

Distribution of ichthyoplankton in the sinu river, Colombia

Abstract

Taking into account that recently the study of ichthyoplankton has become important as an indicator of the reproductive performance of the reofilic fishes, the present investigation studies their distribution in the Sinú River, Colombia, according to the hydraulic variables (area, speed, depth and open surface). 18 samplings were carried out between the years 2001 and 2003, utilizing flow meters, spindles and procedures for the quantification of larvae; it is proposed that a methodology to estimate the total load of ichthyoplankton considering that the distribution follows the same pattern as the distribution of the average speed of the river; the results indicate that the greater load of ichthyoplankton pass by the areas of lesser speed. The estimations of the quantity of ichthyoplankton are overestimated when considering an even distribution; hence it is suggested that the proposed method be utilized, in order to quantify the estimation of ichthyoplankton that passes by the principal canal of a river.

Keywords: reofilic fishes, ictiología, hydraulic variables, transport of larvae, tropical rivers

Volume 3 Issue 4 - 2018

Teobaldis Mercado Fernández,¹ Eduardo Kerguelén Durango,² Victor Atencio García²

¹Professor, University of Córdoba, Hidrociencias, Colombia

²Fish Research Center, Universidad de Córdoba, Colombia

Correspondence: Teobaldis Mercado Fernández, Professor University of Córdoba, PhD, Hidrociencias, Carrera 6a # 76 – 103, Montería, Córdoba, Colombia,
Email tmercado@correo.unicordoba.edu.co

Received: June 18, 2018 | **Published:** August 08, 2018

Introduction

The Sinu River originates from the Nudo de Paramillo (Colombia), travels across 380 Km before flowing into the Caribbean Sea of Colombia, its basin has an area of 15.600 Km² and is 266 Km² from the mouth a hydroelectric power station was constructed. The more important commercial fish from the Colombian rivers are the known reofilic fishes among which stand out carácidos of the genus *Prochilodus*, *Brycon*, *Leporinus* and silúridos such as *Pseudoplatystoma*, *Sorubim*, *Pimelodus*, *Brachyplatystoma*, among others. Those fish abandon the swamps and migrate upstream in the dry period in order to secure areas of maturity; in the Sinú river this event generally occurs between October and February of each year. Subsequently during the rainy period (April–October) they reproduce, considering the months from April to July as those of greater reproductive activity. Then from spawning they return again to the swamps or flood plains where they recuperate and initiate a new reproductive cycle. One of the exceptional characteristics of the reofilic fishes is their reproduction (courting, mating and spawning) occur in the principal canal of the rivers; as well as the incubation and hatching of the larvae, those products called ichthyoplankton are transported to the flood plains (swamps) when they are soon ready to initiate exogenous feeding.^{1–3}

The study of eggs and fish larvae that are transported by the river has gained attention because it offers information about the ecology, biology and systematic of these species.⁴ It allows for the recognition of embryos and fish larvae in natural environments.² it allows for the identification of the hatching areas, reproductive period and their quantitative estimation, it is an indicator of the reproductive performance of reofilic fishes.^{5,6} In general, studies about ichthyoplankton, in South American rivers (Amazona, San Francisco, Panama, Orinoco, Uruguay, Magdalena and Sinu, among others) are focused principally on the description of eggs and larvae.^{2–10} Some to the determination of areas and seasons for hatching^{3–11} and the quantitative estimation of ichthyoplankton as an indicator of reproductive performance of the reofilic fishes has recently become

important, in order to monitor the effects of the disturbances caused in the rivers taken over by antropic action.

Studying the variables that define how ichthyoplankton is transported in the rivers, in particular how is their distribution in the section of the river^{5–12} will allow advancements in the definition of a model of quantitative estimation that considers its distribution, as well as allow for a better way of selecting the sites for sample collection of ichthyoplankton for their study. One of the characteristics of the plankton is that its transportation capacity is limited and therefore is defined by the movement of water; in a river the hydraulic variables that define the characteristics of the movement and therefore of the ichthyoplankton. Araujo Lima et al.,¹² studied the transport of fish larvae in the Amazon River and found that ichthyoplankton of Characiformes and Siluriformes is more abundant near the river banks and they associated it with a strategy to facilitate its dispersion to the flood plains. In the Sinu River Atencio et al.,³ found that the distribution of the larvae was not even in the section of the river and reported that in the margin of lesser speed more ichthyoplankton was collected than in the other. For which the objective of this study was to know the distribution of ichthyoplankton according to the hydraulic variables and define a model to estimate the ichthyoplankton in the section of the river.

Materials and methods

In the lower part of the Sinu river, to the higher part of Cotocá Abajo (Córdoba, Colombia.) 40 Km from its mouth in the Caribbean Sea (Figure 1), 18 samples were taken in 2001 (16, 23/jun, 7,21, 28/ July, 4, 16, 25/august, 1, 8, 15 21/sep) and 6 samples in 2003 (14, 21, 28/jun, 5, 19/July, 2/sep) in order to evaluate the distribution of ichthyoplankton according to the hydraulic variables of the river: area of section and total subsection (m²), volume per time (m³/s) of the subsection and section total, open surface (m), vertical depth (m) and speed (m/s) on the surface, at 20 % and 80% of each depth of the verticals every 8 m from the right margin to the left. The open surface of the river in the site of study oscillated between 132 and 140 m,

which is why the number of verticals for sampling oscillated between 16 and 17 (Figure 1). For the measurement of the speed and depth in each vertical section of the river a flow meter was utilized (A.OTT Kempton, C31-00, Alemania) with a propeller (2-38798, Alemania), flow meter (A.OTT Kempton, Typ 12.400, Alemania) and a spindle (65645PKS, Alemania). The speed (V) was estimated through the equation 1:

$$V = 0,51 \times NR + 0,05 \quad (1)$$

Where V is the speed of the flow (m/s) and NR is the number of revolutions of the propeller in 50 seconds.

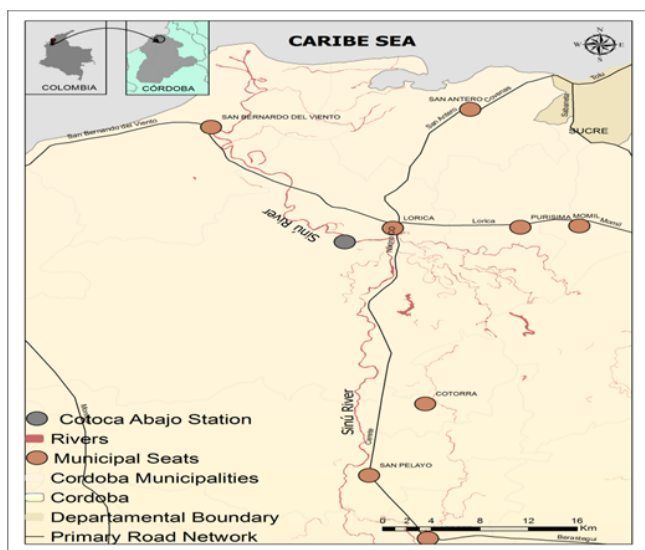


Figure 1 Study area.

The ichthyoplankton was collected with a planktonic net of 0.5 m in diameter and 0.2 mm mesh holes, accompanied by a device that would open to the depth indicated and then in a minute would close. The ichthyoplankton collected, during this time, was transferred to a transparent 1000 mL polypropylene container, it was labeled for its subsequent count and identification in the Centro de Investigación Piscícola de la Universidad de Córdoba CINPIC, Colombia, with the help of stereoscope (Carl Zeiss, Stemi 2000c, Alemania), microscope (Carl Zeiss, Axiostar plus, Alemania) and an image analyzer (Carl Zeiss, Axiovision 4, Alemania). For the identification of the ichthyoplankton the codes described by Nakatani et al.,^{3,4} were used.

The load or total density of ichthyoplankton in the hydraulic section of the river was estimated with equation 2, which considers that its distribution follows the same behavior of the speed in the river and the duration of the event an average time of 8 hours a day.

$$N = \sum_i^n \frac{QS_i \times CIMR_i}{Q_{red_i}} \quad (2)$$

Where N is the total load of ichthyoplankton in the river (individuals/min);

QS_i , the volume per time of the subsection I (m^3/s);

$CIMR_i$, the load of ichthyoplankton from the trap in the subsection $i - nth$ (individuals/min);

Q_{red_i} , the volume per time of the sampling red in the subsection i (m^3/s) and

n the number of subsections.

The load of ichthyoplankton in the average trap in a subsection ($CIMR$) depends on the average sample load in the vertical ($CIMV$), which was estimated following the hydraulic distribution of the average speed utilizing equation 3.^{13,14} The load for the first and last subsection is equal to 2/3 of the average loads and their respective verticals; the load for the second to the antepenultimate subsections is equal to the average of the average loads of its adjacent verticals.

$$CIMV = \frac{CI_{sup} + 3 \times CI_{0,2} + CI_{0,8}}{5} \quad (3)$$

Where $CIMV$ is the average load of ichthyoplankton in each vertical; (individuals/day);

CI_{sup} , the load of simple ichthyoplankton on the surface of each vertical;

$CI_{0,2}$, the load of simple ichthyoplankton to 20% of depth in each vertical and

$CI_{0,8}$ the load of sample ichthyoplankton 80% of the depth of each vertical.

Results

16 larvae states were identified from 13 species of fish, pertaining to eight families of the Characiformes and Siluriformes orders (Table 1) (Figure 2). In the section of the river the distribution of ichthyoplankton was not even and was inversely correlated to the speed of the river for which the greater density of ichthyoplankton was registered in the left margin where the lesser speeds were measured ($P > 0.05$) (Figure 3 & 4). In Figure 3 it is observed that the greater speeds are found between the surface and 20 % of the vertical depth, with the tendency to diminish towards the left margin. Figure 4 shows that the load of ichthyoplankton is greater towards the right margin, in which the lesser speeds of the river presented themselves. Table 2 presents the estimation of the load or total density of ichthyoplankton, in one of the samples (28 of July), utilizing the proposed equations for this study (equations 2 and 3), and in Table 3 the same estimation using equation 4, which considers the even distribution in the main section of the river.

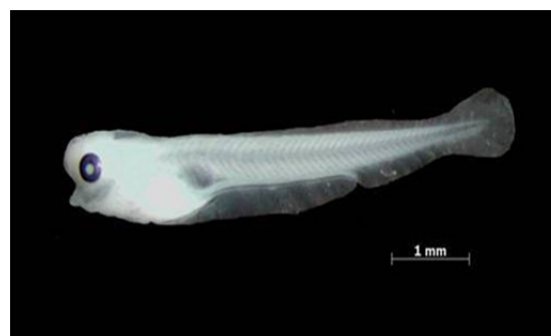


Figure 2 Bocachico larvae (*Prochilodus magdalenae*).

$$N = \frac{Q_{rio} \times n}{Q_{red}} \tag{4}$$

Where *N* is the load of ichthyoplankton in the river (individuals/min);

Q_{rio}, the volume per time of the river (m³/s);

n, the average number of individuals in the sampling net (individuals/min) y *Q_{red}* the volume per time in the ichthyoplankton net (m³/s). One can observe that the estimation with equation 4 is 3.2 times greater compared to the proposed method (equations 2 and 3), which indicate that the estimation with equation 4 generates an overestimation of the load of ichthyoplankton and reproductive performance of the reofilices fishes that pass through the section of the river, due to the fact that only a vertical superficial in one of the banks is being sampled.

Table 1 Identification of ichthyoplankton collected in the Sinú River to the height of Cotocá Abajo (Córdoba, Colombia)

Orders	Family	Specie	
Characiformes	Prochilodontidae	<i>Prochilodus magdalenae</i>	
	Anostomidae	<i>Leporinus muyscorum</i>	
	Curimatidae	<i>Cyphocharax magdalenae</i>	
	Characidae		<i>Brycon sinuensis</i>
			<i>Roebooides sp</i>
			<i>Nanocheirodon insignis Astyanas sp</i>
Siluriformes		<i>Gephyrocharax sinuensis</i>	
	Pimelodidae	<i>Sorubim cuspicaudus Pimelodus sp</i>	
	Cetopsidae	<i>Pseudocetopsis othonops</i>	
	Pseudopimelodidae	<i>Pseudopimelodus bufonius</i>	
	Heptapteridae	<i>Rhamdia sp</i>	

Table 2 Estimation of the load of ichthyoplankton in the Lower Sinú, Cotocá Abajo, Córdoba, Colombia. (28 July of 2001)

D (m)	PV (m)	VV (m)	VMV (m)	VMS (m)	AS (m ²)	Qs (m ³ /s)	CI (ind/min)	CIMV (ind/min)	CIMR (ind/min)	CIMS (ind/day)
8	3,68	0,50	0,36	0,24	14,72	3,48	25	22	14	518180
		0,39					23			
		0,32					14			
16	4,58	0,96	0,82	0,59	33,04	19,41	16	34	28	2261561
		0,95					43			
		0,69					27			
24	4,95	0,99	0,80	0,81	38,12	30,88	53	30	32	3019314
		0,96					24			
		0,64					27			
32	4,95	1,11	0,95	0,88	39,60	34,65	33	19	25	2381445
		1,11					14			
		0,79					19			
40	4,85	1,18	0,99	0,97	39,20	37,93	37	20	20	1878246
		1,11					13			
		0,86					26			
48	4,78	1,19	1,00	0,99	38,52	38,23	7	14	17	1638498
		1,16					17			
		0,84					14			
56	4,62	1,31	1,03	1,01	37,60	38,07	16	50	32	2941360
		1,23					71			
		0,82					19			
64	4,72	1,23	1,01	1,02	37,36	38,01	0	0	25	2265004
		1,18					0			
		0,84					0			
72	4,22	1,27	1,05	1,03	35,76	36,74	13	8	4	349678
		1,16					4			

D (m)	PV (m)	VV (m)	VMV (m)	VMS (m)	AS (m ²)	Qs (m ³ /s)	CI (ind/min)	CIMV (ind/min)	CIMR (ind/min)	CIMS (ind/day)
		0,93					15			
80	4,42	1,06	0,94	0,99	34,56	34,21	0	0	4	337943
		1,11					0			
		0,76					0			
88	3,82	1,15	0,90	0,92	32,96	30,24	15	16	8	660711
		1,13					16			
		0,67					19			
96	3,9	1,13	0,91	0,90	30,88	27,87	0	0	8	619015
		1,14					0			
		0,67					0			
104	4,08	1,13	0,94	0,92	31,92	29,37	26	30	15	1170481
		1,14					31			
		0,73					31			
112	4,18	1,17	1,07	1,00	33,04	33,04	21	52	41	3319649
		1,21					65			
		0,92					45			
120	4,08	0,8	0,75	0,91	33,04	29,90	84	102	77	6235448
		0,86					108			
		0,63					103			
128	3,98	0,61	0,57	0,66	32,24	21,20	105	130	116	9158229
		0,62					149			
		0,52					99			
132	3,48	0,99	0,71	0,64	14,92	9,55	140	28	79	2885065
		0,76					0			
		0,66					0			
134				0,47	3,48	1,65			19	158802

Where PV = Vertical depth, VV = Velocity in the vertical, VMV = Average velocity in the vertical, VMS = Average velocity in the subsection, AS = Area of the subsection, QS = Volume of the subsection, CIMV = Average load of ichthyoplankton in the vertical; CIMR = Average load of ichthyoplankton media in the net of the subsection; CIMS = Average load of ichthyoplankton in the subsection of the river).

Table 3 Estimation with equation 4 of ichthyoplankton in the Sinu river (Cotocá Abajo, Córdoba, Colombia)

Hora	CI (ind/min)	CIM (ind/min)	Qred (m ³ /s)	Qrio (m ³ /s)	N (ind/día)
07 + 00	27	27	0,04712	494,43	135.989.236
12 + 00	25				
18 + 00	29				

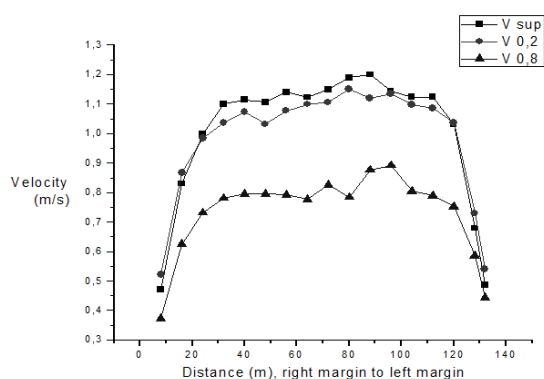


Figure 3 Distribution of average speed (n=18) in the Sinú river to the height of Cotocá Abajo, Colombia.

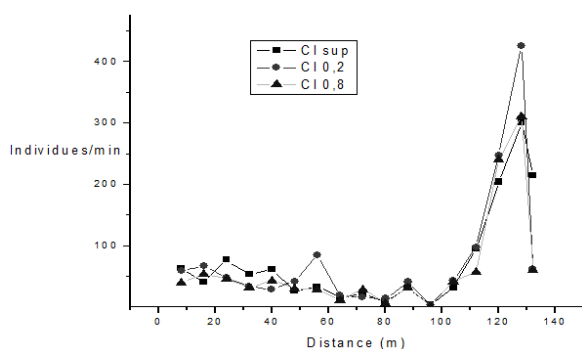


Figure 4 Distribution of accumulated load of ichthyoplankton in the Sinú river, Colombia.

Discussion

During the study 16 larva states of fish, were captured and identified, in a state of pre-flexion between 40 and 66 hours post-fertilization, that is 22.5% of the ichthyofauna (71 species of fish) that have been reported in the Sinú river by Mójica.¹⁵ All the species collected pertained to the orders Characiformes and Siluriformes; which according to Mojica,¹⁵ gather approximately 80% of the fish registered in the Colombian basins. Of the 16 species of larvae, six are reofilic fishes (*Prochilodus magdalenae*, *Brycon sinuensis*, *Sorubim cuspicaudus*, *Leporinus muyscorum*, *Rhamdia sp* and *Pimelodus sp*). The *Prochilodus magdalenae* larvae were the most abundant in the samplings (67.6%), coinciding with the distinction of being the principal fish species in the Colombian and Peruvian rivers;^{16–18} although larva of other species, also reofilic and of fishing interest, such as *Brycon sinuensis* (1.1%), *Sorubim cuspicaudus* (0.8%) and *Pimelodus sp* (1.4%) are present, they can be considered evidence of the decline of these species seeing that the sampling as much as in 2001 as those in 2003, were realized in the rainy period (April–September), the season during which reofilic fishes reproduce.⁵ One of the most unusual features of reofilic fishes is that their life cycle is associated as much with the rivers where they reproduce and the swamps (flood plains) where they feed and grow; which is why their eggs and larvae are transported by the principal canal of the river to the swamps.

On considering hydraulic variables such as depth, total section of the canal, volume per time and speed in the Sinu river, it was observed

that this ultimate variable is that which most affects the distribution of ichthyoplankton. In the Sinú river, the speeds of the right and left margin are different and are related to the process of sedimentation (lesser velocity) and erosion (greater velocity). The greater loads of ichthyoplankton were observed in the areas of lesser speeds (margins); that is to say, the greater loads of ichthyoplankton travel through the river banks. Araujo–Lima et al.,¹² pointed out that the greater larvae density of Characiformes, in the Amazon river near to the Manaos (Brasil), passed near to the river bank.

The water that runs through the river, located on the rotating Earth, suffers the effects of the Coriolis force towards one of its sides. Thus the erosion is generally greater in one of the banks; in the right bank of the Northern hemisphere,¹⁹ as the Sinu River flows in the direction of the equator towards the North Pole, the Coriolis Force tends to displace it towards the right margin, increasing its speed, causing the ichthyoplankton to orient itself towards the lesser speed margin (left). Although it is also probable that the greater larvae density in one of the margins could be influenced by the river margin in which the spawning of these species took place. De Lafontaine²⁰ investigated the distribution and abundance of ichthyoplankton in the estuary of the Manicouagan River (Canada) and pointed out that the distribution of ichthyoplankton depends principally on the spawning areas and estuarine circulation.

When the quantification of ichthyoplankton is estimated considering an even distribution (equation 4), it results in an overestimation of the quantity of ichthyoplankton that passes through the section, because as it is demonstrated in this study of ichthyoplankton, given its limited capacity of movement, its distribution is affected by the behavior of the average speed of the river. Hence this study suggests that it is not convenient to carry out estimations of ichthyoplankton based on the sampling in a vertical in one of the river banks. Therefore, based on the results of the present study it can be suggested that the load of ichthyoplankton is negatively correlated to the speed of the river seeing that the greater densities of ichthyoplankton pass through the sedimentation margin (left) where the lesser speeds were registered. As stated previously, the speed is a variable that affects the distribution of ichthyoplankton in the section of the river, which is why it is important, for the method of estimation to consider the hydraulic variables of all the points where ichthyoplankton is collected from the right margin to the left.

Conclusion

Ichthyoplankton is not evenly distributed in the section of the river. The distribution of ichthyoplankton is intimately related to the hydraulic parameters of the bed (river). The distribution of the load of ichthyoplankton inversely correlates to the speed of the river, hence why the greater loads of ichthyoplankton pass through the margin of lesser speed. It is not recommendable to estimate the load of ichthyoplankton from a single simple sampling in one of the river banks, as one would considerably overestimate the quantity of individuals that pass through the section of the river.

Acknowledgements

The authors would like to thank the Hidroeléctrica Urrá SA–ESP and the Universidad de Córdoba, Colombia, for the funding of this study.

Conflict of interest

The authors declares there is no conflict of interest.

References

- Goulding M. *The fishes and the forest: Explorations in Amazonian natural history*. Los Angeles: University of California press. 1980. p. 280.
- Araujo– Lima C. Egg size and larval development in central Amazon fish. *Journal of Biology*. 1994;44(3):371–389.
- Atencio VJ, Solano JM, Quirós H. *Evaluación de área de desoves entre Urrá I y Tierralta e identificación y cuantificación del ictioplancton*. Montería (Col): Universidad de Córdoba/Urrá SA– ESP. 1996. p. 57.
- Nakatani K, Agostinho A, Baumgartner G, et al. *Ovos e larvas de peixes de agua doce: Desenvolvimento e manual de identificação*. Maringá, Eduem. 2001;378.
- Atencio VJ. *Impactos de la Hidroeléctrica Urrá en los peces migratorios del río Simú*. Temas Agrarios. 2000;8:25–40.
- Atencio VJ, Mercado T, Quiroz H. *Evaluación del desempeño reproductivo de las principales especies reofílicas en el río Simú: Año 2001*. Montería (Col): Universidad de Córdoba/Urrá Sa– ESP. 2001;90.
- Oldani J. Identificación y morfología de larvas, juveniles y adultos de *Mylossoma paraguayensis* Norman 1929 (Pisces, Characidae). *Studies of neotropical fauna and environmental*. 1983;18(2):89–100.
- Araujo– lima C. A larva da branquinha común, *Potamorhina latior* (Curimatidae, Pisces) da Amazônia Central. *Revista Brasileira de Biologia*. 1991;51:45–56.
- Nascimento FL, Araujo– Lima C. Descrição das larvas de *Psectrogaster amazonica* e *Pomamorhina altamazonica* (Cuirmatidae, Pisces) da Amazônia Central. *Acta Amazonica*. 1993;23(4):457–472.
- Baumgartner G. Some aspects of the ecology of fish larvae in the floodplain of the high Paraná river, Brazil. *Revista Brasileira de Zoologia*. 1994;36.
- Jimenez LF. *Temporalidad reproductiva de los peces en la cuenca media Del rio Magdalena, Puerto Berrio (Antioquia), Colombia*. Tesis Ph.D, Medellín: Universidad de Antioquia, 2007.
- Araujo– Lima C, Oliveira EC. Transport of larva fish in the Amazon. *Journal of Fish Biology*. 1998;53(sA):297–306.
- Chow V. *Hidráulica de canales abiertos*. Primera edición. Editorial McGRAW– HILL, Santafé de Bogotá D.C, USA; 1997.
- Mercado T. *Prácticas de hidráulica*. Facultad de Ciencias Agrícolas. Universidad de Córdoba. 1995;95.
- Mójica JI. 1999. *Lista preliminar de las especies de peces dulceacuícolas de Colombia*. Academia Colombiana de Ciencias 23(supl):547–566.
- Valderrama Barco M, Salas Guzmán F, Solano Peña D. Los peces y las pesquerías en el embalse de Urrá: 2001– 2005. Montería: Boques Humedales Fundación/Empresa Urrá SA–ESP. 2006;107.
- Pareja– Carmona M, Jimenez– Segura, Ochoa– Orrego L. 2014. Spatio–temporal variation of the larvae of three species of migratory fish in the stream bed of the Magdalena river (Colombia), during the 2006–2007 hidrological cycle. *Actualidades biológicas*. 2014;36(100):33–38.
- García– Dávila C, Castro– Ruiz D, Sánchez– Ribeiro H, et al. Diversidad de ictioplancton en los ríos curaray, arabela y napo (Amazonia Peruana). *Folia Amazonica*. 2014;23(1):67–78.
- Dingman SL. *Physical Hydrology*. Editorial Prentice– Hall; Estados Unidos de América. 1994;50.
- De Lafontaine Y. Distribution and abundance of ichthyoplankton in the Manicouagan river estuary, a tributary of the Lower St. Lawrence estuary. *Estuaries*. 1990;13(1):43–50.