zone III (1000- 500 m MSL) and zone IV (below 500 m MSL) as described by Sen, 1984 [19]. Total twelve sites were selected for collecting fishes considering accessibility to the site and altitudinal coverage. Global Positioning System (Garmin etrex 30) was used to find out altitudes and co-ordinates of different locations. Biodiversity index estimated as per methods given by Shannon *et al* 1949 [24] and Simpson 1949 (23). Catch

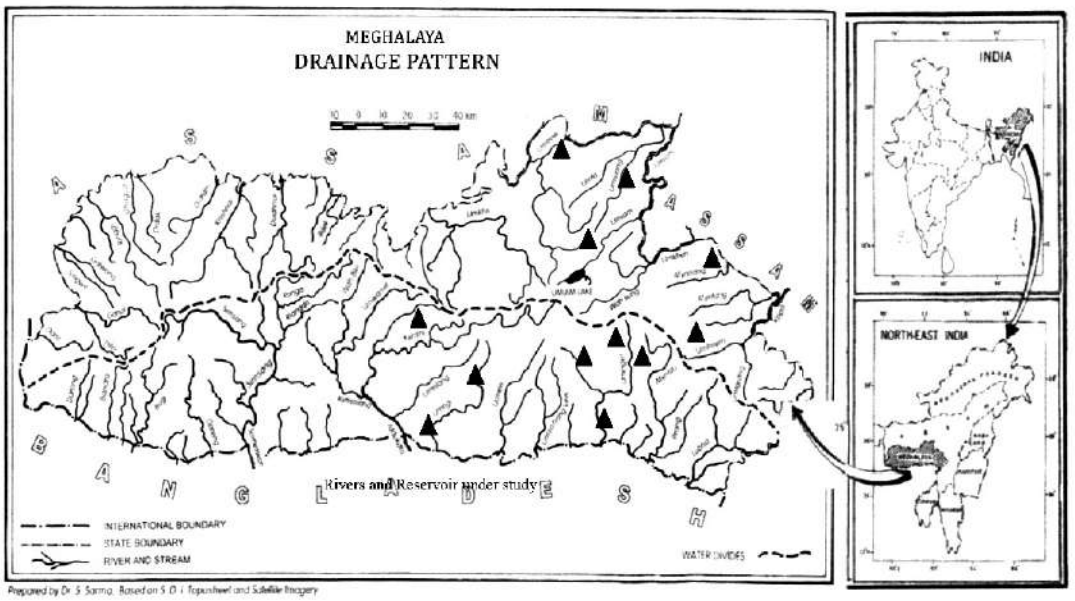
percentage and rank of species was determined for each species determined following Roux *et al* 2015 [18].

3. RESULTS

In total 27 cyprinid species represented by 14 genus and 8 sub families were recorded within altitudinal range 1491 m to 18m above mean sea level (MSL). The Cyprinids catch mainly comprised of fish groups Trout barb (*Barilius bendelisis, Salmostoma bacaila)*, Danionids (*Danio dangila, Danio rerio, Devario aequipinnatus, Devario devario*, and *Laubuka laubuca*), Labeonines (*Garra gotyla, Garra lamta, Garra lissorynchus, Garra nasuta*), Carp (*Cirrhinus reba, Neolissochilus hexagonolepis, Labeo angra, Labeo bata, Labeo calbasu, Labeo dyocheilus, Labeo gonius, Systomus sarana, Tor putitora, Tor tor*, small barb(*Pethia conchonius, Pethia shalynius, Pethia ticto, Puntius sophore*, Rasborines (*Rasbora daniconius*) and flying barb (*Esomus danrica*), The altitudinal distribution of the species revealed that Cyprinids such as *Neolissochilus hexagonolepis, Pethia shalynius, Danio rerio* showed widest distribution pattern from zone I to Zone IV but species *Cirrhinus reba, Labeo bata, Labeo calbasu, Labeo dyocheilus, Labeo gonius, , Systomus sarana, Tor tor, Tor putitora* showed restricted distribution at low altitude in zone IV and recorded only in Umngot river of Barak-Surma-Meghna drainage basin. Fishes under the genus *Garra* commonly known as sucker head was restricted within the altitudinal range 1500 m - below 500 m above MSL at Zone II to Zone IV. The altitudinal diversity analysis based on the diversity index gives more insight to distribution pattern of cyprinid species. Shannon- Weiner Index and Simpson diversity index were estimated minimum i.e. H = 0.25, 1-D = 0.57 at altitude 2000-1501 m above MSL in zone I and maximum with H = 3.05, 1-D = 0.10 at below 500 m above MSL in zone IV. Diversity and evenness of cyprinid species (EH) has shown increasing trend from zone I to zone IV i.e. 0.04 to 0.48 but Dominance of species (D) has decreased from 0.43 to 0.10 in zone I to zone IV respectively (Table 3). Percentage of catch composition of Danionids indicates that species *D rerio* has the highest catch percentage 19.0% followed by *Devario aequipinnatus* (15.5%), *Danio dangila*(8.5%), *Devario devario* (0.5%) and *Laubuka laubuca* (0.3%). Cyprinids of economic importance showed low catch percentage such as *L calbasu* (0.5%), *L dyocheilus* (0.3%), *L angra* (0.3%), *Tor tor* (0.3%), *Tor putitora* (0.3%) *C reba* (1.5%), and except species *N hexagonolepis* (10.8 %), *L gonius* (6.2%), *S sarana* (7.7%)and *L bata* (3.1%). Barbs are comprised of two genus namely *Pethia* and *Puntius* represented by fishes *Pethia shalynius, Pethia ticto, Pethia conchonius, Puntius sophore* with catch percentage 9.3%, 0,3%, 0.5% and 7.7% respectively. Fishes under genus garra are true hill stream fishes comprised of four species namely *Garra gotyla, G nasuta, G lissorynchus and G lamta* with low catch percentage within range 0.5% - 2.3%. Fishes like *B bendelisis, R daniconius, E danrica* and *S bacaila* has also exhibited low catch percentage.

TABLE 1: Water bodies and location of survey sites

Water bodies	Name of the location	Coordinates	Altitude (m) Above MSL	Basin
River Umngot	Lwang	N 25°31/48.24// E 92°03/09//	1188 m	Barak-Surma-Meghna
	Dawki	N 25°11/25.6// E 92°01/07.5//	45 m	Barak-Surma-Meghna
River Umngi	Lawblei	N 25°24/25.6/ E 91° 33/20//	1100	Barak-Surma-Meghna
	Balat	N 25°11/ 84// E 91° 22/58//	18 m	Barak-Surma-Meghna
Kynshi	Kynshi village	N 25°53/94// E 91°60/75//	1491 m	Barak-Surma-Meghna
Amlayee	Nongbareh village	N25° 10/ 23// E92° 47/ 02//	250 m	Barak-Surma-Meghna
Amsohkhri	Khonglah	N 25°14/48// E 92°00/36.6//	460 m	Barak-Surma-Meghna
Nongmahir-reservoir	Zero point	N 25°44/43.3/ E 91°48/45.0//	705 m	Brahmaputra
Umiam	Mawdun	N 25°37/52.6// E 91°51/37.2//	814 m	Brahmaputra
Myntang	Mynsoo	N 25°31/27// E 92°17/55//	1255 m	Brahmaputra
Umiurem	Shangpung	N 25° 22/ E 92° 43/	1275 m	Brahmaputra
Umraleng	Umraleng pool	N 25°20/5// E 91°52/51//	903 m	Brahmaputra



River & Reservoir understudy ▲

TABLE 2: Check list of cyprinids of Meghalaya

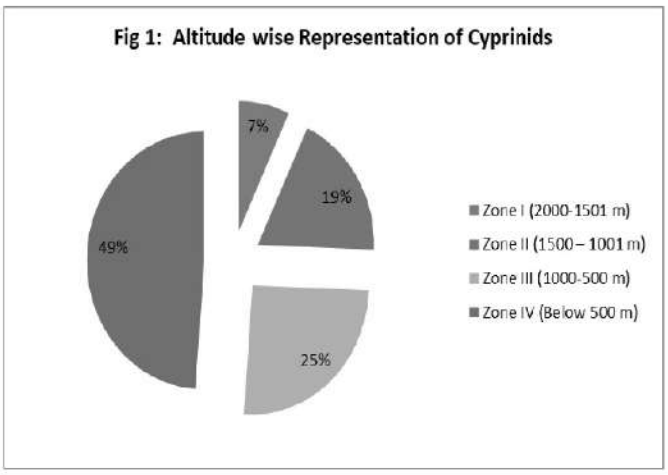
Order	**Cypriniformes**		
	Family		**Genus Species**
Sub order Cyprinoidei			
	Cyprinidae		
		Labeo	*Labeo calbasu*
			Labeo gonius
			Labeo angra
			Labeo dyocheilus
			Labeo bata
		Cirrhinus	*Cirrhinus reba*
		Systomus	*Systomus sarana*
		Garra	*Garra gotyla*
			Garra nasuta
			Garra lamta
			Garra lissorynchus
		Pethia	*Pethia shalynius*
			Pethia ticto
			Pethia conchonius
		Puntius	*Puntius sophore*
		Tor	*Tor putitora*
			Tor tor
		Neolissochilus	*Neolissochilus hexagonolepis*
	Danionidae	*Salmostoma*	*Salmostoma bacaila*
			BarīliusBarilius bendelisis
		Rasbora	*Rasbora daniconius*
			EsomusEsomus danrica
		Danio	*Danio dangila*
			Danio rerio
		Devario	*Devario aequipinnatus*
			Devario devario

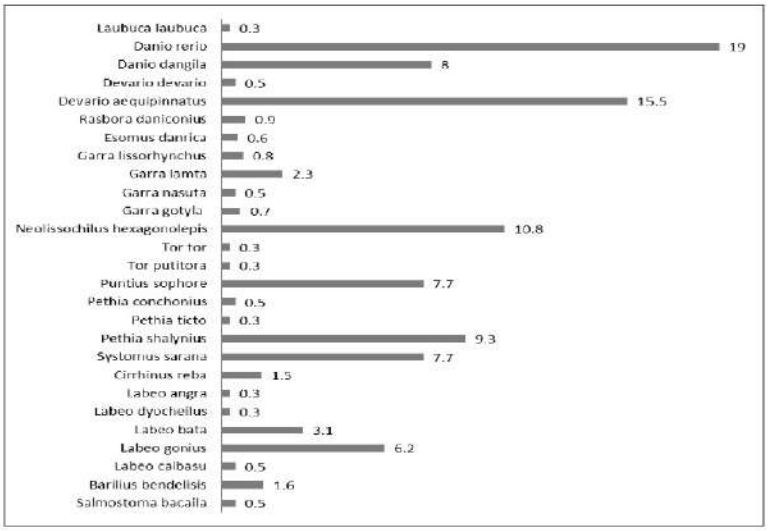
TABLE 3: Intra drainage distribution of cyprinid species

Barak-Surma-Meghna drainage		Brahmaputra drainage	
River Umngot	*Labeo gonius, L calbasu, L dyocheilus, L bata, Systomus sarana, Cirrhinus reba, Garra lamta, G lissorynchus, Tor tor, Tor putitora, Barilius bendelisis, Neolissochilus hexagonolepis, Pethia ticto, Puntius sophore, Pethia conchonius*	**Myntang**	*P shalynius,N hexagonolepis, D rerio, D dangila, G gotyla, B bendelisis, G nasuta,*
River Umngi	*L gonius, L calbasu, L dyocheilus, C reba, Pethia shalynius, D dangila, D aequipinnatus, D devario, P ticto, B bendelisis, G lamta, Salmostoma bacaila*	**Umiurem**	*N hexagonolepis, B bendelisis, D rerio, G nasuta, L laubuca*
River Kynshi	*P shalynius, N hexagonolepis, B bendelisis, D dangila, G nasuta*	**Umiam**	*N hexagonolepis, G gotyla, P sophore, D rerio, Tor tor, L angra*
River Amsohkhri	*G lissorynchus, G lamta, D aequipinnatus*	**Nongmahir**	*N hexagonolepis,Tor putitora, D aequipinnatus, P sophore,*
Amlayee (Fish Sanctuary)	*N hexagonolepis, G nasuta,*	**Umraleng**	*N hexagonolepis, R daniconius, E danrica*

TABLE 4: Species abundance and diversity of Cyprinid fish resources at different altitudes

Parameters	**Altitudinal Zone m above MSL**			
	Zone I 2000-1501	**Zone II 1500-1001**	**Zone III 1000-500**	**Zone IV Below 500**
No of species	3	7	8	19
Shannon-Wiener diversity index (H)	0.25	0.88	1.04	3.05
Shannon's equitability (EH)	0.04	0.14	0.16	0.48
Simpson's dominance index (D)	0.43	0.23	0.21	0.10
Simpson index of diversity (1-D)	0.57	0.77	0.79	0.90





4. DISCUSSION

Diversity of Cyprinids was observed highest in Zone IV at altitude below 500 m above MSL and minimum in Zone I at altitude 2000-1501 m above MSL (Table 2). This result is in agreement with previous findings of Yazdani 1977 Sen, 1984. Yazdani 1977 arranged streams of Khasi hills of Meghalaya into two groups based on elevation and reported that number of fishes in Khasi hills showed marked decline at elevation 1,219 m [28]. Sen 1984 reported that maximum percentage of fish from gradient zone IV followed by Zone III, Zone II and minimum in gradient zone I [19]. Danionids and small barbs such as *Danio dangila, D rerio, Devario aequipinnatus, Pethia shalynius, Puntius sophore* and *Esomus danrica* are also important as an aquarium fish has exhibited common occurrence with high catch percentage. These small fishes have good demand in rural area and also consumed by the native people of Meghalaya either in dry or fermented form. Cyprinids like *G nasuta, G lissorynchus, G lamta* and *G gotyla* inhabits hill streams has shown low catch percentage with occasional occurrence may be due to habitat destruction or over exploitation. It was observed that distribution of major segment of the economically important cyprinids species *viz., L gonius, L calbasu, L dyocheilus, S sarana, C reba* and *L bata* are restricted to rivers Umngot and Umngi of Barak-Surma-Meghna drainage basin at an altitude below 500 m above MSL. The previous analysis on distribution of Cyprinids revealed that the Indian Major Carps are found only below 500m and other carps and minnows are distributed widely covering all gradient zones [18]. This findings is an agreement of previous report on high number cyprinids (70%) in river Umngot at low altitude location in Dawki near Bangladesh border [13]. Meghalaya has witnessed a significant decrease in cyprinids fish from its water bodies due the over exploitation of fishes. Majority of Cyprinids catch composition has shown within the range 0.1- 4% qualify the category 'Occasional' occurrence in the state indicates that population of this important fish group is declining. Several anthropogenic stresses are responsible for declining population of cyprinids in Meghalaya. Use of destructive

fishing methods like use piscicidal plants derivatives is responsible of reducing fish population including cyprinids. Fishes under genus *Garra, Tor* and *Neolissochilus* prefers to take shelter under the crevices of rocks and buried under sand. Catching these fishes is not easy, so some time native people have resorted to illegal practice like poisoning water with plants derivatives like roots, bark, tender leaf and fruits are crushed and applied in the stream or river water to poison the fishes. Kharu (*Millettia achycarpa*) and Jaiur (*Zanthoxylu malatum*) are most commonly used plants to poison the fishes [4, 14, 22, 27]. Pollution and habitat destruction are also responsible of reduction of cyprinid population in the state. Pollutants like Acid Mine Drainage a product generated during coal mining and detergents used to wash clothes were also found to be liable of deteriorating water quality in streams and responsible of killing fishes in Meghalaya [25, 11]. Destructive fishing is banned and considered illegal in the state as per existing act namely 'The United Khasi-Jaiñtia Hills District Fisheries Act, 1954' and 'The Garo Hills District Fisheries Act, 1953. But due to inadequate enforcement of existing fishing regulation is resulted large scale exploitation of brooders and juveniles during breeding seasons in certain remote areas of the state.

5. CONCLUSION

Considering the present status of cyprinids resources in Meghalaya, it is alarming to note that restricted distribution of commercially important cyprinids belong to genus *Labeo, Tor, Cirrhinus* and *Systomus* in few rivers of Barak-Surma-Meghna drainage basin and coupled with low catch composition of other cyprinids having medium food value makes the entire group more vulnerable to anthropogenic stress. Prolonged unchecked exploitation of the cyprinid resources in the state has pushed many species like *Devario devario Pethia shalynius, Tor putitora, Tor tor* to the position in danger of extinction. This calls for an urgent need to bring in awareness among the fishers so that the cyprinids fisheries resources are optimally exploited. Protecting the habitat by taking both long term like in-situ conservation measures and short term measures like adequate enforcement of fisheries legislation to stop destructive fishing, catching brooders during breeding season can enhance wild population of cyprinids.

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Computational Overhead of a Novel Scheme for Identity Confidentiality on IoT Devices in 5G Mobile Networks

Hiten Choudhury[1]**

[1]*Department of Computer Science & Information Technology*
Cotton University, Guwahati, Assam
**Corresponding author: hiten.choudhury@cottonuniversity.ac.in*

Abstract: Mobile networks are becoming a preferred choice for the Internet of Things (IoT), due to its flexibility, broad coverage, increasing bandwidth, low latency and low subscription cost. However, a long-standing security issue in any mobile network across the various generations is identity confidentiality. In a recent technical specification standardised by 3rd Generation Partnership Project (3GPP) for 5G mobile network, a novel scheme called the Elliptic Curve Integrated Encryption Scheme (ECIES) is adopted to tackle the issue of identity confidentiality. While this mechanism seems to provide a reasonable solution for modern resource affluent smart phones, it's suitability for resource constrained IoT devices needs to be analysed. In this paper, we study the computational overhead of the ECIES on IoT devices.

Keywords: *Identity Confidentiality, 5G Mobile Network, IoT, Elliptic Curve Integrated*

1. INTRODUCTION

5G mobile network is becoming a popular backbone network for IoT deployments due to its flexibility, broad coverage, high bandwidth, low latency and low subscription cost [1][2]. Therefore, dealing with 'identity confidentiality' - a challenging security issue in mobile network across the various generations, has become important. If it is not dealt with aptly at this stage, things around us that are connected to the IoT may compromise critical information about the identity of their owner [3][4][5][6].

In mobile networks, a device has to be authenticated before any voice or data service may be offered to it. The authentication process requires transmission of the identity of the device through the wireless link, which is open for access to everybody including people with malicious intentions. Therefore, a common practice to avoid frequent transmission of the permanent identity of the device is the use of pseudonyms or short-lived temporary identities in place of the permanent identity. However, there are certain situations when the device is allowed to transmit its permanent identity in clear text through the radio link. Unfortunately, adversaries may take advantage of such situations to compromise the identity privacy of the owner of the device by tracking it using its identity.

Recently, an Elliptic Curve Integrated Encryption Scheme (ECIES) is introduced by

the Third Generation Partnership Project (3GPP) in its technical specification: TS 33.501, to tackle the issue of identity confidentiality on 5G mobile networks [7]. This scheme succeeds in providing a practical solution for identity confidentiality in present-day smart phones having substantial processing capability. However, it's suitability for resource constrained IoT devices requires further study. In this paper, the computational overhead of ECIES on an IoT device is analysed.

The rest of the paper is organised as follows. In Section 2, the status of identity confidentiality in earlier mobile networks up to 3G and 4G is presented. In Section 3, the status of identity confidentiality in 5G mobile networks with regards to the introduction of the novel ECIES is presented. In Section 4, we analyse the computational overhead of the ECIES in IoT devices (specifically, using the Arduino uno microcontroller). In Section 6, we conclude the paper.

2. IDENTITY CONFIDENTIALITY IN 3G/4G

There are three major stakeholders in a mobile network, viz., the User Equipment (UE), the Serving Network (SN), and the Home Network (HN). The communication medium between the UE and the SN is wireless and hence is considered vulnerable. To ensure identity confidentiality, the identity of the subscriber, i.e., the International Mobile Subscriber Identity (IMSI), should never be transmitted in clear text over the wireless link. Therefore, in 3G mobile network, short lived pseudonyms called TMSIs (Temporary Mobile Subscriber Identity) are transmitted instead of the IMSI. The pseudonyms are assigned to the UE by the SN through confidentiality protected channel established during authentication and key agreement. A mapping between a TMSI and the corresponding IMSI is maintained at the SN. However, in spite of this arrangement there is a provision that allows transmission of the IMSI through the radio interface [8]. This provision exists as a backup mechanism to overcome the following situations (TS 33.401 Section 5.1.1 [8]).

- During the first authentication, when the UE does not have a valid TMSI.
- When the SN cannot map a TMSI with the corresponding IMSI.
- When the current SN cannot obtain the TMSI-to-IMSI mapping from the previous SN.

The downside of the above provision is that it gives a fake/malicious SN scope to compromise identity confidentiality by requesting the devise for its IMSI in the pretext of not being able to map a received TMSI to its corresponding IMSI. In 4G mobile network, the scenario is similar. The pseudonyms used here are called Globally Unique Temporary Identity (GUTI). The only difference with 3G is the fact that the pseudonyms used in 4G are assigned to the UE by the HN instead of the SN, to have better home control. Mapping between the GUTI and the IMSI is maintained at the HN. Like 3G, in 4G also the vulnerability with reference to identity confidentiality is similar because the backup mechanism of transmitting the IMSI in clear text is same as 3G networks.

3. IDENTITY CONFIDENTIALITY IN 5G

In 5G, the UE's IMSI: also called Subscriber Permanent Identifier (SUPI), is

never sent in clear text over the radio network [9] [7]. Instead, a randomized GUTI is used for identity presentation over the radio link. Fresh GUTIs are assigned periodically to the UE through the secured channel established at the end of a successful authentication. In rare situations, when a fresh GUTI is not available, an encrypted Subscriber Concealed Identifier (SUCI) is transmitted instead of the SUPI. This security feature may be considered as a significant improvement for identity confidentiality in 5G over prior generations of mobile networks such as 4G. The SUCI is a confidentiality preserving identifier that contains the concealed SUPI. The UE generates a SUCI by encrypting the SUPI using an Elliptic Curve Integrated Encryption Scheme (ECIES) [7]. For smooth functioning of ECIES, the public key of the Home Network is securely provisioned in the USIM through an alternate channel during USIM

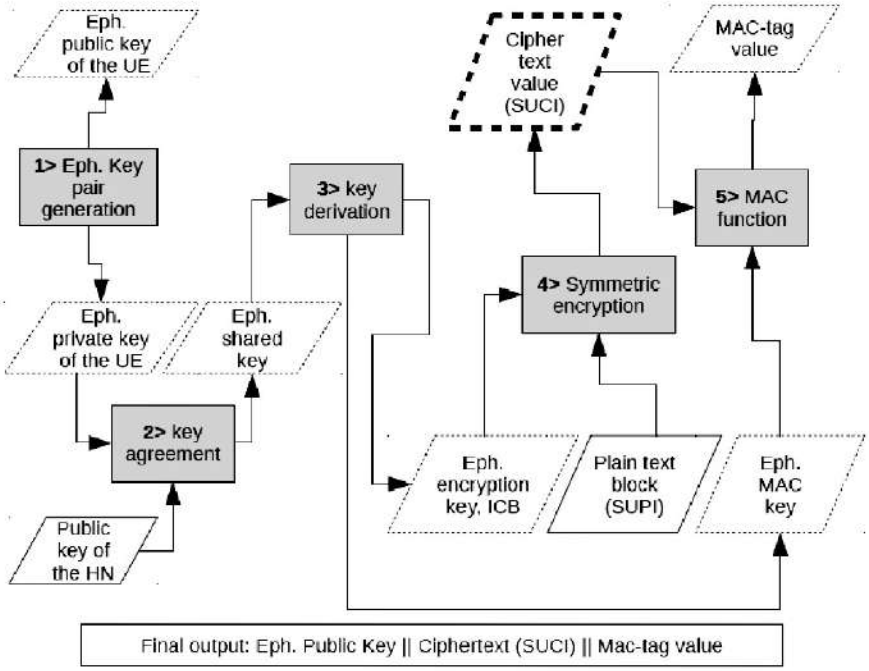

Figure 1: Generation of a SUCI from a SUPI using ECIES

distribution. The steps involved in the process of generating a SUCI from a given SUPI using ECIES are as follows (Figure: 1).

1. The UE generates a pair of Ephemeral Private Key and Public Key using ECC.
2. From the Ephemeral Private Key of the UE and the public Key of the HN (provisioned by the HN in the USIM), the UE generates an Ephemeral Shared Key using Deffie-Hellman primitive [10].
3. Using a key derivation function, two separate keys are generated from the Ephemeral Shared Key viz., an Ephemeral Encryption Key and an Ephemeral MAC (Message Authentication Code) Key.
4. Taking the Ephemeral Encryption Key

and an Initial Counter Block (ICB) as input, the UE encrypts the Plain Text (SUPI) to generate the Cipher Text (SUCI). A symmetric block cipher like AES is used for the encryption.

5. Taking the Ephemeral MAC Key as input, the SUCI is then tagged by generating a MAC-tag value using a standard HMAC function like SHA256.

6. The final output of this process is: [Ephemeral Public Key of UE, Ciphertext (SUCI), MAC-tag value], which is communicated to the HN through the SN.

When the HN receives [Ephemeral Public Key of UE, Ciphertext (SUCI), MAC-tag value], it extracts the corresponding SUPI from the received SUCI. The steps

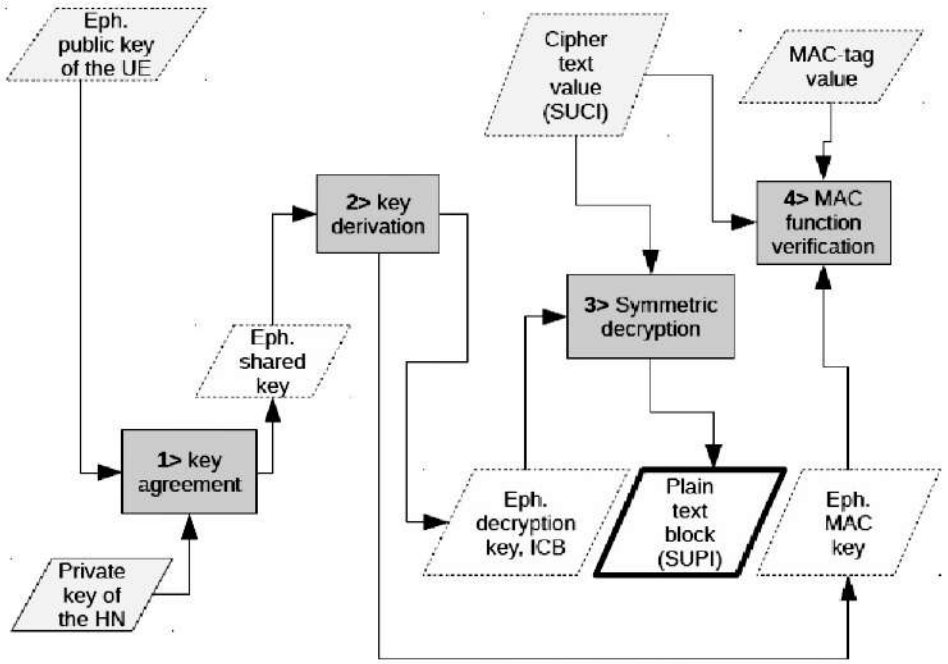

Figure 2: Extraction of SUPI from SUCI using ECIES

involved in extracting the SUPI from a given SUCI are as follows (Figure: 2).

1. From the Ephemeral Public Key of the UE and the Private Key of the HN, the HN generates an Ephemeral Shared Key using Deffie-Hellman primitive.

2. Using a key derivation function, two separate keys are generated from the Ephemeral Shared Key viz., an Ephemeral Decryption Key and an Ephemeral MAC (Message Authentication Code) Key.

3. Taking the Ephemeral MAC Key as input, a MAC verification function verifies the authenticity of the received Cipher Text (SUCI) by generating a fresh MAC-tag value and comparing it with the received MAC-tag value.

4. Taking the Ephemeral Decryption Key and an Initial Counter Block (ICB) as input, the HN decrypts the Cipher Text

(SUCI) to find the Plain Text (SUPI).

4. The final output of this process is: [Plaintext (SUPI)], which is used by the HN to identify the subscriber and to complete the rest of the authentication process.

5. COMPUTATIONAL OVERHEAD

In this section, we analyse the computation cost of Elliptic Curve Integrated Encryption Scheme (ECIES) proposed by 3GPP for improved identity confidentiality in 5G mobile networks. For the analysis, let us assume 't_{ECC}' to be the time required to generate a ECC public-private key pair, 't_{DH}' to be the time required for Deffie-Hellman primitive to generate a shared secret; '$t_{SC.en}$' to be the time required for encryption using a symmetric cypher; '$t_{SC.dc}$' be the time required for decryption using a symmetric cypher; and 't_{hash}' be the time required to execute a hash function. A summary of all the symbols along with their descriptions is presented in Table 1. As explained in Section 3, the amount of time required by the UE to generate the SUCI from a given SUPI may be expressed mathematically in the form of the following

Table 1. Symbols used in the analysis

Symbols	Description
t_{ECC}	Time required to generate a ECC public-private key pair.
t_{DH}	Time required for Deffie-Hellman primitive to generate a shared secret.
$t_{SC.en}$	Time required for encryption using a symmetric cypher.
$t_{SC.dc}$	Time required for decryption using a symmetric cypher.

To have a fair idea on the amount of time required to generate a SUCI from a given SUPI in a IoT device, the 'Arduino Uno Rev3' is used. Arduino Uno Rev3 is a widely used microcontroller board in the IoT domain that is based on the 8-bit ATmega328P microchip (Figure: 3). It has 32KB of flash memory, 2KB SRAM and 1KB EEPROM with a clock speed of 16Mhz. For implementing the programs, the following header files and Arduino libraries were used.

Figure 3: An Arduino Uno Microcontroller board based on ATmega328P.

sha256.h: Available in Arduino Cryptography Library (https://www.arduinolibraries.info/libraries/crypto)
.uECC.h: Available in Arduino micro-ecc library (https://www.arduinolibraries.info/libraries/micro-ecc).
AESLib.h: Available in Arduino AES Library (https://www.arduinolibraries.info/libraries/aes-lib).

The cryptographic operations that are used in ECIES along with their execution time in the Arduino Uno Rev3 microcontroller are listed below and graphically presented in Figure 4. The average execution times in microseconds (μs) for these cryptographic operations were computed by writing necessary programs and using the function: '*unsigned long int time = micros ()*'.

ECC Key Pair Generation (ECC Key Pair Gen.) = $1073796\,\mu s$

Deffie-Hellman Shared Key Generation (DH Shard. Key Gen.) = $1071064\,\mu s$

AES Encryption (AES Enc.) = $2172\,\mu s$

AES Decryption (AES Dec.) = $2572\,\mu s$

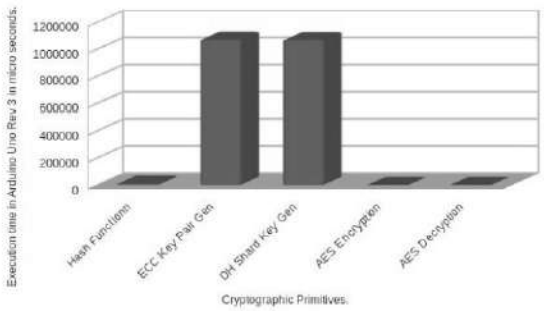

Figure 4: Execution time of different cryptographic functions in Arduino Uno.

Based on the execution times of the above cryptographic functions, the execution time of the ECIES in the 'Arduino Uno Rev3' may be derived from Equation 1 as follows.

$$T_{UE} = t_{ECC} + t_{DH} + t_{SCen} + t_{SCen}$$
$$= 1073796\mu s + 1071064\mu s + 2172\mu s + 12736\mu s$$
$$= 2159768\mu s$$
$$= 2.159768s \quad (2)$$

6. DISCUSSION

Since identity presentation precedes access security, identity confidentiality in mobile networks up to 4G, has been a challenging issue. A natural solution to this problem would have been the use of public key cryptography, which has been avoided because it was considered computationally intensive for the resource constrained mobile devices. Advent of ECC and many folds improvement in processing capability of smart phones have led 3GPP to recently incorporate an Elliptic Curve Integrated Encryption Scheme for protection of identity confidentiality in 5G mobile networks. However, there was a requirement to study the overhead of this mechanism in resource constrained IoT devices. In this paper, we calculated the computational overhead of the ECIES in a popular microcontroller board 'Arduino Uno Rev3' that is used in the IoT domain. It was found that the ECIES introduces approximately 2 additional seconds to the authentication process, when executed in 'Arduino Uno Rev3'. An additional 2 seconds is a significant delay that is added to the authentication time. Therefore, it may be inferred that in spite of ECIES being a step forward in improving identity confidentiality in mobile networks, the requirement to formulate a mechanism that is more efficient in the IoT domain continues to exist.

6. CONCLUSION

Identity confidentiality is a challenging issue in mobile networks. Recently, a novel scheme called ECIES is adopted in 5G mobile networks that seems to provide a concrete solution to this long-standing issue. Since this solution uses elliptic curve based public key cryptography and is originally designed for resource affluent present-day smart phones, there is a need to access its computation overhead in IoT devices. In this paper, we compute the cost of execution of ECIES in 'Arduino Uno Rev3', a widely used microcontroller in IoT. It is found that when ECIES is executed in Arduino Uno Rev3, a latency of 2 seconds (approximately) is introduced. Therefore, it is felt that there is a requirement to further improve this scheme so that the latency may be reduced.

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Prospect of Small Indigenous Fish (SIF) Culture in Assam

Parinita Borgohain[1]* and Shyama Prasad Biswas[1]

Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam-786004
**Corresponding author: parinitatsk88@gmail.com*

Abstract: Assam is an abode of hundreds of small indigenous fish species (SIF) which are used as highly nutritious food and preparation of traditional dishes by the ethnic groups. As most of the population are fish eaters, the demand for fish is ever increasing. Rampant fishing, destruction as well as shrinkage of fishing habitats and above all, our ignorance about the true value of so called 'trash fish' have already wiped out many of our indigenous small fish species. People in general, are not aware of the importance of small fish other than their food value. The sub-tropical climate and rich water resources of the state provide good opportunity for small fish culture. This status paper highlights the importance of SIF as food, aesthetic, bio-controlling agent and therapeutic values and also their rearing prospects in captive conditions.

Keywords: *Small Indigenous Fish (SIF); nutritional and ornamental values; bio-controlling agent; aesthetic value; rearing prospects; Assam*

1. INTRODUCTION

By the turn of the 20th century, policy makers around the globe were deeply worried about the food security for the burgeoning population growth in the third world in 2050 and beyond. With fish production growing at an average annual rate of 5.7% per year since 2000 [1], aquaculture has already been recognised as a rapidly expanding sector. It has been identified as potential sector that have a great role to feed the people of the developing countries. Although there is a great regional disparity in the aquacultural production across the globe, the inclusion of suitable small sized fish species which are overlooked in many countries for commercial reason can boost diversification and expansion of aquaculture.

The Brahmaputra and the Barak with their 53 prominent tributaries cover 4,820km^2 water spread area in Assam. Apart from riverine resources, there are low-lying areas, wetlands, derelict water bodies, tanks, beels and ponds covering 2.86 lakh ha of water area which, by any standard, a huge water resource for fish production. However, against the estimated demand of 3.42 lakh mt, the state produced 3.07 lakh mt of fish only in 2016-17 [2]. Lack of management and almost zero investment on capture fisheries, the yield per unit area from wetland ecosystem is moderate and often very erratic [3]. Rampant fishing, destruction as well as shrinkage of fishing habitats [21]and above all, our ignorance about the true value of so called 'trash fish' have already wiped out many our indigenous small fish species. People in general, are not aware of the

importance of small fish other than their food value. At present, the gap between supply and demand of fish production in Assam is estimated to be 0.5 lakh mt/year. The gap is widening with every passing year as fish yield from natural water bodies is almost stagnant in recent decades for one reason or other [13, 21]. SIF culture on a commercial scale, as on date, is non-existent in Assam. Therefore, an analysis is done mainly focussing on the scope and challenges of small wild fish species which are either food, ornamental, medicinal or larvicidal in nature. The present communication is an attempt to assess the prospects of small indigenous fish (SIF) culture as a measure of enhancing food security and boost employment generation.

2. UTILITIES OF SMALL INDIGENOUS FISH (SIF)

Out of 765 indigenous freshwater fish species documented by NBFGR in India, 450 species were considered as SIF [4]. Northeast India is said to have maximum diversity of SIF's and was estimated to have 33% of the total indigenous fish species of the country [4, 5]. SIF's are the cheapest, highly nutritional foods that are easily available to the people of rural Assam. Apart from being rich in micronutrients [6], many SIF's of the state have aesthetic and other usage [Table 1]. The utility of locally available small fishes in the state is described as follows:-

2.1 As food

In a state where 95% population being fish consumers [7], different types of fish preparation including boiling, steaming, frying, smoking and roasting are popular among different ethnic groups. A good number of special ethnic dishes such as *Napham, Nakham, and Nichaow* are prepared from fermented SIF's product by Bodo, Garo and Rabha tribes respectively [8]. *Chucha, Hidal, Hukoti, Nah-grain, Namsing* are some other ethnic SIF food products of Assam which are prepared from *Amblypharyngodon mola, Anabas testudineus, Cabdio morar, Botia*spp., *Channa* spp., *Chela laubuca, Danio* spp, *Gudusia chapra, Puntius* spp. and*Trichogaster* spp. [9]. Ethnic groups of Assam (Ahom, Chingfou, Moran and Motok) prepare the dry fish product, *Hukoti* and believe it to have anti-malarial property. *Hukoti* is also used as painkiller among these ethnic groups. However, authenticity of these traditional beliefs is yet to be scientifically verified [10]. Ulla *et al.* [11] found almost all-important elements needed for a healthy diet in local dry fish preparations.

2.2 As ornamental

Indian ornamental fishes have high demand in international market. Out of the 217 fish species recorded from Assam, 150 fish species are stated to have ornamental values [12]. Sarma *et al.* [13] and Mahapatra *et al.* [14] also enlisted the ornamental fishes of the region. It has been reported that 70 ornamental fish species from upper Assam have commercial value in overseas and domestic market [15].Goswami and Zade [16] listed a good number of indigenous small fish species of the Brahmaputra valley of Assam. Very recently about 70 ornamental fish species has been reported from beels of Assam by Biswal *et al.* [17].

2.3 As bio-controlling agent

Larvivorous fish like *Poecilia reticulate* and *Gambusia affinis* are used worldwide as

bio-controlling agents for controlling mosquito larvae. However, there are serious ecological concerns about the use of alien fish for mosquito control [18]. Fish not only forms an important biotic component but it can also serve as a bio-indicator in any aquatic ecosystem.

The presence or absence of diverse kind of fish species inhabiting a particular reach along with other organism can be used as the indicator for assessing the general health status and habitat condition of a water body. Phukon and Biswas [19] recommended utilization of *Trichogaster fasciata, Channa gachua* and *Puntius sophore* for bio-controlling of mosquito larvae in integrated pest management programme.

2.4 As therapeutic value

Some of the indigenous small fishes like *Chaca chaca, Glossogobius giuris,* and *Monopterus cuchia* have medicinal values. In some areas in Assam, people use murrels *(Channa spp)* against a variety of ailments.

Table 1: Economical values of SIF commonly found in wetlands of Assam

Sl. No	Species Name	Edible	Ornament	Larvicida	Therapeu
1	*Acanthocobitis botia* (Hamilton, 1822)		✓		
2	*Amblypharyngodon mola* (Hamilton, 1822)	✓	✓	✓	✓
3	*Anabas testudineus* (Bloch, 1792)	✓	✓		✓
4	*Aplocheilus panchax* (Hamilton, 1822)		✓	✓	
5	*Badis badis* (Hamilton, 1822)	✓	✓	✓	
6	*Barilius bendelisis* (Hamilton, 1807)	✓	✓	✓	
7	*Botia dario* (Hamilton, 1822)	✓	✓		
8	*Botia rostrata* (Günther, 1868)	✓	✓		
9	*Cabdio morar* (Hamilton, 1822)	✓	✓		
10	*Chanda nama* (Hamilton, 1822)	✓	✓	✓	
11	*Channa aurolineata* Pethiyagoda & Kottelat, 1994	✓	✓	✓	
12	*Channa gachua* (Hamilton, 1822)	✓	✓	✓	✓
13	*Chela cachius* (Hamilton, 1822)	✓	✓	✓	
14	*Danio rerio* (Hamilton, 1822)	✓	✓	✓	
15	*Esomus danricus* (Hamilton, 1822)	✓	✓	✓	✓
16	*Glossogobius giuris* (Hamilton, 1822)	✓	✓	✓	✓
17	*Gudusia chapra* (Hamilton, 1822)	✓	✓		✓
18	*Heteropneustes fossilis* (Bloch, 1794)		✓	✓	
19	*Lepidocephalus guntea* (Hamilton, 1822)	✓	✓		
20	*Macrognathus aculeatus* (Bloch, 1786)	✓	✓		
21	*Macrognathus pancalus* (Bloch & Schneider, 1801)	✓	✓		
22	*Macrognathus pancalus* (Hamilton, 1822)	✓	✓		
23	*Mystus bleekeri* (Day, 1877)	✓	✓	✓	
24	*Mystus tengara* (Hamilton, 1822)	✓	✓	✓	
25	*Mystus vittatus* (Bloch, 1794)	✓	✓		
26	*Osteobrama cotio* (Hamilton, 1822)	✓	✓		
27	*Parambassis ranga* (Hamilton, 1822)	✓	✓		
28	*Pethia conchonius* (Hamilton, 1822)	✓	✓	✓	
29	*Pethia gelius* (Hamilton, 1822)	✓	✓	✓	
30	*Pethia phutunio* (Hamilton, 1822)	✓	✓	✓	
31	*Pethia ticto* (Hamilton, 1822)	✓	✓	✓	
32	*Poecilia reticulata* Peters, 1859		✓	✓	
33	*Puntius chola* (Hamilton, 1822)	✓	✓	✓	
34	*Puntius sophore* (Hamilton, 1822)	✓	✓	✓	✓
35	*Rasbora daniconius* (Hamilton, 1822)	✓	✓	✓	
36	*Systomus sarana* (Hamilton, 1822)	✓	✓	✓	
37	*Trichogaster fasciata* Bloch & Schneider, 1801	✓	✓	✓	
38	*Trichogaster lalius* (Hamilton, 1822)	✓	✓	✓	

3. HABITAT AND SEASONAL DISTRIBUTION OF SMALL FISH SPECIES

Small sized fishes which are commonly treated as weed or trash fishes are found in all types of habitats – seasonal or perennial, lentic or lotic and also at different altitudinal gradients. Based on the classification of fish habitats put forwarded by Biswas and Boruah [3] the habitat types of small fishes of the Brahmaputra basin may be categorized as follows:-

(a) River confluents: The junction of two rivers (tributary and the main river) is an ideal place for fish assemblages. The churning action of two diverge currents facilitates proper mixing of nutrients which consequently influence the growth of planktonic organisms. Therefore, confluences are always ideal homes for small planktophagus fishes throughout the year.

(b) River meanderings: Deep pools offer suitable habitats for large varieties of small fish species

(c) *Ephemeral streams*: These steams are 'alive' during rainy months. A variety of small fish including hill stream species are encountered from this habitat

(d) *Seasonal water bodies*: During rainy season, inundated paddy fields, derelict ponds, road-side nallahs, swampy area are also important 'homes' for small sized fishes

(e) *Open River*: Streams or rivulets in the plains harbour a wide variety of fish species

(f) *Floodplain Lakes* (FPL): These weed infested shallow water bodies, locally known as *beel* usually temporarily (closed type) or permanently connected (open type) with the main river or tributaries. These act as feeding and breeding grounds for many lotic (riverine) species but do have a 'residential' fish population of which air-breathing forms like *Channa, Clarias, Anabas*, etc. constitute about 40 % of the wetland fisheries. However, there are certain inherent issues involved related to aquaculture in Assam. The key issues are institution related, infrastructure and production related, supply and delivery related and also societal as mentioned below:-

1. Need to motivate educated youths including girls for taking up aquaculture as a profession;
2. To organize skill and aquapreneurship development programme;
3. Proven breeding techniques and economically viable breeding protocols for mass scale seed production of target species;
4. Value added products and quality control measures need to be emphasized;
5. Development of small/ornamental fishery as a small scale industry

3.1 Strategies for development

Strategies are to be chalked out considering different agro-climatic conditions as well as societal and economical criteria in the plains and hilly regions of the state. Selection of species needs to be site specific. Nevertheless, certain basic steps to be taken for expansion of small fish culture have been summarized as follows:-

(a) *Establishment of 'brood bank'*: Brood bank should be created locally for ready supply of brooders/ seed.

(b) *Involvement of women folk*: More participation of locals especially by involving Women SHG's.

(c) *Sustainable collection*: Species specific collection methods are to be followed that will minimize the collateral loss through mortality of non-targeted species.

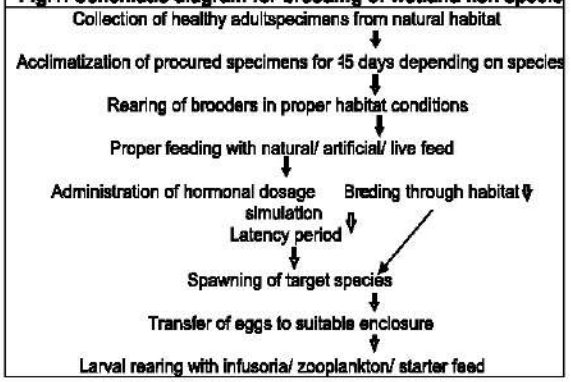
(d) *Monitoring of water quality*: Regular monitoring of water quality particularly temperature and dissolved oxygen of the rearing enclosures as well as fish health.

(e) *Coordinated approach of concerned agencies*: Coordination of all stakeholders including the concerned Government department is necessary for successful implantation of the programme.

3.2 Potential SIF for aquaculture

About 250 fish species were described from Assam and approx. 80% of them may be categorized as small fishes (<15cm). Some small food/ ornamental fishes of the region are – *Amblypharyngodon mola, Badis assamensis, Botia dario, Chaca chaca, Channa bleheri, C. gachua, C. stewartii, Danio devario, Esomus danricus, Glossogobius giuris, Mystus dibrugarensis, M. vitattus, M. tengara, Puntius/Pethia* spp., *Rasbora daniconius, Trichogaster fasciata, T. lalia, Macrognathus aral, Nandus nandus, Xenentodon cancila* etc. None of the above are reared commercially. Some of small varieties fish particularly the 'lentic species' can be bred without much technical knowhow. Mature and disease free fishes are very much necessary for successful captive breeding. In fact, a few of the wetland species are successfully bred [20] at Dibrugarh University Campus following a protocol developed for this purpose [Fig.1].

Fig.1: Schematic diagram for breeding of wetland fish specie



4. DISCUSSION

Assam is endowed with a vast expanse of fresh water habitats mainly flood plain rivers including the mighty Brahmaputra. Availability of myriads of water-bodies, variety of micro-habitats, and the suitable climatic condition have made the state highly suitable for diversification of aquaculture. Further, floodplain lakes (beels) are other potential fishery resources and they offer tremendous scope for both culture and capture fisheries [15].Many of our 200 odd fish species found in the Brahmaputra basin are sharply dwindling due to habitat alteration and injudicious exploitation of these fishes. A good number of endemic and rare varieties of fishes which are sold in markets and exported as aquarium fish need to be conserved before they are wiped out from their natural habitat. Of late, some of the murrels or snakehead fishes like *Channa aurantimaculata, C. barca, C. bleheri, C. stewartii* are in more demand in the international market. Artificial propagation can reduce pressure on the natural stock of

these prized species. Habitat destruction due to urbanization and natural calamities is the major threat to SIF. Rapid development of human masses on earth has basically elevated the demand for industrialization, urbanization and sustenance for its survival, development and progress, which in turn prompted crumbling of water quality and shrinking of freshwater biodiversity. Apart from this, pollution of water bodies by pesticides, insecticides, domestic and industrial pollutant [21]; diseases and invasion of exotic species are other major threats to SIF [4, 21]. Moreover, unrestricted exploitation of small fish varieties has already threatened the very existence of some rare native varieties of the state. Thus, proper management of the fishing activity and ecological restoration of the wetlands are very much important for SIF conservation [22].

SIF has high market value inside and outside of the state and thus the proper, scientific culture of SIF is cost-effective [23]. SIF with larvicidal properties control the mosquito population and thus the mosquito born diseases such as malaria and dengue which is another advantage of SIF culture. Apart from their nutritive value, SIF of north east region contribute 85% of the Indian freshwater ornamental fish trade [5, 24]. Ironically, very few people in the state are concerned about the culture of SIF and these fishes are exclusively collected from the wild. This practice may lead to the extinction of more and more SIF species in near future. Some of the small and medium sized fishes found in wetlands and seasonal water bodies such as *Amblypharyngodon, Botia, Esomus, Channa, Crossocheilus, Danio, Glossogobius, Labeo, Macrognathus, Pethia, Puntius, Rasbora, Salmophasia, Trichogaster and Xenentodon* are suitable candidates for culture and propagation without much effort [16]. However, proper rearing technique, feeding and breeding of these species in captive condition require adequate field trial for mass propagation. Emphasis need to be given to utilize seasonal water bodies for rearing of SIF. Therefore, it is a paramount need to make other people concern about the necessity of SIF culture. No huge work force or special management skills are needed for small fish rearing which can be considered as an advantage in SIF culture. Different fish culture method can be adopted for extended and profitable SIF culture in Assam. Providing the technical knowledge about the new methods of fish farming including aquaponics, biofloc system and rooftop culture of fish to the local youths can boost fish production many fold even in urban areas. Apart from this, ethnic foods prepared with SIF by different tribes can also be commercialized by canning, packaging and exporting the food worldwide. This can lead to a movement of self-employment and entrepreneurship in the state and could make realization to the people about the sustainable use of natural resources [25].

Many SIF species of the state which are either endemic or having restricted area distribution, have been declining vary sharply due to various natural and anthropogenic factors. A combination of factors like overexploitation, pesticide and aquatic pollution, spread of disease, uncontrolled introduction of exotic fishes and habitat modification due to industrialization and urbanization are responsible for depletion of natural stock. Clandestine trade of organisms and

indiscriminate collection of wild stock are major causes of concern[21,26].It is often advocate for inclusion of more indigenous species in aquaculture programme for increased fish production. Another major issue is the standardization of breeding protocol suitable to the climatic condition of the region. But the major impediment in artificial propagation of indigenous larvicidal/ornamental fish is the limited knowledge of their biology particularly spawning behaviour. Knowledge of the habitat and biology especially feeding and reproductive biology of the species concerned is vital for successful rearing of any wild species. Furthermore adequate amount of quality seed of the target species is also a prerequisite to achieve this, standardization of breeding technique for mass production of spawn in controlled condition have to be developed before taking up any new venture. Emphasis need to be given to utilize seasonal water bodies like wetlands, swampy areas, paddy fields and nallahs for mass rearing of ornamental fishes. Practically seasonal water bodies act as nursery ground for all the wild fish species.

5. CONCLUSION

Development of aquaculture in the region will reduce overexploitation of aquatic resources from natural water coupled with poverty alleviation in rural areas. High fish diversity of the region, water resources and climatic condition offer ample opportunities for diversifying aquaculture in NE region of India, particularly in Assam. Incidentally, some small varieties of lentic fish species of Assam can be reared in small enclosures without much technical knowhow.

SIF culture can uplift the curve of economy of the state as it adds value to a large number of fields including nutrition, tradition, gene preservation, economy and sustainable growth of the society. Thus more focus should be given to the culture and management of SIF. Both individual and government sector can play important role in uplifting the SIF culture in the state of Assam.

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Herd Immunity and COVID-19

Indira S. Laishram

Former Faculty, Department of Biochemistry, St. Anthony's College
Shillong-793001, Meghalaya, India
**Corresponding author: laishramsingha@gmail.com*

Abstract: Herd immunity provided by vaccines holds immense power to stop the spread of a pandemic, and to possibly eradicate it. The world continues to lose precious lives to the COVID-19 pandemic caused by SARS-CoV-2. An end to the pandemic can be brought about by acquisition of herd immunity to SARS-CoV-2 through mass immunization campaigns. This article discusses the concept of herd immunity and its potential contribution to ending the COVID-19 pandemic.

Keywords: *COVID-19, pandemic, SARS-CoV-2, immunity, herd immunity threshold*

Abbreviations: severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), coronavirus disease (COVID-19), infection fatality rate (IFR)

1. INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has caused over 82 million cases of coronavirus disease (COVID-19) and 1.8 million deaths worldwide as of December 30, 2020 [1]. The pandemic, already in its second wave in many countries of the Northern Hemisphere, besides taking an immense toll on human lives, is bringing a destructive impact to economy and is an overall threat to the well-being of society. In the absence of a widely available therapeutic against the disease, an effective means of stopping the disease in its tracks is the acquisition of immunity. Individuals can acquire immunity to COVID-19 via natural infection or via immunization with a vaccine. The population as a whole can acquire immunity through mass vaccinations, thus conferring herd immunity. Herd immunity is the term used to describe indirect immunity conferred on susceptible individuals of a population when a sufficient proportion of individuals in a population have attained immunity.

2. PROTECTION THROUGH HERD IMMUNITY

When a significant percentage of a population has become immune to an infectious disease, it is said to have attained herd immunity. At this point, the risk of the disease spreading from person to person decreases. This indirectly protects individuals who are not immune to the disease by minimizing exposure to it. In other words, in a population with herd immunity the pathogen would keep encountering people who are protected against infection, and hence cannot spread as easily.

The percentage of the population that must be immune to the disease to achieve herd immunity is known as the herd immunity threshold. Herd immunity threshold is different for every disease, and depends on how contagious a disease is. This is measured by the average number of infections caused by a single infectious individual. A person with measles can infect an average of 11 to 16 people, while a person with COVID-19 infects 1 to 7 people [2]. The more infectious a disease is, the higher the herd immunity threshold would be. A highly infectious disease like measles would require 90% and higher of the population to be vaccinated to achieve herd immunity [3, 4].

3. HERD IMMUNITY IN A POPULATION

Consider the following scenarios in Figure 1. The first panel shows a scenario where there is no vaccination. Here the infection can spread from infected individuals to healthy and susceptible individuals, and eventually, throughout the entire population. The second panel shows a scenario where there is vaccination, but the population protected by the vaccine is below the threshold for herd immunity that is required to stop the spread. In this case the infection can still spread from an infected individual to unvaccinated individuals, but those that are vaccinated are protected. A third scenario is seen where the population has received vaccination at or above the threshold that is needed to provide herd immunity. Most individuals are protected by

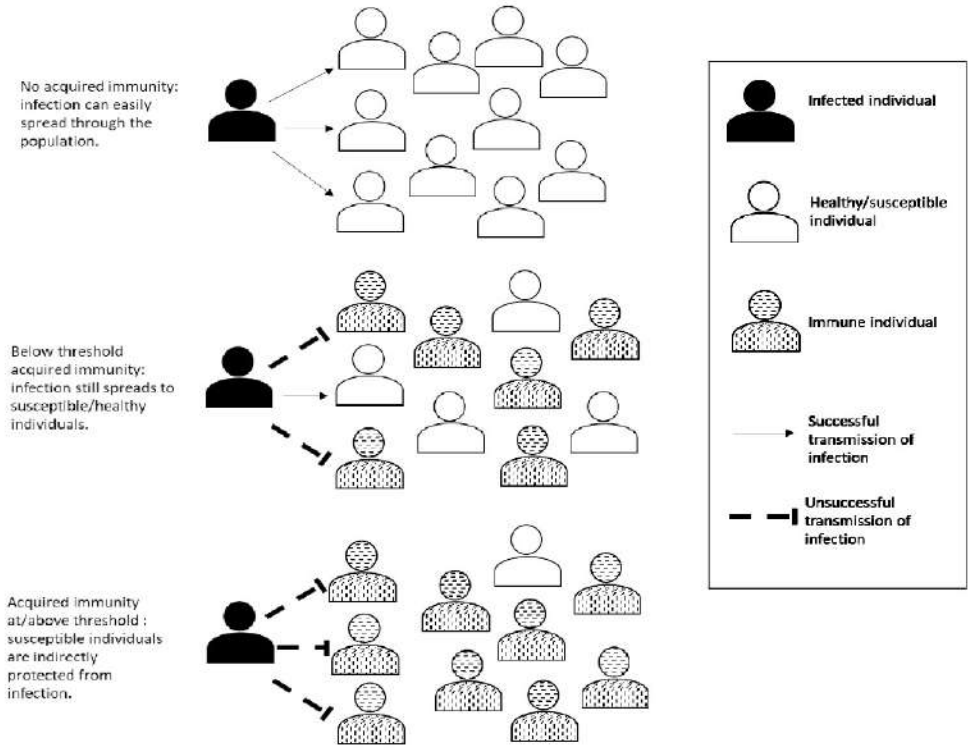

Fig 1. Acquisition of Herd Immunity in a Population

the vaccine. Besides, those that have not been vaccinated are indirectly protected by vaccinated individuals. This time the chain of infection can be halted, thus making it less likely to spread.

4. HERD IMMUNITY TO COVID-19

Herd immunity can be acquired in one of two ways- naturally or through vaccinations.

Naturally building up herd immunity in the population is theoretically possible, but has devastating consequences on society. The societal cost of attaining SARS-COV-2 herd immunity is evaluated by its overall infection fatality rate (IFR). The IFR measures the proportion of deaths caused by the infection out of the total number of infected individuals. This number may not be accurately estimated due to factors such as insufficient testing. The outbreak puts tremendous pressure on health care systems, often exceeding its limits, and eventually increasing the negative consequences of the infection. Since acquisition of natural herd immunity essentially depend on allowing the disease to run through the population, countries with limited resources of surge capacity and healthcare infrastructure will have devastating consequences [5]. Needless to say, this method of achieving herd immunity is profoundly flawed and undeniably dangerous. Moreover, herd immunity at a global scale can only be achieved by mass immunizations.

Smallpox, for example is believed to have appeared in 10,000 BC in northeastern Africa. From there it slowly spread with traders and travelers to the rest of the globe. A global vaccination campaign started in 1967 finally succeeded in eradicating smallpox in 1977 [6]. The eradication of smallpox through mass vaccination programs is perhaps the best example of achieving herd immunity at the global level. Outbreaks of measles and mumps for which we have vaccines today, are still seen in populations that have not been vaccinated, further demonstrating the importance of a concerted effort of mass vaccinations for successfully achieving herd immunity. These historic and current cases are essential while framing strategies to end or at least control the current scourge of COVID-19.

4. CONCLUSION

Even after herd immunity has been acquired, the length of the immunity acquired will determine the efficacy of the immunity. It is known that vaccination for diseases like measles offer life-long immunity, whereas immunity for pertussis is short-lived, and diminishes over time. The risk for resurgence of diseases whose vaccination provides temporary immunity, has a chance of resurgence in the future. Acquisition of herd immunity through mass vaccinations remains the safest and most ethical path to ending the current COVID-19 pandemic.

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Status of Ornamental Fish Diversity of Urpod *Beel* of Goalpara District, Assam

Anupam Sharma

District Fishery Development Office, Goalpara, Assam, Pin 783121

Corresponding author: anupamsharmaglp@gmail.com

Abstract: The North Eastern *States* including Assam are very rich in aquatic bio-resources and dominated by several endemic fish resources. The study was conducted from June 2018- July 2019 in two different fish assembling villages *viz.* Chamaguri (W) and Garokuta (North) of Urpad *Beel* and fish species were recorded along with their IUCN Conservation status. Altogether, 31 ornamental fish species belonging to 16 Genera, 15 Families, and 6 Orders belonging to orders like Beloniformes, Cypriniformes, Osteoglossiformes, Siluriformes, Symbranchiformes, Perciformes, Tetradontiformes were recorded. Out of the recorded fish species, *Lepidocephalichthys guntea* (Hamilton-Buchanan,1822), *Channa gachua* (Hamilton, 1822) and *Chanda nama* (Hamilton, 1822) were assessed as NE, *Botia rostrata* (Gunther,1868) and *Channa gachua* (Hamilton, 1822), *Mystus vittatus* (Bloch, 1794) as VU, *Ctenops nobilis* (Mc Clelland, 1845) as NT as per IUCN Status 2013. The ornamental fishes are found in the weed assemblage of the Beel including *Eichhornia crassipes, Hydrilla verticillate* and *Ceratophyllum demersum* .

Keywords: *Ornamental fish, Diversity, endemic fish, bio-resources, IUCN Red list*

1. INTRODUCTION:

North Eastern India (between 21.50 ° to 29. 50 ° N latitude and 85.50° to 97.50° E longitude) with the Brahmaputra and Barak river flowing through different states and myriads of various lentic water bodies harbour a very rich in aquatic bio-resources and dominated by several endemic fish resources [7, 8]. Owing to its diversity of topographic and climatic features, aquatic resources of North East India are rich in fish germplasm. The varied freshwater resources of the region harbour 274 fish species out of the 806 freshwater reported in India [8] Assam including other North Eastern States is one of the major contributors of ornamental fish trade in India [4].

Floodplain wetlands locally called as *Beels* of Assam play a vital role in the recruitment of fish population in the riverine ecosystem and is an ideal habitat for many ornamental fishes [2] and out of 217 species from Assam, 150 species have been listed under potential Ornamental value [3]. Ornamental fish are tiny attractive colourful fishes and sometimes with particular mode of movement and peculiar mode of food taking. Assam is blessed with many classified types of ornamental fish like loach, barbs, danios, snakehead, gourami, catfish etc. that can be reared in the aquarium throughout their life span are treated as unwanted for conventional farming have good potential as ornamental fish due to their varied shapes, sizes, colour finnage etc. [5] . On the other

hand, some larger food fishes like *Labeo gonius, Channa marulius etc.* treated as ornamental fishes in their juvenile stage and are termed as non-classified ornamental fish are also widely available in floodplain wetlands being extremely rich in plant nutrition and high biological productivity. However, indiscriminate exploitation of ornamental fish from floodplain wetlands has led to extinction of some of the rare varieties of ornamental fishes and declination in numbers of others. An investigation on ichthyofaunal diversity of Urpad *Beel* of Goalpara district along with their conservation status has been attempted as there is no any scientific information regarding availability and abundance of ornamental fish from the particular wetland. The present study aims to record indigenous ornamental fish along with their IUCN status.

2. MATERIALS AND METHODS:

In the present study, random rapid field survey was conducted during June 2018- July 2019 in two different fish assembling villages viz. Chamaguri (W) and Garokuta (North) where fish assemblages were seen. Monthly sampling was carried out during pre-monsoon (March–June), Monsoon (July-September), post-monsoon (November-February) seasons. The information about the availability of the fish species was gathered from the fishing community of the area. Ornamental fishes was categorized based on the criteria like body coloration, shapes, banding pattern, fins, suckers and transparent body and preying habits. Fish specimens were taken to laboratory for morphological identification done [6,9,10] and the nomenclature was guided by information in www.fishbase.org. The conservation status of recorded species was based on IUCN conservation status, 2013.[13]

3. STUDY AREA

The study area Urpad *Beel* is located in village Urpad near Agia Gaon Panchayat under Balijana Development Block of Balijana Revenue Circle in Goalpara District of Assam (Longitude 26.15′N and Latitude 90.40′E) . The wetland is connected by rural road from NH 37 and Goalpara – Agia road and is bounded by Garokuta village in the North Khagrabari Village in the East Chandamari and Paharkata in the South and Ulupara Village in the West. At Full Storage Level (FSL) level the water spread area (WSA) is 291 hectares while at Dead Storage Level (DSL) water Spread Area is 283 Hectares under Revenue Record, Dag No 4, 8, 14, 19, and 20 of Balijana Revenue Circle. The depth of the Beel was found to range from 1.5 to 2.5 metre. The wetland has vast catchment area comprising of villages such as Solmari, Chandamari, Chamaguri, Goroimari, Garobasti, Kuruabhasa, Bhoiskhuli, Baladmari and Saat Bhani Hills and Agia. The Beel is mainly fed through an inlet known as Haramkhor from the tributary Jinary which flows along its eastern side from South to North to meet the Brahmaputra. At the South western side of the *Beel* there is an outlet called "Gol-Goli" which is source of river Jinjiram also a tributary of the river Brahmaputra.

Table1: List of ornamental fish species recorded from Urpod Beel and their IUCN Conservation Status, 2013

Order	Family	Name of the species	IUCN Category	Relative Abundance
Beloniformes	Belontidae	*Xenontodon cancila* (Hamilton, 1822)	LC	C
Cypriniformes	Cobitidae	*Lepidocephalichthys guntea* (Hamilton- Buchanan,1822)	NE	R
		Botia derio (Hamilton,1822)	LC	C
		Botia rostrata (Gunther,1868)	VU	C
	Cyprinidae	*Pethia ticto* (Hamilton, 1822)	LC	C
		Pethia sophore (Hamilton, 1822)	LC	C
		Pethia gelius (Hamilton, 1822)	LC	R
		Devario devario (Hamilton, 1822)	LC	O
		Danio rerio (Hamilton, 1822)	LC	C
		Amblypharyngodon mola (Hamilton, 1822)	LC	C
		Esomus danricus (Hamilton, 1882)	LC	C
	Balitoridae	*Acanthocobitis botia* (Hamilton, 1822)	LC	C
Siluriformes	Chacidae	*Chaca chaca* (Hamilton, 1822)	NE	R
	Claridae	*Clarias magur* (Linnaeus, 1758)	LC	C
		Heteropneustus fossils (Bloch,1794)	LC	C
	Bagridae	*Mystus vittatus* (Bloch, 1794)	VU	R
		Mystus tengara (Hamilton, 1822)	LC	C
Symbranchiformes	Mestacembelidae	*Mestacembalus armatus* (Lacepede, 1800)	LC	C
	Nanidae	*Nandus nandus* (Hamilton, 1822)	LC	O
		Badis badis (Hamilton, 1822)	LC	O
	Osphronemidae	*Ctenops nobilis* (Mc Clelland, 1845)	NT	R
	Belontidae	*Trichogaster fasciatus* (Bloch and Schneider, 1801)	LC	C
Osteoglossiformes	Notopteridae	*Notopterus notopterus* (Pallas, 1769)	LC	C
		Trichogaster lalius (Hamilton, 1822)	LC	C
Perciformes	Chanidae	*Channa gachua* (Hamilton, 1822)	VU	C
		Channa marulius (Hamilton, 1822)	LC	C
		Channa striatus (Bloch, 1793)	LC	C
		Channa punctata (Bloch, 1793)	LC	C
	Ambassidae	*Chanda nama* (Hamilton, 1822)	NE	C
	Gobidae	*Glossogobius giuris* (Hamilton-Buchanan, 1822)	LC	C
Tetradontiformes	Tetradontidae	*Tetradon cutcutia* (Hamilton, 1822)	LC	O

Relative Abundance: O: Occasional, R: Rare, C: Common

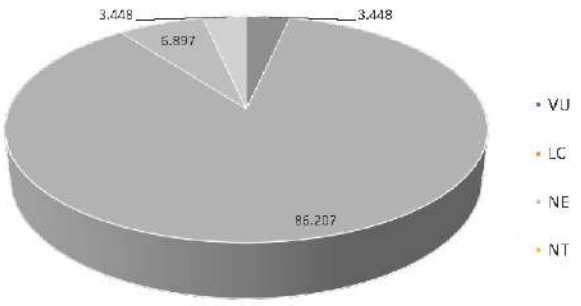

Fig1: Percentage distribition of IUCN Categories of Ornamental Fish Species in Urpod Beel

Table2: Seasonal availability of ornamental fish species recorded from Urpod Beel during 2018-19

Name of the species	Seasonal Abundance		
	Pre- Monsoon	Monsoon	Post Mon Soo
Xenontodon cancila (Hamilton, 1822)	*		
Lepidocephalichthys guntea (Hamilton- Buchanan,1822)	*		
Botia derio (Hamilton,1822)	*		
Botia rostrata (Gunther,1868)	*		
Pethia ticto (Hamilton, 1822)	*		
Pethia sophore (Hamilton, 1822)	*		
Pethia gelius (Hamilton, 1822)	*		
Devario devario (Hamilton, 1822)	*		
Danio rerio (Hamilton, 1822)	*		*
Amblypharyngodon mola (Hamilton, 1822)	*		*
Esomus danricus (Hamilton, 1882)	*		*
Acanthocobitis botia (Hamilton, 1822)	*		*
Chaca chaca (Hamilton, 1822)			*
Clarias magur (Linnaeus, 1758)	*	*	*
Heteropneustus fossils (Bloch,1794)	*	*	*
Mystus vittatus (Bloch, 1794)	*		*
Mystus tengara (Hamilton, 1822)	*	*	*
Mestacembalus armatus (Lacepede, 1800)	*		*
Nandus nandus (Hamilton, 1822)	*		*
Badis badis (Hamilton, 1822)			*
Ctenops nobilis (Mc Clelland, 1845)			*
Trichogaster fasciatus (Bloch and Schneider, 1801)	*		*
Trichogaster lalius (Hamilton, 1822)	*		*
Channa gachua (Hamilton, 1822)	*		*
Channa marulius (Hamilton, 1822)	*		*
Channa striatus (Bloch, 1793)	*		*
Chanda nama (Hamilton, 1822)	*		*
Glossogobius giuris (Hamilton-Buchanan, 1822)	*		*
Tetradon cutcutia (Hamilton, 1822)	*		*

Table3: Macrophyte Genera Recorded in Urpod Beel

Category		Taxa
Submerged	*1.*	*Myriophyllum indicum* Wiild
1. Free Floating	*2.*	*Utricularia stellaris* Linn
	3.	*Ceratophyllum demersum* Linn
	4.	*Najas indica*
	5.	*Hydrilla verticillate* Casp.
2. Anchored to hydro soil	*6.*	*Vallisneria spiralis* Linn
	7.	*Nechamendra attrifolia* Roxb
	8.	*Chara*
	9.	*Nymphea nauchali* Wiild
	10.	*Nelumbo nucifera* Gaertn
Rooted floating	*11.*	*Potamogeton crispus* Linn
	12.	*Eichhornia crassipes*
	13.	*Pistia stratiotes* Linn.
	14.	*Lemna perpisulla* Linn.
	15.	*Wolffia arrhizal* Wimm
Free floating	*16.*	*Azolla pinnata* R. Br.
	17.	*Salivinia cuculata* Roxb.
Shore plants	*18.*	*Typha angustata* Bory and Chaub
	19.	*Colocasia esculenta (L.)* Scrott.
	20.	*Penicum proliferum*
	21.	*Sprganuim erctum*
	22.	*Cyperus iria* Linn
	23.	*Marsilea quadrifolia* Linn
	24.	*Monocharia hastate (L)* Solms
	25.	*Eleocharis sp*
	26.	*Fimbristylis monostachaya* Hassk
	27.	*Phragmites karka* Trin.
	28.	*Jussia repens* Linn
	29.	*Trapa bispinosa* Roxb.

4. RESULTS

Altogether, 31 ornamental fish species belonging to 16 Genera, 15 Families, and 6 Orders have been recorded from two different sampling locations during the study period. The ornamental fish belonging to following orders like Beloniformes, Cypriniformes, Osteoglossiformes, Siluriformes, Symbranchiformes, Perciformes, Tetradontiformes. Out of 31 species, 1 species belongs to each Ambassidae, Belontidae, Chacidae, Gobidae Balitoridae, Osphronomidae and Belontidae; 2 each species belong to Claridae, Bagridae, Nanidae, Notopteridae, Bagridae, Nanidae , 3 species belong to Cobitidae, 5 species belong to Chanidae and 7 species belong to Cyprinidae. Out of the recorded fish species, *Lepidocephalichthys guntea* (Hamilton-Buchanan,1822), *Channa gachua* (Hamilton, 1822) and *Chanda nama* (Hamilton, 1822) were assessed as NE, *Botia rostrata* (Gunther,1868) and *Channa gachua* (Hamilton, 1822), *Mystus vittatus* (Bloch, 1794) as VU, *Ctenops nobilis* (Mc Clelland, 1845) as NT and others were assessed as LC as per IUCN. Out of the ornamental fish recorded in the area, 86.21% belong to LC while 6,89 % belong to NE, 3.44 % belong to VU category.

Lepidocephalichthys guntea (Hamilton-Buchanan, 1822), *Pethia gelius* (Hamilton, 1822), *Mytus vittatus* (Bloch, 1794), *Ctenops nobilis* (Mc Clelland, 1845) were rarely found while *Devario devario* (Hamilton, 1822), *Nandus nandus* (Hamilton, 1822), *Badis badis* (Hamilton, 1822), *Tetradon cutcutia* (Hamilton, 1822) were occasionally found during the investigation period. *Mystus tengara* (Hamilton, 1822), *Channa gachua* (Hamilton,1822) and *Channa marulius* (Hamilton, 1822) are only the species found during all Pre-Monsoon, Monsoon and Winter season while *Amblypharyngodon mola* (Hamilton, 1822), *Chaca chaca* (Hamilton, 1822) *Badis badis* (Hamilton, 1822), *Ctenops nobilis* (Mc Clelland, 1845) and *Glossogobius giuris* (Hamilton-Buchanan, 1822) are found during post- monsoon period only while others were found during both pre and post-monsoon season. *Lepidocephalus guntea* (Hamilton- Buchanan,1822), *Pethia gelius* (Hamilton, 1822), *Chaca chaca* (Hamilton, 1822), *Mystus vittatus* (Bloch , 1794), *Ctenops nobilis* (Mc Clelland, 1845) were rarely (R) occurred whereas *Devario devario* (Hamilton, 1822), *Nandus nandus* (Hamilton,1822), *Badis badis* (Hamilton, 1822) and *Tetradon cutcutia* (Hamilton, 1822) were occasionally (O) found in the study area.

5. DISCUSSION

Ornamental fishes are available in natural water bodies like rivers, rivulets, lakes, swamps and paddy fields of the study area. Ornamental fishes are geographically distributed widely, reflect great taxonomic and ecological diversity. Out of the total 250 native ornamental fish species of North Eastern Region, highest number of ornamental fish 187 numbers. have been recorded form Assam [8.] In the study area, Ornamental fishes are found in the weed assemblage of the *Beel* including *Eichhornia crassipes, Hydrilla verticillate* and *Ceratophyllum demersum* in all the sampling locations of the study area during pre-monsoon and post-monsoon seasons. Species belonging to Osphronemidae and Tetradontidae and Gobidae were noticed

during post monsoon season and rarely noticed during post monsoon. The *Beel* is not leased out and there is no proper management regime and is an open access of fishing among the local fishing community. Fishing is irregular and happens mostly during post-monsoon season. Gill nets are dominant fishing gear followed by traps and a few other local gears. During the investigation, it has been observed that Urpod *Beel* is choked with massive infestation of aquatic weed and is in poor health due to higher degree of eutrophication. Due to conversion to swamp, Indian Major Carp have dwindled in the *Beel* and fishes of low economic value have occupied the niche on a larger scale. The high incidence of macrophytes have been found to interfere during fishing operations, reduce plankton population, restrict the living space and movement of the fishes and reduce water quality by changing the amount of dissolved gases [1].

6. CONCLUSION

The present study documents fish species in Urpod *Beel* which exhibits a good number of ornamental fish which are highly unprotected and an injudicious exploitation was noticed. Further, due to siltation in the feeding channel, habitat loss and overfishing, the ornamental fishes are getting depleted over the years. Hence, there is a need to enforce regulation and awareness for ecological restoration. Local communities are not fully aware about the environmental health of the ecosystem and the prospects of breeding and the artificial propagation of potential indigenous ornamental fish. However, steps may be initiated to boost up local economy by involving local youth for *in situ* conservation and captive breeding. Such initiatives can play a role in helping unemployed youth of the locality and create potential entrepreneur.

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Ethnobotanical Studies on Some Medicinal Plant Resources Practiced by the Deori Community of Biswanath District, Assam

Nabin Saikia[1*] and Jayanta Gogoi[2]

Department of Botany[1], Department of Zoology[2],
Arya Vidyapeeth College, Gopinath Nagar, Guwahati 781016, Assam, India.
Corresponding authors : drnabinsaikia@gmail.com

Abstract: The present study evaluates 23 medicinal plants used by the Deori community of Biswanath District, Assam, of which some are more special and new report in medicinal aspects. Generally, these medicinal plants are used to treat some common as well as special diseases and are practiced by a person called *"Bez"*. The efficacy of these disease depend on the selection of the medicinal plants and proper method of administration. The active ingredients of these medicinal plants are another important aspects for their phytochemical as well as clinical studies.

Keywords: *Ethnobotany, Medicinal Plant Resources, Deori Community, Biswanath District, Bez, Efficacy, Phytochemical and Clinical studies.*

1. INTRODUCTION

Man from ancient time has used plant as a source of medicine. Initially, these formed bulk or folk ethnomedicine, practiced in India and some other part of the world like China, Middle East, Africa and South America. Later, a considerable part of these indigenous knowledge was formulated, documented and eventually passed into the organized system of medicine such as *'Ayurveda', 'Yunani', 'Sidha'* or some other system of outside India [31]. This medicinal plants are critical resource for rural and indigenous people [5]. The distribution of such useful species and their economy plays an important role in the sustainable development of a particular area. It is more meaningful to use multi-utilitarian species for plantation program in areas inhabited by aborigine [41]. In recent years, there is a revival of interest in the traditional system of medicine and medicinal plants are a major source of biodynamic compound of therapeutic value [10]. The ethno-medico-botanical study can bring out many efficient drugs for treatment of many human diseases.

Exploration and documentation of medicinal plant use by indigenous peoples is a promising area of botanical research now a days. The area of botanical study has been coined as *"Ethnobotany"* [11]. It is described as a branch of botanical sciences which deals with all the aspect of new and less known relationships of plants with human.

The role of ethnobotany has been by far well-established because of its relevance in discovery and development of new and less

known economic plants [4, 7 & 14]. The *"Introduction of Ethnobotany"* by P. J. Faulk, 1958 [6] was the first book on the subject ethnobotany. However, Schulte later gave a comprehensive definition and concept with a very broad dimension to the field of ethnobotany.

In India the organized studies and researches of ethnobotany are of recent origin. Since 1960, ethnobotanical researches in India have been intensified by number of workers from different research institute, universities throughout the county [2, 13, 19, 21, 22, 25 & 29]. S. K. Jain (2002) [17] has reviewed the details bibliography work on Indian ethnobotany and listed about 1600 references.

Northeast region of India due to its vast forest, rich flora and tribal inhabitants has become the center of interest of ethnobotany in recent years. Over the few decades considerable works on ethnobotany have been conducted in Northeast India [1, 3, 8, 12, 18, 20, 23, 27, 32 & 40]. The works on ethnobotany of Northeast India have been reviewed by many authors [26]. After this work several reports have been published [9, 15, 28 & 33-39]. However, reports on the medicinal plant resources practiced by the Deori community of Biswanath District, Assam are still scanty.

2. METHODOLOGY

Survey and collection of the plant was done during 2018 - 2019 following the procedure for plant exploration for floristic [30], ethnobotany [16 & 18] and evaluation of active ingredients [24]. Identification was done by the Reference Herbarium of BSI Eastern Circle, Shillong, Meghalaya. Special emphasis was given to tap the local people knowledge associated with the utility and utilitarian aspects of medicinal plant resources pertaining to parts that are used for treatment of diseases, collection, processing, extraction etc. During survey work in the field necessary data like local name, part(s), purpose of use and mode of administration have been recorded in the field note-book apart from the incorporation of their visible morphological and other characters.

For evaluation of the ethnobotanical aspects the plants were alphabetically arranged according to their botanical name, family, vernacular name, diseases, plant parts used, method of administration and its active ingredients.

2.1 STUDY AREA

Biswanath District is one of the 33 districts of Assam and it is bounded by the West Kameng and Papumpara District of Auranachal Pradesh in North, Lakhimpur District in the East, Golaghat District in the South and Sonitpur District in the West (Figure. 1). Area covered by Biswanath district is about 1100 km^2. The district is located at 44°74'52" N and 90°09'62" W with a range elevation of 48-390 meters from sea level. The district have 2 Sub-Divisions, consisting 3 Circle Offices, 7 Developmental Blocks and 832 Villages. The major castes of the population are Deori (Figure. 2), Bodo, Rabha, Kachari, Koch, Mishing, Khamti etc belonging to schedule tribes in addition to the groups of Hindu castes.

The district has a sub-tropical humid climate with 75 % humidity and average temperature of 24.5°C in summer. It is cold and dry in winter. The annual rainfall is about 2,000 mm while from November to March the average rainfall is about 119.2 mm and from April to October it is about 1832 mm. The range

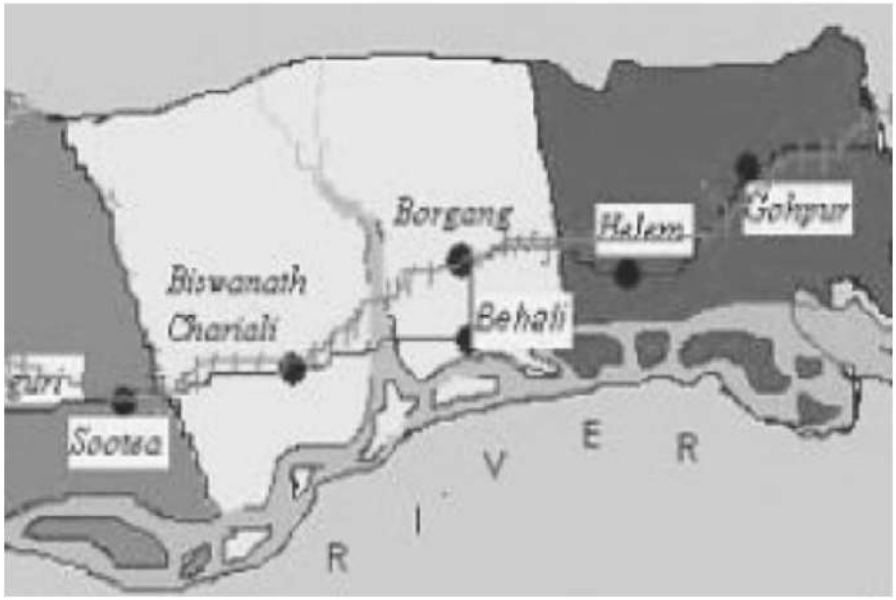

Figure 1 : Geographical representation of study area.

Figure 2: One section of Deori community.

3. RESULT

The present study revealed 23 medicinal plant species belonging to 16 families which are used in various diseases in various ways. The enumerations of the collected plants are represented in the Table - 1.

Table 1: Enumeration of the plants studied.

Sl No.	Botanical Nam	Family	Vernacular Name	Disease	Plant Parts Used	Method of Administratio	Active Ingredien
1.	*Averrhoa carambola*L	Oxalidaceae	Sir tenga	Cough & Jaundice	Fruit	50 ml decoction from fresh fruit is taken orally in empty stomach once daily for 10 days in cough and 30 days in jaundice.	Organic acids
2.	*Bryophyllum pinnatum* (Lam) Oken	Crassul aceae	Pat gaji	Diabetes & Kidney stone	Tender shoot	100 ml decoction from freshly collect tender shoot is taken orally in empty stomach once daily for 30 days in both diseases.	Organic acids
3.	*Catharanthus roseus* (L) G. Don	Apocyan aceae	Jangfu	Diabetes	Leaves	50 ml decoction from freshly collect leaves is taken orally twice daily for 30 days.	Alkaloids
4.	*Cassia alata*(L) Roxb	Fabaceae	Pankha	Skin diseases	Leaves	Paste of tender leaves applied locally twice daily for 7 days	Alkaloids
5.	*Centella asiatica L*	Apiaceae	Manimuni	Dysentery & Gastric	Whole plant	50 ml decoction from fresh plant is taken orally in empty stomach once daily for 10 days.	Alkaloids
6.	*Colocasia esculanta* (L) Schott	Araceae	Kasu	Boil	Rhizome	Paste of rhizome applied locally once daily for 5 days	Alkaloids
7.	*Dillenia indica* L	Dilleniaceae	Oteng	Dysentery & Dandruff	Fruit	For dysentery 50 ml decoction from mature fruit is taken twice daily for 7 days and for dandruff, paste of mature endosperm apply on head once daily for 7 days	Organic acids
8.	*Ficushispida*L	Moraceae	Dambru	Jaundice	Leaves & Fruits	50 ml decoction from freshly collect tender leaves and immature fruit of the plant along with 2 or 3 tender leaves of *Mangifera indica* L is taken orally in empty stomach once daily for 20 days.	Alkaloids
9.	*Houttuynia cordata* Thunb	Saururaceae	Maisun dari	Stomach problem	Leaves	50 ml decoction from freshly collect tender leaves is taken orally in empty stomach once daily for 10 days.	Alkaloids
10.	*Hydrocotyle rotendifolia* L	Apiaceae	Salni	Stomach problem	Leaves	50 ml decoction from freshly collect tender leaves is taken orally in empty stomach once daily for 10 days.	Alkaloids
11.	*Leonurus sibiricus*L	Lamiaceae	Borom Buthur	Fever	Leaves & Roots	100 ml decoction from freshly collect tender leaves and root is taken orally thrice daily for 5 days.	Alkaloids
12.	*Leucus aspera* Steng	Lamiaceae	Singia	Nasal diseases & Stomach problem	Leaves & Flower	5 ml decoction from freshly collect tender leaves and flower is applied locally once daily for 5 days in nasal diseases. 100 ml decoction from freshly collect tender leaves and root is taken orally at empty stomach daily for 10 days in stomach problem.	Alkaloids
13	*Mikania micrantha* Kunth	Asteraceae	Gendhal Lata	Wound & Skin diseases	Tender leaves	Paste of freshly collectlender leaves applied locally thrice daily for 5 days.	Alkaloids
14.	*Murraya koenigii* (L)	Rutaceae	Narasinga	Stomach problem &	Tender leaves	100 ml decoction from freshly collect tender leaves is taken	Alkaloids

	Sprang			Heart disease		orally at empty stomach daily for 10 days in stomach problem and 30 days in heart disease.	
15.	*Ocimum sanctum*L	Lamiaceae	Tulusi	Cough & Stomach problem	Tender leaves	10 ml decoction from freshly collect tender leaves mixed with 10 ml honey is taken orally thrice daily for 7 days in cough. 100 ml decoction from freshly collect tender leaves is taken orally at empty stomach daily for 10 days in stomach problem.	Essential oil
16.	*Paederia foetide* L	Rubiaceae	Mosang	Fever and Stomach problem	Whole plant	10 ml decoction from freshly collect tender plant is taken orally thrice daily for 5 days in fever. 50 ml decoction from fresh tender plant is taken orally at empty stomach daily for 10 days in stomach problem.	Alkaloids
17.	*Piper betle*L	Piperaceae	Pandai	Sinusitis & Blood purifier	Leaves & mature inflorescence	5 ml decoction from freshly collect tender leaves is applied locally once daily for 5 days in sinusitis. 50 ml decoction from freshly collect leaves and mature inflorescence is taken orally at empty stomach daily for 15 days as blood purifier.	Essential oil
18.	*Pisidium guajava*L	Mytaceae	Gutaiphai	Dysentery	Tender leaves & fruit	50 ml decoction from either freshly collect tender leaves or fruit is taken orally at empty stomach daily for 10 days.	Alkaloids
19.	*Scoporia dulsic* L	Plantagin aceae	Rakhebsia	Wound & Body pain	Tender leaves	Paste of freshly collect tender leaves is applied locally thrice daily for 5 days.	Alkaloids
20.	*Spilanthus peniculata* Wall ex D.C.	Asteraceae	Mou sak	Mouth diseases	Tender leaves & inflorescence	Paste of freshly collect tender leaves and inflorescence is applied locally twice daily for 7 days	Alkaloids
21.	*Stephania japonica* (Thumb) Miers	Manisperm aceae	Thubki Latai	Boils	Tender leaves	Paste offreshly collect tender leaves and inflorescence is applied locally twice daily for 5 days	Alkaloids
22.	*Tabernaemontana divericata* R.Br. ex Roem & Schult	Apocyn aceae	Daodwai	Eye diseases & Mouth diseases	Tender leaves & mature fruit.	5 ml decoction from freshly collect tender leaves is applied locally twice daily for 5 days in eye diseases. Paste of mature fruit is taken locally twice daily for 5 days in mouth diseases	Alkaloids
23.	*Ziziphus jujube* Mill	Rhamnaceae	Bogri	Boils	Tender leaves	Paste of freshly collect tender leaves is applied locally twice daily for 5 days	Alkaloids

4. DISCUSSION

The data from the evaluation of ethnobotanical aspects of collected medicinal plants reveals that the different plant parts like root, leave, tender leaf and shoot, rhizome, inflorescence, flower, fruit, endosperm and even whole plant are used for treating various diseases. Use of *F. hispida, M. koenigii, T. divericata,* for treatment respectively of Jaundice, heart, eye and mouth diseases are new report for ethnobotanical aspects.

A number of plants are used for some

common problems boil, wound, fever, cough, stomach problems, dysentery, gastric, dandruff, body pain and skin diseases while some are very special for diabetics, jaundice, sinusitis, kidney stone, heart diseases and as blood purifier.

The tribal people have evolved this traditional knowledge by trial and error method and have developed their own way of diagnosis and treatment for different diseases. Generally, a few person known as *"Bez"* – the local traditional medicine practitioner is well versed about the diagnosis and treatment of different diseases by using these medicinal plants. The common people generally used to go to the medicine man for the treatment of different diseases.

Regarding the mode of administration, the decoction from freshly collected plant parts, paste, raw material, juice and their products are administered either orally or locally based on nature of diseases. However, the doses of administration per day and duration of treatment are differ in respect to the nature and history of the diseases.

The efficacy of these diseases mainly depends on the selection of the medicinal plants and their proper method of administration.

Future Prospects

The active ingredients recorded in the study like alkaloids, organic acids, essential oils, opens an aspect for phytochemical as well as clinical evaluations.

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Feeding Behaviour of Tank Goby, *Glossogobius giuris* (Hamilton) and Its Rearing Feasibility in Upper Assam

Monjeet Sonowal[1*], Nipen Nayak[2] and S P Biswas[3]

[1]*Department of Zoology, Faculty of Sciences, Arunachal University of Studies Namsai, Arunachal Pradesh*
[2,3] *Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam*
[*]*Corresponding author: sonowal.monjeet@gmail.com*

Abstract : Feeding behaviour and rearing feasibility of a multipurpose wild goby fish, *Glossogobius giuris* in backyard ponds has been discussed. The fish shows inclination towards animal diet with wide range of food preferences at various trophic levels. Specimens collected from natural habitat and also from rearing pond indicate its preference towards small sized fishes. The fish is a voracious feeder and exhibit somewhat aggressive behaviour when kept in fasting mode for a period of 12 to 24 hour. Further, the fish prefers mostly in live food, be it small fish, earthworm or mosquito larvae but exhibit little interest towards homemade and commercial fish feed.

Keywords: *Rearing feasibility; Glossogobius giuris; feeding preferences*

1. INTRODUCTION

Glossogobius giuris is a widely distributed fish commonly known as sleeper goby or tank goby. It is a potential aquarium fish due to its odd attractive look [1], alternate mosquito control measure [2, 3], larvicidal characteristics and also reported as bioindicator in pesticide polluted areas [4]. The species is known as *Pati-mutura* in the Brahmaputra valley and apart from its food value, it is widely used as medicinal fish by indigenous tribes like Sonowal-Kachari, Missing and Deori. However, the scientific study and authenticity of its medicinal role in physiological manipulation is yet to be ascertained. Biological vector control and bio monitoring of aquatic systems using small indigenous fishes is an area of interest to reduce the adverse effect of xenobiotics both in artificial and natural ecosystem.

Although it is an important and utility fish; however, the species has been suffering high depletion in its natural habitat due to various direct and indirect anthropogenic activities in aquatic ecosystems [5, 6]. Without any natural revival and increase or artificial introduction of seed population in natural water bodies as well as meeting the demand of supply by inclusion of more of wild fish like *Glossogobius giuris* in aquaculture programme, it is impossible to compensate the rate of extinction of numbers of species. Therefore, the present study of feeding behaviour and rearing feasibility of *Glossogobius giuris* is an attempt to minimize the research gap in biological information with farm aquaculture development of the species in

sub-tropical climatic condition.

2. METHODOLOGY

2.1 Gut content analysis: The analysis of food item was done both qualitatively and quantitatively [7]. For actual assessment of food consumed, volumetric and percentage of occurrence of individual food item in the gut was recorded [8, 9].

2.2 Index of preponderance: The grading of broad category of food items found in the gut was assessed by calculating 'index of preponderance' $I_i = ViOi \times 100 / \sum ViOi$ [10] Where, I_i is index of preponderance; Vi & Oi are volume and occurrence of a particular food item (i).

2.3 Feeding behaviour: Fishes were kept separately with respect to their size and group. Feeding behaviour was observed with different feed with fasting period of 12 hour and 24 hours. To study larvicidal efficacy, fish were given with different stages of mosquito larvae and their feeding preferences were noted [2]. Feeding experiments were done with an interval of two days along with a control set.

2.4. Rearing techniques: Glossogobius giuris enter in ponds accidentally while stocking of ponds or during flood and thus the traditional rearing is extensive fish culture type [11] by fish farmers. The species thrives well in aquarium [Fig.1] and captive culture of the species is done as mentioned for small ornamental fishes [12] and following the guidelines of Central Inland Agricultural Research Institute [13]. The Fry stages of *G. giuris* were reared in cemented cistern, earthen ponds and aquaria with different types of artificial and natural live feed and their feeding preferences towards various items with different intervals of fasting period were recorded.

3. RESULTS and DISCUSSION

***3.1 Seasonal variation of food composition*:** Gut content analysis of the species was conducted from the specimens collected from a backyard pond in Dibrugarh District as well as in aquarium condition. The salient feature of the

Table 1: Diet composition of *Glossogobius giuris*

Food items	Major groups	Approx share (%)
Algae	Chlorophyceae, Bacillariophyceae and Myxophyceae	12
Insects	Coleoptera, Odonata and Diptera	19
Small fishes	*Puntius* sp. *Esomus* and *Chanda*	39
Miscellaneous	Fragments of plants, animal particles, larvae/eggs	10
Detritus	Finely divided organic materials	10
Insect larvae	Larval stage of different insects	1
Earthworm	Artificially feed in pond	2
Coarse matter	Sand and silt particles	7

Seasonal variation in the composition of the gut content was also studied and the findings have been summarized in Table 2. The species showed its highest preference towards small size fishes collected from backyard ponds (38.75 %) and aquarium rearing (45.42 %). The species showed its next preference towards insect [18.25 %] in pond habitat whereas for earthworm [28.49 %] in aquarium condition. Further, the fish collected from pond habitat showed preference towards miscellaneous items [15.38 %], algae [12.75%], detritus [9.79%], earthworms [2.83%] and insect/ mosquito larvae [2.25%] in descending order [Table 2]. In aquarium condition, the feeding preferences were as follows: - insect/ mosquito larvae (8.5%) > detritus (7.10%) > miscellaneous items (5.10%) > algae (4.25%) > artificial fish feed (1.07%).

Fig 1A : *Glossogobius giuris* reared in backyard ponds

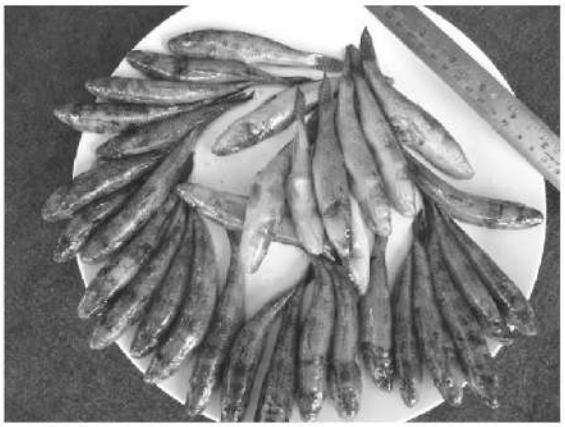

Fig.2 *Glossogobius giuris* collected from backyard ponds

Table 2: Comparative analysis of gut content of *G. giuris* from ponds and captive condition

Food Composition	Backyard Ponds Approx. %	Aquarium rearing Approx. %	Major food items
Algae	12.75	4.25	Chlorophyceae, Bacillariophyceae and Myxophyceae
Earthworms	2.83	28.49	Small earthworms
Insects	18.25	0	Coleoptera, Odonata, and Diptera
Mosquito larvae	2.25	8.5	3rd and 4th instars mosquito larvae
Small fishes	38.75	45.42	*Puntius* sp., *Botia*, *Esomus* and *Chanda*
Artificial fish feed	—	1.07	Commercial feed like Tetracolet, broiler feed
			Rice Bran with dry fish / dry chicken meat/ finely chopped prawns, MOC etc.
Miscellaneous	15.38	5.1	Fragments of decomposing particles
Detritus	9.79	7.1	Finely divided organic materials
Coarse matter	8.75	4.17	Sand and silt particles

G. giuris collected from natural habitat and collected from captive rearing showed its highest preference for small fish (64.96%) and (73.59%) respectively. The next preferred food being insect [20.74%] in natural habitat and earthworm [14.02%] in captive condition [Table 3].

3.2 Feeding behaviour: *G. giuris* showed very high feeding preference only towards live feeds. The fry and fingerlings were found to consume voraciously insect eggs and larvae including mosquito larvae. Highest feeding efficiency was observed at 24 hour fasting period. The fish showed very low (10%) preference for commercial fish feed or home-made feed even after 12- and 24-hours fasting period. Larger specimens [7 - 13 cm] kept for fasting period of 12 and 24 hours showed no attraction towards 1st and 2nd instars larvae. However, 7 - 13 cm size group found to consume 3rd and 4th instars larvae whereas same size group kept for 24 hours fasting readily consumed 4th instars larvae.

The food and feeding habit off *Glossogobius giuris* collected from natural habitat and also from captive rearing showed its highest preference for small fishes (Table 3). This indicated its predatory, invasive carnivorous behaviours which places it as first carnivore in its food web in both natural and artificial habitat [14, 15, 16]. The adaptation of the species from surface to bottom area is indicated from its wide range of food preferences at various trophic levels. Its preference towards insect (20.74%), insect / mosquito larvae (0.19%) in natural habitat whereas it is earthworm (14.02), insect/ mosquito larvae (2.68%) in captive condition explains its foraging behaviour at different columns of water. The fish observed to have very little choice for earthworms, algae, detritus and other benthic fauna while foraging in natural habitat, but in controlled conditions (captive rearing), the species becomes carni-omnivorous. Similar observations were also made for the same species by other workers [17, 18, 19] *G. giuris* showed interesting feeding behaviour differently towards different food items. The fish is habitually concerned towards any living creature such as insect larvae, pupal stages of silkworm, earthworm and small fishes like *Puntius* spp., *Botia* sp., *Esomus danricus* and *Chanda* spp. Highest feeding efficiency was noticed at 24 hour fasting period towards live small fish and earthworms (Fig 2) in both captive and natural backyard ponds habitat resulting differential percentage value observation. However, the fish showed little or no interest towards commercially available fish feed or homemade feed even after 12- and 24-hours fasting period.

The fish showed adaptive behaviour towards availability of food and its abundance. But study shows a high preference for live feeds including mosquito larvae which is why *G. giuris* is a high valued fish as far as vector control is concerned [20].

Fig 3: *Glossogobius giuris* reared in aquarium

Table 3: Comparative Index of preponderance of *Glossogobius giuris* from Natural habitat and captive condition

Composition	Pond		Aquarium		Pond	Aquarium	Pond habitat		Aquarium habitat	
	Vol %	Occ %	Vol %	Occ %	V_1O_1	V_2O_2	$V_1O_1X100 /\sum V_1O_1$	Grading	$V_2O_2X100 /\sum V_1O_1$	Grading
Algae	11.75	4.45	1.25	3.55	52.29	4.44	2.33	VI	0.18	VII
Earthworm	0.83	2.22	28.33	12.44	1.84	352.43	0.08	VIII	14.02	II
Insect	18.25	25.5	0.00	0	465.38	0.00	20.74	II	0.00	VIII
Insect/ mosquito larvae	1.25	3.45	7.5	8.98	4.31	67.35	0.19	VII	2.68	V
Small fish	38.75	37.62	40.42	45.77	1457.78	1850.02	64.96	I	73.59	I
Misc.	11.25	9.89	9.17	12.02	111.26	110.22	4.96	III	4.38	III
Detritus	9.17	8.99	9.17	11.6	82.44	106.37	3.67	IV	4.23	IV
Sand	8.75	7.88	4.17	5.64	68.95	23.52	3.07	V	0.94	VI
Total	100	100	100	100	2244	2514				

Table 4: Artificial Feeding prospect of *Glossogobius giuris* for aquarium rearing

Sample site	Fish size (cm)	Fasting period (hour)	Feeding preference towards different feed in %				
			Commercial aquarium fish feed	Homemade fish feed	Live small fish	Live small earthworm	Mosquitoes larvae (4th instars)
AQ 01	7 - 10	12	0	0	50	50	25
AQ 02	7 - 10	24	10	10	100	100	50
AQ 03	11 -13	12	0	0	50	75	0
AQ 04	11 -13	24	20	10	100	100	50
AQ 05	13-15	12	0	0	50	25	0
AQ 06	13-15	24	0	0	100	50	0
AQ 07	7 - 15	24	20	10	100	75	25

Glossogobius giuris is a carnivorous and voracious feeder. The species prefer live food in controlled condition. The species shows preference for live mosquito larvae when they are fry and fingerling stage. Adult fishes prefer particularly small fish and earthworm. They show very little or no preference to artificially prepared food, normally fed to other aquarium fish. *G. giuris* is a bottom dweller fish with unique body coloration showing sensitive response to the habited ecology. In general, the fish observed playful in presence of other fishes but highly aggressive and predatory, if kept for fasting for a longer period. It exhibited aggressive predatory behaviour and predate on small size fishes in aquarium condition. The fish was also observed to consume their own eggs and hatchlings in aquarium if kept unfed for long time.

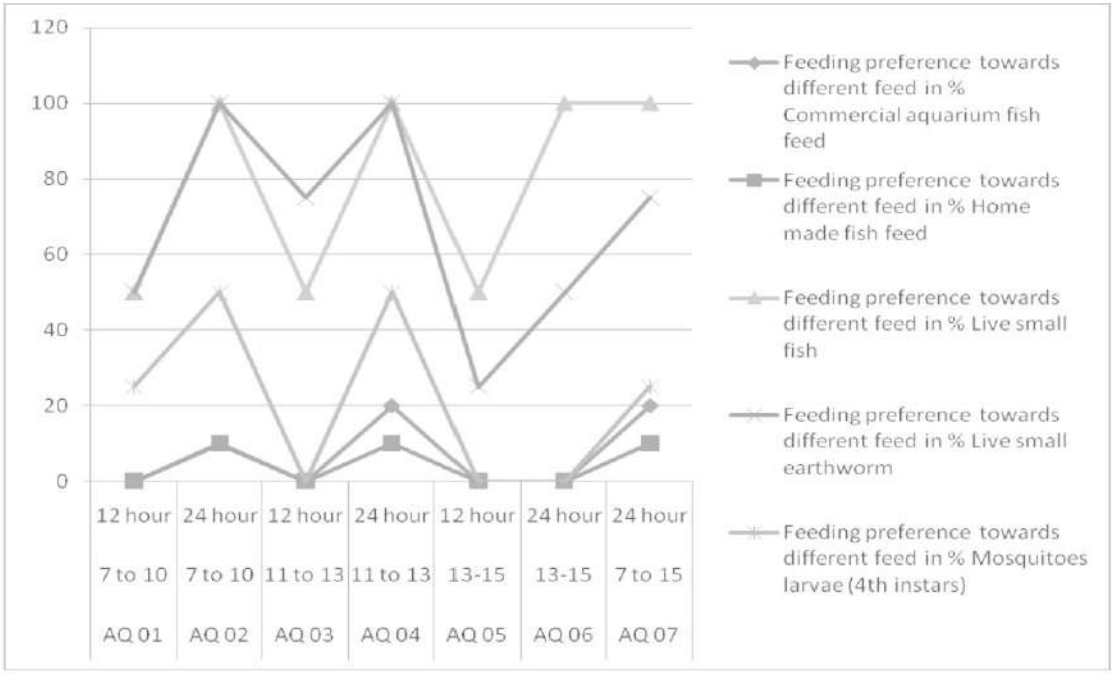

Fig 4: Artificial feeding regime of *Glossogobius giuris*

G. giuris breeds normally in backyard ponds. Breeding starts from February- March in Upper Assam when water temperature starts increasing. In an earlier experiment on induced breeding of *G. giuris*, the rate of hatching was found higher with 0.4 ml / kg body wt having 2: 1 and 3:1 (M: F) ratio [21]. However, Roy et al. [22] observed that the peak breeding season of this species was August and September. Aquarium rearing with co-species or other species of same size is possible provided *G. giuris* is fed timely and properly. Due to its dependency on a piscivorous diet, a tropic level 5 can be assigned to this fish [23]

4. CONCLUSION

Glossogobius giuris is found in lentic as well as lotic ecosystem of upper Assam and shows normal feeding behavior in backyard ponds and also in aquarium after acclimatization. The species is widely considered as ornamental fish in the region and can be reared and commercialized in aquarium trade. Further, this species can be effectively used as bioindicator of pesticide pollution due to agricultural wash off as goby fish is quite sensitive to aquatic pollution [4]. Rearing of *G. giuris* in backyard pond (Fig. 3A, B) is feasible with others species notably with carp fingerlings (>10 cm). and Commercial rearing of the species can be developed as one of the beneficial economical practices in rural areas of upper Assam [Fig.4] as it has a reasonably high market value as food as well as in ornamental fish trade.

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A Review of the Virology of SARS-CoV-2

Aldonna Maria Susngi[1]*, Clara Ermine Sawian[1]

[1]*St. Anthony's College, Shillong-793001, Meghalaya, India*

**Corresponding author: asusngi@gmail.com*

Abstract: The novel severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2), the causative agent of Coronavirus disease 2019 (COVID-19) is a β-coronavirus, which also includes the highly pathogenic severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome Coronavirus (MERS-CoV). Emerging in December 2019 from Wuhan, China, it has spread worldwide resulting in a pandemic that has not ended till date. This review highlights some of the key features of the virology of SARS-CoV-2.

Keywords: *SARS-CoV-2; COVID-19; Coronavirus; virology; RT-PCR*

1. INTRODUCTION

In December 2019, a pneumonia of unknown etiology characterized mainly by fever, with a few cases having difficulty in breathing, emerged in a seafood wet market situated in Wuhan, Hubei Province in China [1,2,3,4]. The disease then spread to other countries around the world, resulting in a pandemic. The pathogen responsible for the disease was identified as a novel β-coronavirus initially named 2019 novel Coronavirus (2019-nCoV) and later renamed Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2). The disease was also called 2019-nCoV, after the virus, but it was officially renamed Coronavirus disease 2019 (COVID-19) by the World Health Organisation (WHO) in February 11, 2020 [5]. According to the WHO there are a total 81,475,053 confirmed COVID-19 cases with 1,798,050 deaths globally as of 31 December, 2020 [6].

This review aims to give an insight into the virology of SARS-CoV-2 which will include the general structure of the virus, its genetics, its process of replication and the diagnostic tools that are used to detect and identify it.

2. VIRAL STRUCTURE AND GENETICS

Coronaviruses are enveloped, positive single-strand RNA viruses and as the name suggests there are spike-like structures on theirs surface, giving them a characteristic *corona* or "crown-like" appearance [7, 8, 9] (Figure 1). The size of SARS-CoV-2 virion ranges from about 60 to 140 nm [10]. The viral genome is approximately 30kb in size and forms part of the helical nucleocapsid along with the nucleocapsid (N) protein [9]. The viral RNA is capped and polyadenylated [11]. Besides N protein, the SARS-CoV-2 genome encodes three other structural proteins: the spike (S) protein, membrane (M) protein, and the envelope (E) protein [12].

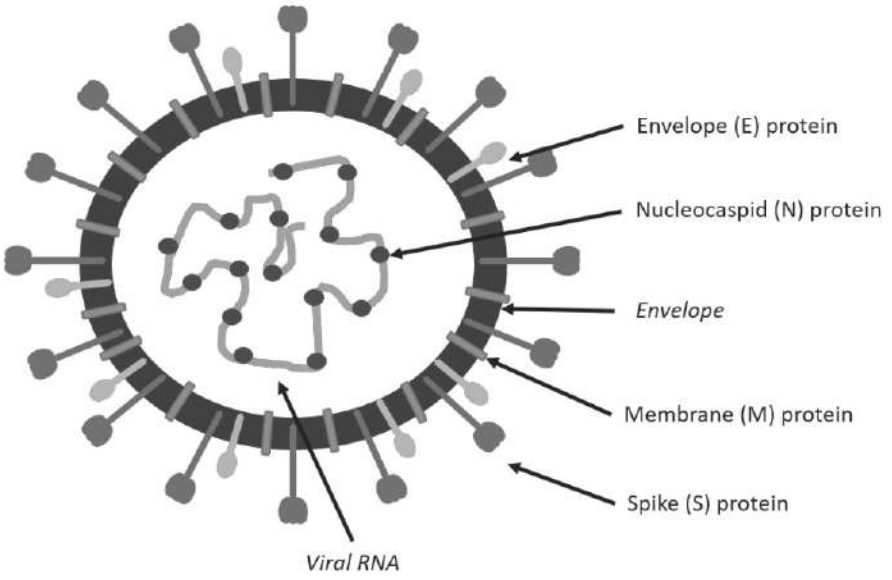

Fig 1: Schematic representation of the SARS-CoV-2 virion. The envelope (E) transmembrane proteins, the membrane (M) proteins and the spike (S) glycoproteins are represented on the viral envelope. The positive-sense viral genomic RNA is associated with the nucleocapsid (N) protein forming the nucleocapsid.

The three structural proteins S protein, M protein and E protein are embedded on the viral envelope and are required to produce a structurally complete virion. The S protein consists of three copies of the S glycoprotein [13]. The S protein recognises the receptors on the host cell, mediating the attachment of the virus and subsequent fusion with the host cell membrane. The M protein is the most abundant structural protein in coronaviruses [9, 13]. The M protein is important for the assembly of the S protein in the viral envelope and outlines the shape of the envelope [14]. The E protein, a small integral membrane protein is involved in the assembly, budding and trafficking of the nascent virions [13]. The N protein is the only structural protein that: interacts directly with the viral RNA, protects the viral RNA and is not found on the envelope [9, 13, 14].

There have been two major coronavirus outbreaks, SARS-CoV (severe acute respiratory syndrome coronavirus) in 2002 and MERS-CoV (Middle East respiratory syndrome Coronavirus) in 2012 and recently in 2019, the SARS-CoV-2 the third highly pathogenic outbreak, of which have crossed the species barrier to cause deadly pneumonia in humans [16].

Analysis of the genomes of SARS-CoV-2 and SARS-CoV has revealed great similarity between them. Thus, researchers classified it as a member of lineage B (from the International Committee on Taxonomy of Viruses) [17]. The genome of SARS-CoV-2 consists of six major ORFs and shares less than an 80% nucleotide sequence identity with SARS-CoV. However, the seven conserved replicase domains in the ORF1ab amino acid sequence share a 94.4% identity

with those in SARS-CoV [18]. MERS-CoV was the first β-coronavirus lineage C member identified as a "novel coronavirus" with a genome size of 30,119 nucleotides. The genome of MERS-CoV encodes 10 proteins. These 10 proteins comprise two polyproteins (ORF1ab and ORF1a), four structural proteins (E, N, S, and M), and four non-structural proteins (ORFs 3, 4a, 4b, and 5)[19].

Although the case fatality rate of SARS-CoV-2 (3.7%) is lower compared to those of SARS-CoV (9.14%) and MERS-CoV (34.4%), it is evident that the SARS-CoV-2 is more infectious [20]. The structural differences in the S proteins between the SARS-CoV-2 and SARS-CoV could be one of the reasons for the former to spread more rapidly as compared to the latter. Therefore, molecular characterization of SARS-CoV-2 S protein is highly important [21].

Another characteristic feature of SARS-CoV-2 is a polybasic cleavage site (PRRARSV), which is found at the junction of S1 and S2 of the S protein [16, 22]. This furin recognition motif permits effective cleavage by furin and other proteases and this may facilitate the priming of the S protein and possible increase the efficiency of the spread of SARS-CoV-2 as compared to other β-coronaviruses.

3. VIRAL REPLICATION CYCLE

The replication cycle of SARS-CoV-2 (Figure 2) is assumed to be similar to that of the viruses that cause SARS and MERs. SARS-CoV-2 binds to host cells via the membrane-bound glycoprotein angiotensin-converting enzyme 2 (ACE2). The binding is mediated by the S protein on the viral surface [11-13]. The virus then enters the host cell via endocytosis. Another membrane bound protease known as transmembrane serine protease 2 (TMPRSS2) on the host cell, which cleaves the S protein, is also essential for membrane fusion [12].

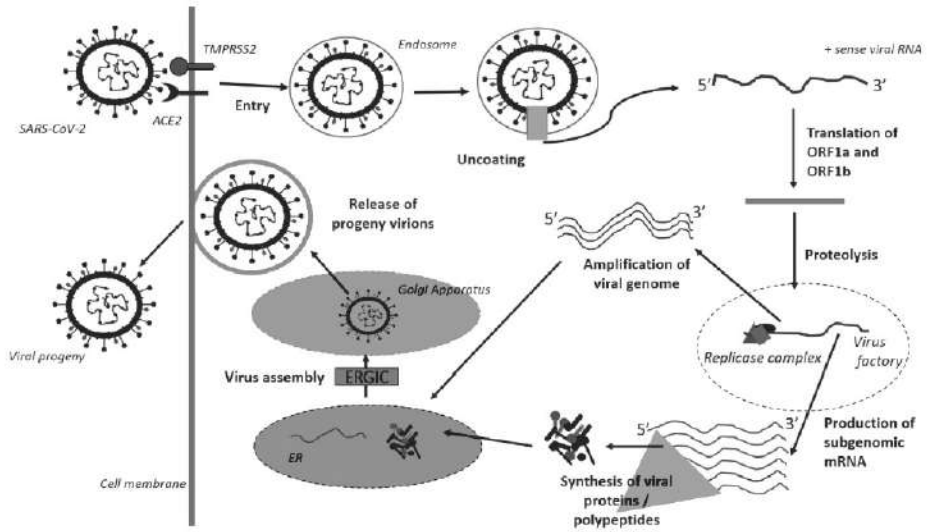

Fig 2: SARS-CoV-2 replication cycle.

Inside the host cell, the positive sense viral RNA is released, exposing two large open reading frames, ORF1a and ORF1b [11,12,13]. The resulting polyproteins are processed by proteases into 16 non-structural proteins that form the viral replication and transcription complex. The non-structural proteins include RNA processing, RNA modifying enzymes, proteases, helicase and the RNA-dependent RNA polymerase (RdRp). RdRp is responsible for generating and amplifying positive sense viral genomic RNA that can then be packaged into individual virions [23].

The ORFs that encode the four structural proteins and the accessory proteins are transcribed from the 3'end of the genome to form a nested set of sub-genomic mRNA molecules [11-13, 23]. After translation, the structural proteins translocate into the endoplasmic reticulum (ER) membranes and transit through the ER-to-Golgi intermediate compartment (ERGIC). The nascent SARS-CoV-2 virions are assembled in the ERGIC and they are then finally secreted from the host cell by exocytosis [9, 11, 23].

4. DIAGNOSTIC TOOLS FOR SARS-COV-2 VIRUS

To help in containment of COVID 19, diagnostics play an important role, limiting the spread and enabling rapid implementation of control, isolation, and contact tracing (*i.e.* identifying the people that a COVID-19 patient has come in contact with) [24].

There is a revolution in the manufacturing of diagnostic tests in response to the ever-increasing of Covid 19 infections globally. These tests are based either on detection of proteins from the SARS-CoV-2 virus in respiratory samples from sputum or throat/nasal swabs; or detection of human antibodies in blood or serum, which have been generated in response to the viral infection [15,25].

4.1. REAL TIME REVERSE TRANSCRIPTION POLYMERASE CHAIN REACTION (RT-PCR)

Real time reverse transcription polymerase chain reaction (rRT-PCR) assays are considered the "gold standard" in SARS-CoV-2 detection. RT-PCR testing of respiratory tract samples is the method recommended for the identification and laboratory confirmation of COVID-19 cases. By this assay, it detects RNA which is the genetic material of the virus and can detect its presence within days of infection, even those who are "asymptomatic" or show no symptoms while having the disease [26, 27].

Amplification of the virus' nucleic acid is necessary in order to be able to detect its presence. RT-PCR will amplify only DNA, so the RNA which is the genetic material of the virus, has to be first converted into DNA (cDNA) by a process called reverse transcription (Figure:3). The cDNA produced is followed by amplification of specific regions using primers and fluorescent probes for detection purposes in the real time thermocycler.

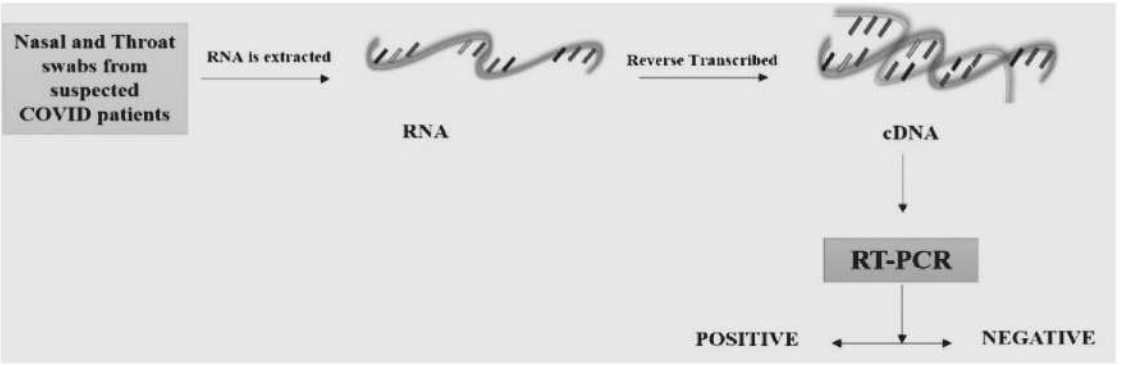

Fig 3: Real time reverse transcription polymerase chain reaction (RT-PCR) assay

A negative result does not eliminate the possibility of SARS-CoV-2 infection. Therefore, it should not be used as the only criterion for treatment or patient management decisions. It seems that combination of real-time RT-PCR and clinical features facilitates management of SARS-CoV-2 outbreak.

4.2. ANTIGEN BASED TESTING

Antigen tests are immunoassays indicating the presence of the SARS-CoV-2 virus, and reveal whether a person is currently infected with the virus. These tests detect the proteins or glycans like the spike proteins that are present on the surface of the virus [28].

The tests have been developed as both laboratory-based tests, and for near-patient use, so called rapid diagnostic tests, or RDTs, where sampling is performed from the nasopharyngeal or nasal area and the secretions placed directly into the assay's extraction buffer or reagent (Figure 4). A few drops from that are then added to the sample well (S). The results should be viewed within 15-30 mins and not after that, may give false results. The Control (C) well will change colour (here red) indicating the test is working properly. If the test well (T) shows a coloured band, indicating that the test is positive for SARS-CoV-2 antigen. Even if the color is very faint in the test-window it should be taken as positive. If there is no change in colour in the test window, then the test indicates that it is negative for the presence of the virus [29].

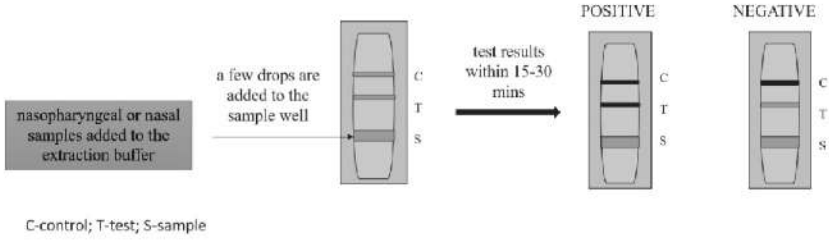

Fig 4: Antigen-based RDT for SARS-CoV-2

The antigen-based tests are comparatively inexpensive however are less sensitive when compared to the real-time reverse transcription polymerase chain reaction. If an antigen shows a positive result, a confirmatory testing should be followed (like RT-PCR) which is important for accurate clinical management of patients.

Many factors may influence the performance of the antigen test, such as: the onset of the symptoms, the incorrect sampling procedures and areas, viral load, poor product design and quality of the kits etc. [29].

4.3. ANTIBODY BASED TESTING

Antibodies are proteins that are formed in response to an infection. This production of antibodies, an immune response, can be detected in the blood of people. The antibody test is a lateral flow immunoassay that will assess qualitatively the presence of antibodies, IgG and IgM antibodies, specific for SARS-CoV-2 in the sample (whole blood, serum or plasma). The test cassette is a qualitative membrane-based immunoassay for the detection of IgG and IgM antibodies [30].

An antibody test does not detect the presence of the SARS-CoV-2 virus and therefore cannot use as a diagnostic tool for COVID 19. It can show a false negative result even if the person is infected with the virus, because development of the antibodies against it has not occurred. It can even show a false positive result even after the person has recovered from the infection but because the antibodies to the virus are still present in the persons system. It can also show false positive if the person has antibodies against another virus of the same Coronavirus family [31, 32]. Antibody test results are especially important for detecting previous infections in people who had few or no symptoms [33].

There are other diagnostic tools for SARS-CoV2 for example: the use of Crispr Cas 12, nanotechnology etc. that have not been discussed here but are still being perfected for general use [34, 35].

5. CONCLUSION

With new strains of SARS-CoV-2 emerging, it seems unlikely that the pandemic will die out anytime soon. We have to continue following prescribed protocols such as social distancing, wearing masks, frequent washing of our hands and using hand sanitizers. This pandemic is a wakeup call. It will certainly not be the last pandemic of its kind; new novel viruses will continue to emerge. The scientific community has to be alert and prepared.

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Presented paper:

Zekeri, Andrew A. and Rueben C. Warren. 2011. "Coping with Hurricane Katrina: Psychological Resilience among African American Families in Rural Alabama." Paper presented at the annual meeting of the Southern Rural Sociological Association. Corpus Christi, TX. Feb. 7.

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Wimberley, Ronald and Libby V. Morris. 2002. "The Regionalization of Poverty: Assistance for the Black Belt South." *Southern Rural Sociology* 18(1):294-306. Retrieved April 30, 2008 http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/SRS%202002%2018%201%20294-306.pdf).

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