

# ANALYSIS OF QUANTITATIVE STRUCTURES OF THE LAKE ICHTHYOFAUNA BY STANDARD USE OF VERTICAL NETS

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## **Problematic and objective**

The vertical structure of lacustrine systems is particularly difficult to characterize rapidly in terms of its nature, trophic state and function (HUTCHINSON 1957, DUSSART 1966, POURRIOT and MEYBECK 1995) due to its variation in terms of time and volume. Study of the fish fauna can form the basis of a reliable diagnosis while providing the essential components for the proper management of fish communities (EIFAC 1975, DEGIORGI 1994).

To achieve this goal, the structure of fish communities must be studied according to methods in which the capability, robustness and precision are well defined. Consequently, we have used an integrated approach based on the deployment of "vertical" multimesh nets according to a standard protocol established by DEGIORGI and GRANDMOTTET (1993) then amended by DEGIORGI et al. (2002). The components, advantages and limits of this method are presented in this paper.

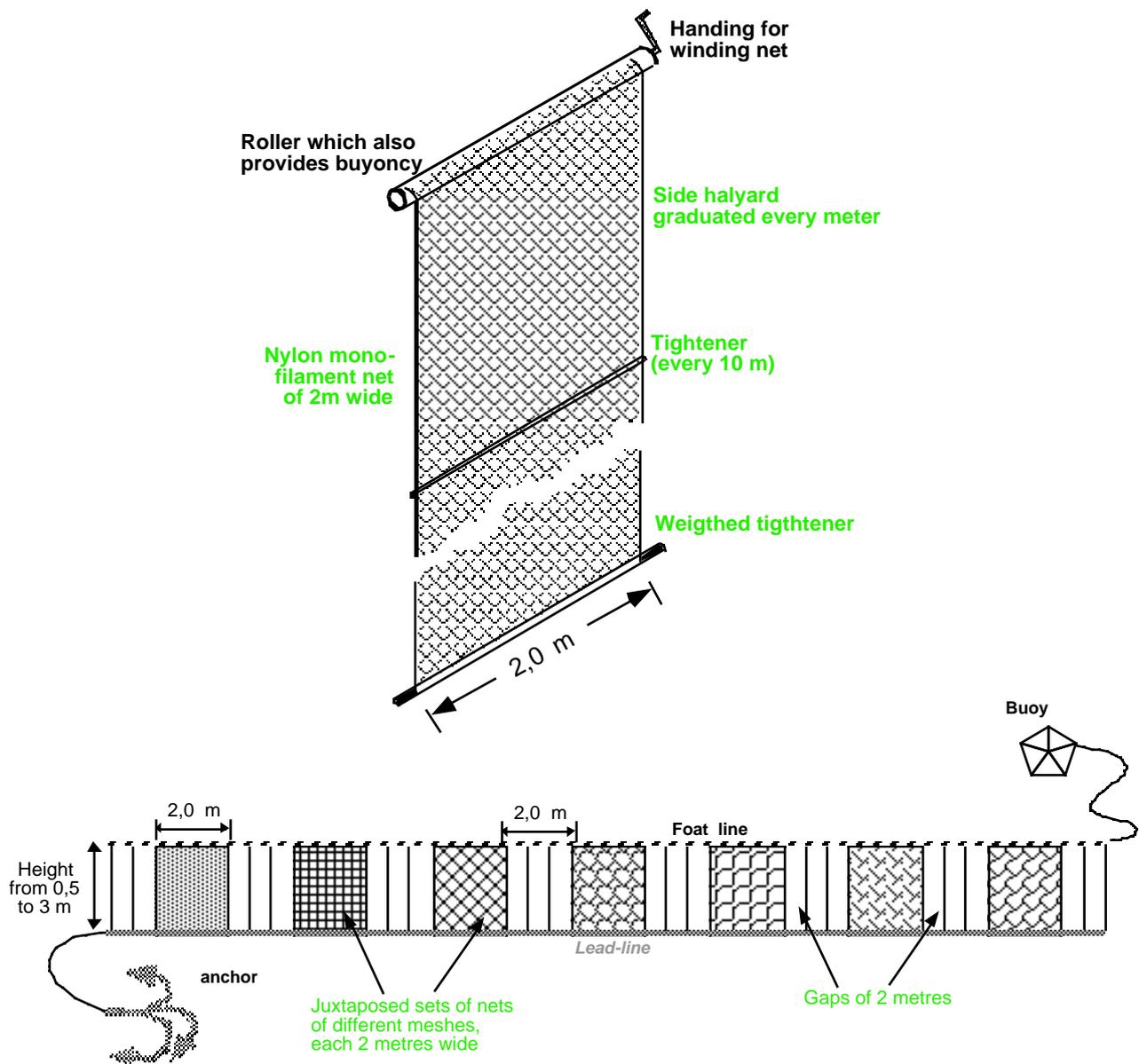
## **Development of a protocol for standard sampling**

### *Choice of a relevant technique: vertical roller nets*

Many procedures have been used for stock-taking or observing lacustrine ichthyofauna (DEGIORGI *et al.*, 1994). Among these devices, vertical roller gill nets of American (HARTMANN, 1962) were used by several authors (HORAK and TANNER 1964, LACKEY 1968, BARTOO et al. 1973). Adapted to the French lakes by GRANDMOTTET and VAUDAUX (1989), they were tested by GUYARD et al. (1989).

These devices are only 2 metres wide, but are designed to sample the complete water depth, from 1 to 80 metres. Indeed, the Nylon monofilament nets, of a total length 80 metres, are rolled tightly on PVC tubes which also act as floats (fig.1). They consist of multimesh sets which capture fish of several size ranges. They make it possible to locate the zones of occurrence of the various species during a 24-hour cycle. An "integrated" image of their circadian vertical distribution is also obtained.

In parallel, to allow the simultaneous sampling of a greater number of stations in littoral zones (under 3 m of depth), bottom "multimesh" gill nets were designed in a similar manner (fig.1). They consist of several juxtaposed sets of nets, each 2 metres wide, (just like the vertical nets), and of different meshes. The size of these nets is chosen from 0,5 to 3 meters in order to sample the complete depth of the water,. To avoid interference, each section of the net is separated by gaps of 2 metres. The line of floats is connected to the lead-line by ropes ensuring the cohesion of the unit. A multimesh bottom net on one hand and a series of vertical nets with the corresponding meshes on the other, produce statistically similar fishing efforts in the littoral zone (DEGIORGI 1994).



**Figure 1 : roller nets and equivalent multimesh bottom nets : technical diagram**

The joint use of these two devices presents three major advantages:

- 1° These nets sample the complete water depth, and thus maximum information is recorded. The effort of capture is identical in each type of site sampled ; the risk of missing an individual, a school in a stratum or a non-sampled habitat is minimised. Moreover, the precise depth of capture can be located.
- 2° Their narrow width (2 m) limits fish mortality, even with repeated sampling. Moreover, this dimension permits use of the same surface of net for all the meshes, a situation prohibited in the case of the traditional nets (cf. above): the under representation of species and individuals of small size is thus limited.
- 3° Their compactness and their very flexible handling make it possible to target their use in the different habitats sampled.

On the other hand, it must be said that the handling time *in situ* can be long. In the case of heavy densities of captures, the raising and resetting of a set of 7 nets in a zone over 50 m deep can exceed 2 hours. In spite of the time required to install, the vertical nets, thanks to their many practical advantages, allow a systematically repeated sampling throughout the water-body. Thus is possible to determine the space-time variability of the outputs of the captures.

Like all procedures based on gill nets, the capture of fish under 6 cm is almost impossible. Moreover, their efficiency varies from one species to another as well as, to a lesser extent, for a range of sizes. They must be used with these constraints in mind.

### *Stratified strategy*

In order to obtain a stable and comparable image of fish populations, this device was used according to a standard protocol described and tested in several lakes (DEGIORGI et GRANDMOTTET 1993, DEGIORGI 1994, FLESH et al. 1991, DE CRESPIAN et DITCHE 2001). The space-time considerations of this stratified strategy are briefly pointed out below (FRONTIER 1983).

- 1° The unit effort of fishing consists of one set of 7 vertical nets with meshes of 10, 15, 20, 30, 40, 50 and 60 mm. This unit, the selectivity of which has been verified by DEGIORGI (1994) according to the method of HELSER and CONDREY (1991), is set in the sampling site and left for 24 hours.
- 2° The water stretches must be divided into compartments of differential attraction according to a standardized codification based on lacustrine topography (morphology of the basin, mineral substrate and vegetal support, depth of water : fig.2). Indeed, these elements define "attraction poles", around which the ichthyofauna is dynamically distributed (SAVARD and MOREAU 1981, GRANDMOTTET 1983, DEGIORGI and GRANDMOTTET 1993).
- 3° All these compartments are mapped then sampled simultaneously during a "global" effort (also called "sequence"), during which the unit effort is applied to every pole at the rate of a site per pole.
- 4° This Global Effort (GE) is repeated three times in each exercise.

According to each case, two or three seasonal sampling exercises are recommended. The statistical analysis of the Catch per Global Effort has been carried out during each of the sixty fishing campaigns that were carried out (tab. I). It shows that the variability in numerical and weight CPGE does not exceed 20 % for all species except those of exceptionally low density (DEGIORGI and GRANDMOTTET 1993, DEGIORGI et al. 2002).

## **Structure of settlements and populations**

### *Stability of the Catch Per Global Effort (standard CPGE)*

The first aim of the method is to provide comparable CPUE's. Indeed, for each species, we obtain, for each "global effort", a number of captures each called CPGE (Catch Per Global Effort). The overall measures of the fish community obtained for successive Global Effort are close to each other (DEGIORGI and GRANDMOTTET 1993). If we examine each species, the relative variation of successive CPGE's obtained during the same exercise can present several aspects.

Catégorie	Name	max. depth (m)	Dpt	Number of exercises			TOTAL per lake	Operator
				Aut.	Été	Print.		
Gravel pit	RESERVOIR DE CASTELJAU	7	7			1	1	CSP
	LES MAILLYS	8	21		1+		1	TEL/CSP
	CHOUR	16	21		1+		1	TEL/CSP
	GRAVIERE DE REMORAY	11	25			1	1	CSP
	GRAVIERE DE VUILLECIN	8	25			1	1	CSP
	ETANG D'ANDANCETTE	3	26			1	1	CSP
	BLETTA	9	69			1	1	CSP
	DRAPEAU	7	69			1	1	CSP
	EAUX BLEUES	8	69			1	1	CSP
	ILE PAUL	5	69			1	1	CSP
	DARDILLY	4	69			1	1	CSP
	ETANG DU VILLARET	9	73	1			1	CSP
	GRESY-SUR-ISERE	8	73	1		1	2	CSP
	PLAN D'EAU DE GURGY	4	89	1	1	1	3	CSP
	PLAN D'EAU DES HURTIERES	13	73	1	1	1	3	GEN
<b>Sub-total</b>			<b>15</b>	<b>4</b>	<b>4</b>	<b>12</b>	<b>20</b>	
Lakes	NANTUA	43	1	1	1	1	3	CSP
	SYLANS	22	1	1			1	CSP
	REMORAY	32	25	1	1	1	3	UFC
	SAINT-POINT	43	25	2*	1		3	UFC
	CROZET	36	38		1		1	CSP
	ILAY	30	39	1	2	1	4	UFC
	LAMOURA	7	39		1		1	UFC
	LES ROUSSES	22	39		2	1	3	UFC/CSP
	AIGUEBELETTE	72	73	1	1	2	4	CSP
	LOU	17	73		1		1	CSP
	FLAINE	4	74		1		1	CSP
	<b>Sub-total</b>			<b>11</b>	<b>7</b>	<b>12</b>	<b>6</b>	<b>25</b>
Articial ponds (dam)	CHATELOT	58	25		1	1	2	CSP
	MONTEYNARD	112	38	1		1	2	CSP
	VOUGLANS	110	39	1	2		3	CSP/TEL
	MARCENAY	3	21		1+		1	
	PONT	18	21		1+		1	TEL/CSP
	GRANGENT	48	42	1	1*		2	TEL
	VASSIVIERES	33	87	1	1		2	TEL
	CHAZILLY	12	21		1+		1	TEL/CSP
	VIEUX PRE	65	54	2	1	2	5	UFC +MNEP
	PANNECIERES	55	58	1	1	1	3	CSP
	<b>Sub-total</b>			<b>10</b>	<b>7</b>	<b>10</b>	<b>5</b>	<b>22</b>
<b>TOTAL</b>			<b>36</b>	<b>18</b>	<b>26</b>	<b>23</b>	<b>67</b>	

#### Operators

<b>CSP</b>	Conseil Supérieur de la Pêche	1+	intercalibration with traditionnal nets
<b>TEL</b>	SARL Teleos	1*	intercalibration with hydro-acoustic
<b>UFC</b>	University of Franche-Comté - Besançon		
<b>GEB</b>	SARL GEN	dpt	département

**Table I : list of French lakes and ponds studied**

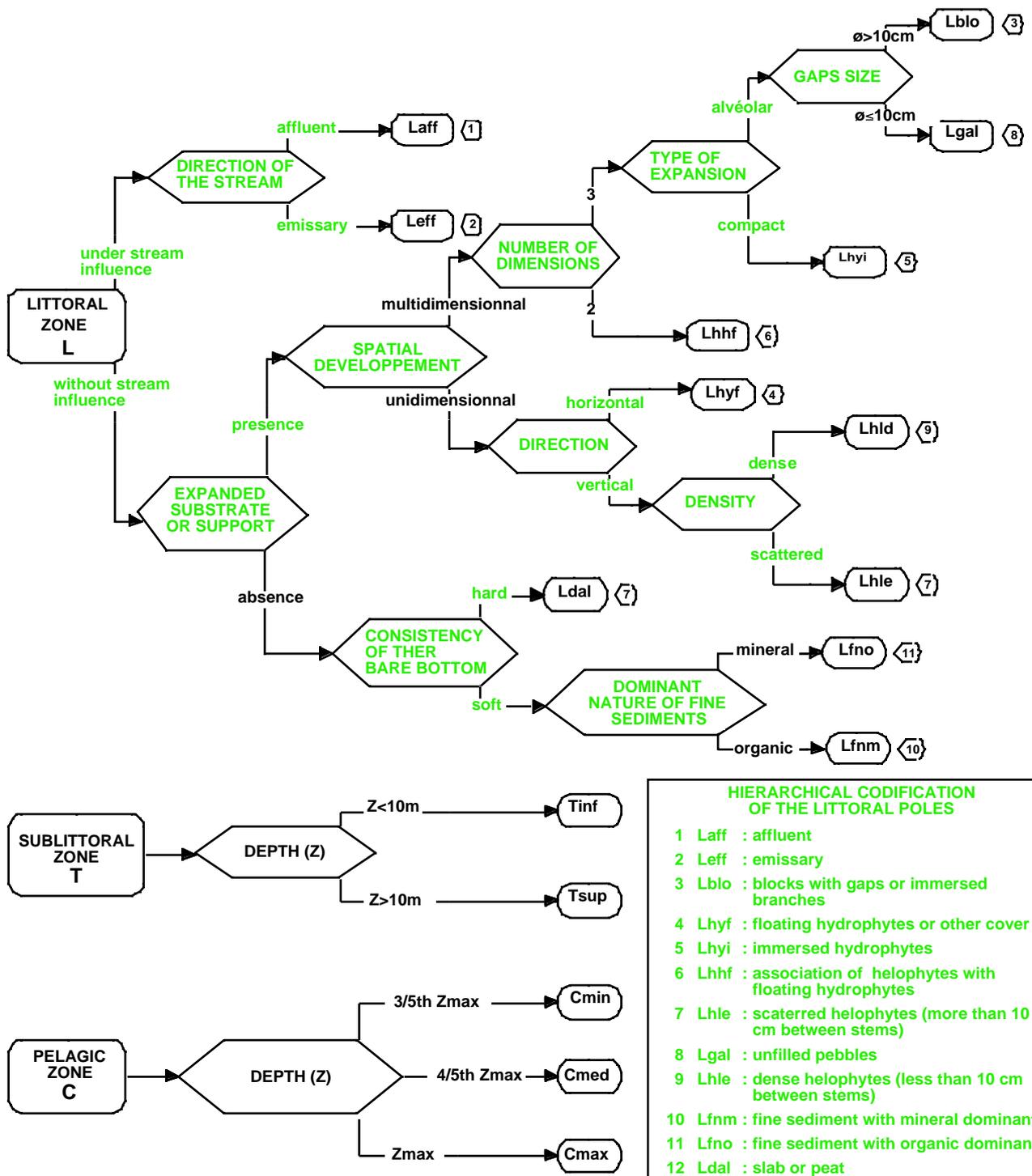
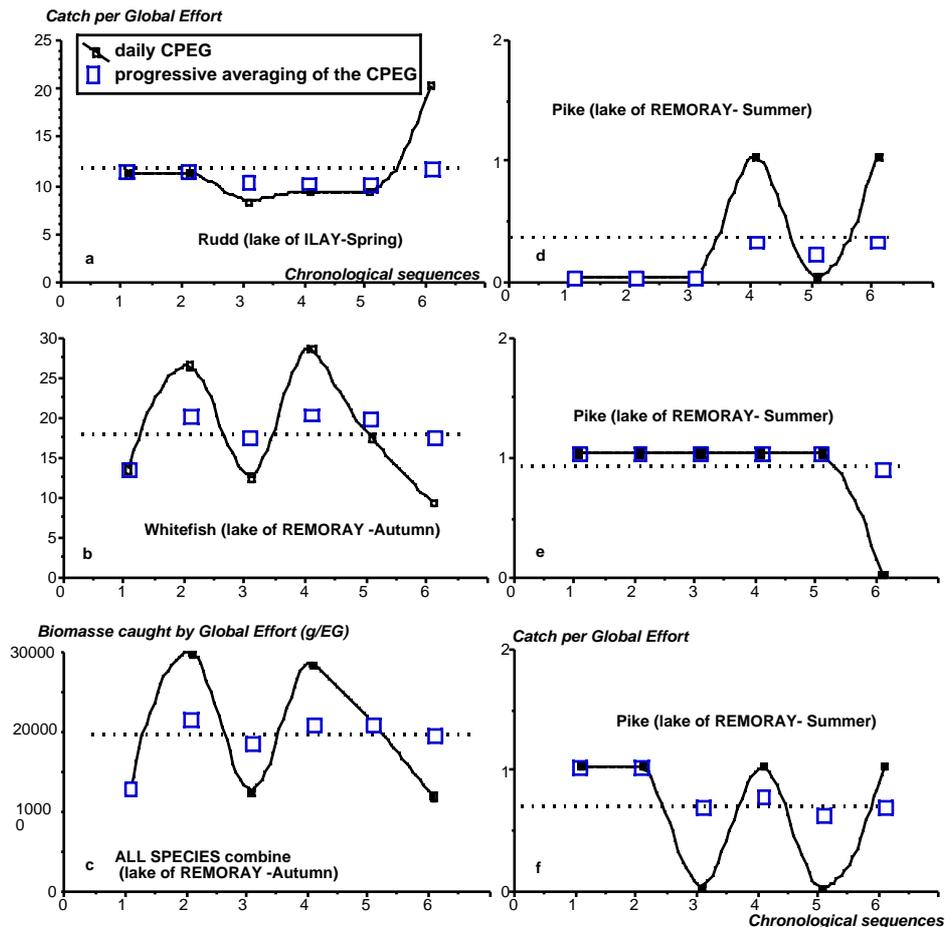


Figure 2 : decision-tree diagram for partition and codification of the lacustrine space

For the main species, the successive CPGE's are similar (fig. 3a). Their progressive average (RICOU 1967) seems to stabilize as of the second set of exercises. Thus, the instantaneous values of the CPGE often show more significant fluctuations, but at periodic paces (fig.3 b-c), the progressive average becomes more similar from the 2nd or the 3rd Global Effort.

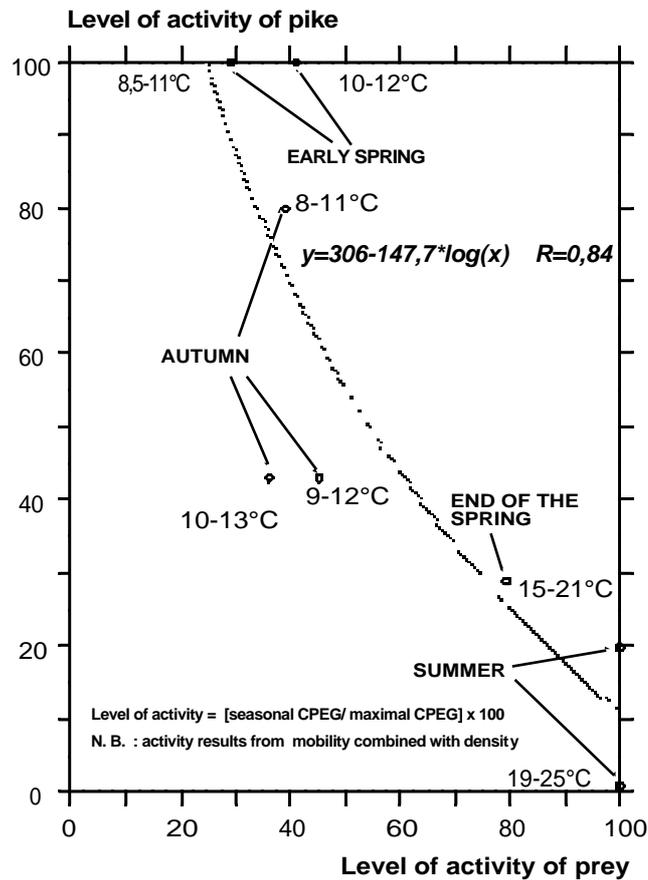


**Figure 3 : variations of Catch Per Global Effort, instantaneous and mean, recorded during the application of 6 successive Global Efforts ; examples of rudd (*Scardinius erythrophthalmus*), whitefish (*Coregonus lavaretus*), pike (*Esox lucius*) and whole biomass caught in the lakes of Remoray et Ilay**

Species with a low density or which are seasonally less vulnerable to the capture by nets due to their low mobility (e.g. top predators in summer, RICKER 1980), the variation of averages obtained is greater (fig. 3d). However, the variations of the CPEG of this type become less during other periods (fig. 3e-f).

In particular the top predators are regularly more active in the cold season whereas their prey (cyprinids, young perch of the year...) become less mobile (fig. 4). Similarly, periods of warm water are more effective for the estimation of abundance of the minority ultra thermophilous species (fig .3f).

For the main species, the temporal evolution of CPEG shows a pace compatible with the assumption of a periodicity of the activity of fish as well as significant inter-seasonal variations. The approach is therefore particularly appropriate to study the activity of fish. The decrease in variability of successive CPEG's shows the possibility of obtaining specific seasonal results which are associated with a variability under 20 % and which are comparable to each other.



**Figure 4 : comparison of the relative activities of pike and its prey (cyprinids, small percids ...) in relation to temperature and season**

*Significance of the CPGE for each species and its diagnosis reference frame*

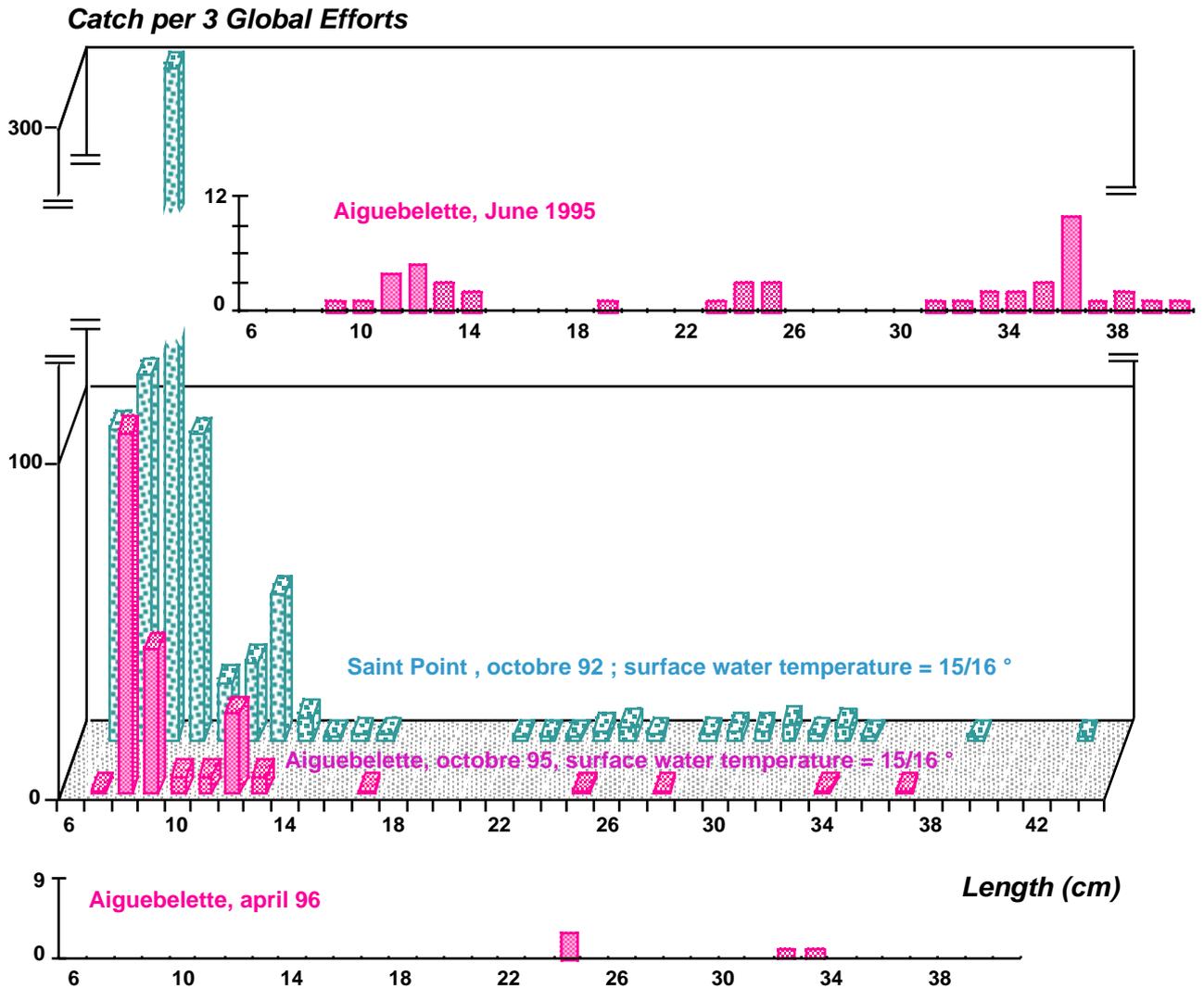
It is thus possible to compare the Catch Per Unit Effort of the same species between lakes, or for the same lake, from year to year, provided that the results used are obtained during the same season and in a similar thermal regime. Under these conditions, the differences between CPGE recorded for contrasting ecological configurations are much higher than instrumental variations. As a result, the different situations show distinct outputs while similar scenarios demonstrate similar outputs (tab. II).

The standard outputs allow a first diagnosis. Indeed, the CPGE obtained for a given species in a given system is highlighted by locating it within a range of results obtained in a range of lakes including ecologically intact" systems (*id est* : non polluted) (VERNEAUX *et al.* 1993).

To confirm this diagnosis, it is advisable to examine the ecological potential of the system examined. This process requires the use of a typological reference frame, which is still under development. The range of the output of CPUE available allows a rational interpretation of the results obtained for each lake. Moreover, the data obtained in connection with the structure of the populations or their spatial distribution provide support for the explanatory assumptions.

*Structure and dynamics of the populations*

For the same species, the output of Catch per Global Effort obtained for the same age group are compared between exercises, or, for the same season, between lakes instead of comparing the various age groups within the same exercise. This approach cancels any skewed selectivity inherent to the gill nets. By reference to the "best" water stretches, it is possible to locate the stages of the development showing a shortfall for one or several species.



**Figure 5 : Structure size/frequencies of the seasonal sample caught in the lake of Aiguebelette and comparison with the autumnal sample caught in the lake of Saint Point.**

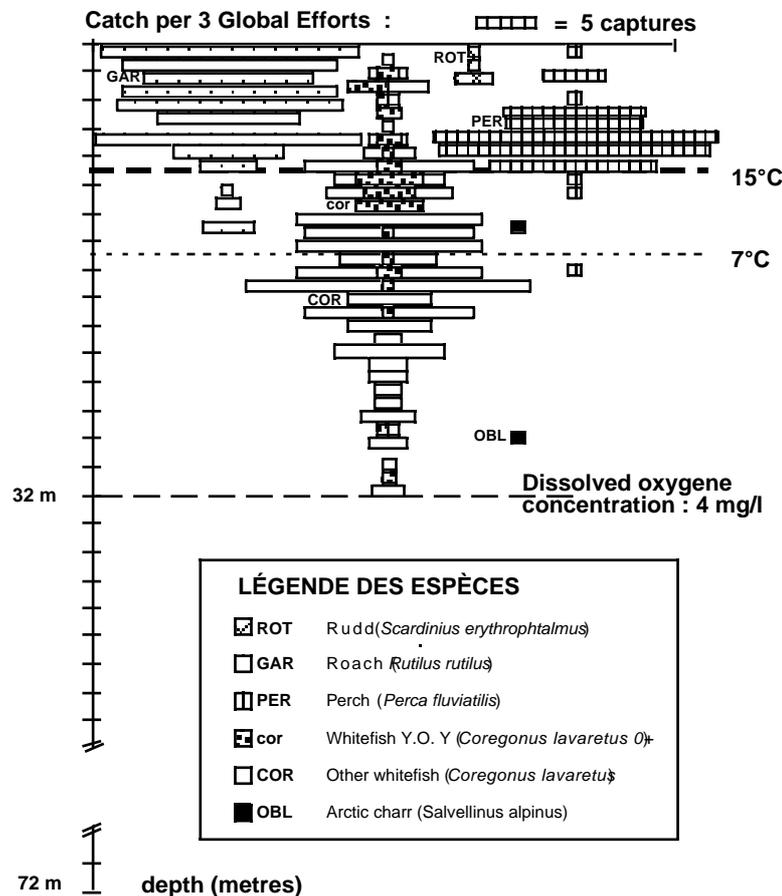
Accordingly, it is advisable sample in the same season, and in similar thermal ranges, according to methods' suggested in the standard protocol. For example, the quantity of perch of the year captured in the lake of Saint-Point at the beginning of October is absolutely higher than the quantity sampled in Lake Aiguebelette during the same period and for the same surface temperature of surface water (fig. 5). The growth of the young of the year captured in the first lake also seems faster. These tendencies are influenced by the rapid variations of the water level due to the hydroelectric activity in Lake Aiguebelette, as is the poverty of its littoral zones (CSP 1997).

## Spatial organization of fish and metabolism of the systems

The method presented also makes it possible to study the variation in spatial distribution of fish, in relation to the physical and biological characteristics of the lake. Indeed, the distribution of the captures can be studied horizontally, thanks to the cartographic approach, as well as on the vertical axis, since the total depth of the water of the site sampled, and the distance to the bottom of the captures is known.

### Vertical distribution

The analysis of the vertical distribution of the captures carried out according to the standard protocol applied on about sixty exercises, showed that the distribution depths of capture is strongly correlated with the metabolism of the lake (DEGIORGI 1994). Indeed, the species seem to share the space on the vertical axis, initially according to the physicochemical stratification, which determines thresholds of survival or "comfort" for each species, then according to the trophic availabilities, correlated with the first factor (DEGIORGI and GRANDMOTTET 1992).



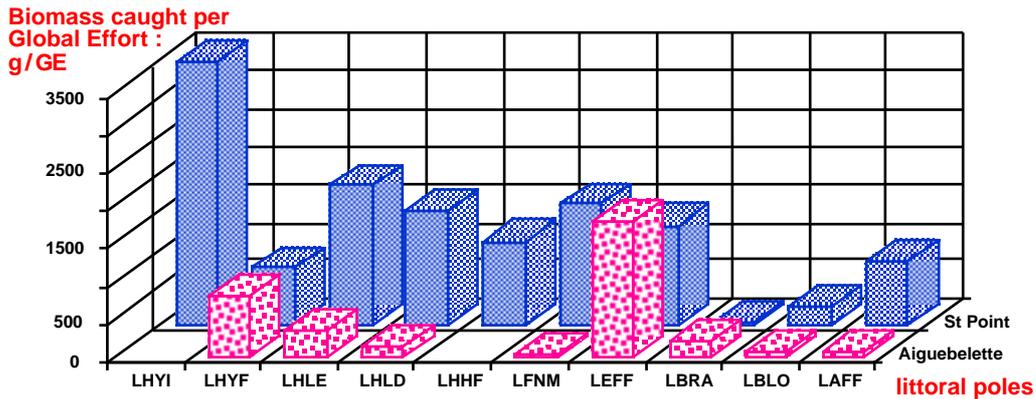
**Figure 6 : vertical partitioning of the autumnal captures recorded in the central zone of the Lake Aiguebelette during the application of 3 successive Global Efforts.**

As an example, the distribution according to the depth of the captures obtained in the lake of Aiguebelette in autumn shows the relative position of the schools of roach and perch above the thermocline (fig. 6). The whitefish occupy the colder layers of water, but without using the layers where dissolved oxygen is lower than 4 mg/l. Since the minimal depth of the schools of whitefish decreases with the upward movement of the deoxygenation front (DEGIORGI and GRANDMOTTET 1992), this value can be regarded as that limiting the space available for this species.

*Horizontal distribution*

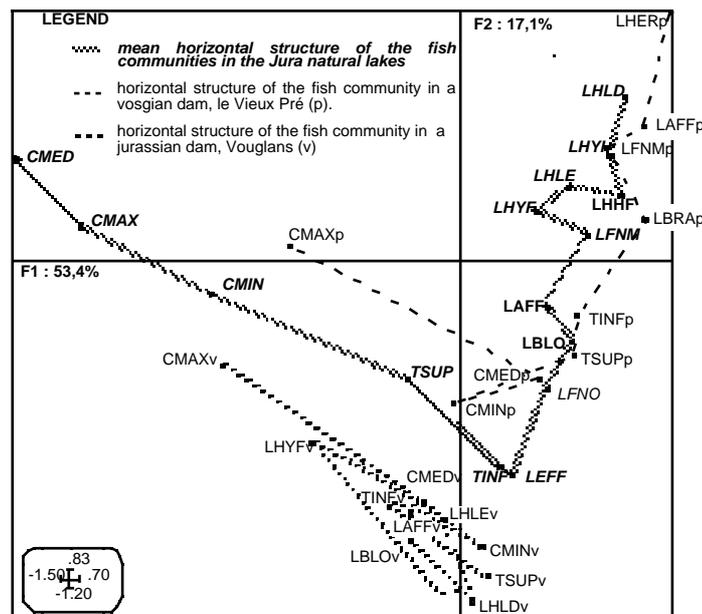
The cartography used as a basis for the strategy of sampling makes it possible to compare the physical heterogeneity and the available capacity of the aquatic habitat for the fish. However, it is also possible to analyse the horizontal distribution of the captures to determine the causes of low fish density.

It is possible to compare in different lakes the attraction of a number of habitats to the ichthyofauna. This step highlights the poverty of the littoral zone of the Lake Aiguebelette, the comparable indexes of biomass measured in autumn near the littoral habitats of this lake are definitely lower than those observed during the same season in Lake Saint-Point (fig. 7).



**Figure 7 :** comparisons of biomass by Standard Global Effort caught near the respective littoral poles of the lakes Aiguebelette and Saint Point (see codes fig. 2).

Thanks to this approach, the horizontal distribution of the ichthyofaune of a lake can also be appreciated from a larger perspective. For example, the horizontal distribution of fish in two hydroelectric dams, Vouglans and the Vieux Pré, was projected using the model of the “standard” horizontal distribution of natural lakes with differentiated morphology (fig. 8, DEGIORGI 1994).



**Figure 8 :** projections of the horizontal structure recorded in two artificial impoundments using the model organisation of differentiated natural lakes with little or no physical disturbance (see codes fig. 2).

This model was built using Correspondence Analysis (HILL 1978, BENZÉCRI 1981) calculated from the relative affinity of 11 major species with 15 attraction poles prospected in 4 Jurassic natural lakes. Comparatively, the spatial organization of the 2 artificial ponds appears strongly homogeneous, although different from each other.

In particular, the poles prospected in Vouglans all produced the same fish distribution, similar to that of the sub-littoral zones of natural lakes. This uniformly "sub-littoral" shape of the horizontal distribution of the fish community of this dam may be explained by its "V-deep" morphology as well as by the absence of macrophyte beds induced by the extent of the draw-down (VERNEAUX and VERGON, 1974).

In contrast, the spatial structure of the fish community of the Vieux Pré, is dominated by littoral type arrangements. This may be explained by sloping bathymetry, as well as by the obstruction of the littoral and sub-littoral zones, not deforested before the filling of the dam. The phenomenon is amplified by the deoxygenation of the water, which makes the central zones un-attractive. Furthermore, the initial phase of trophic impulse, which characterized the studied dam at the time of fishing exercises may explain the invasion of the central surface layers by species usually considered to have strong littoral affinities (NÜMANN 1970).

## Conclusions

The space/time methods of the sampling standard of the ichthyofauna using vertical nets were conceived to provide comparable images of the fish communities and populations. This approach, the relevance and robustness of which were checked and validated in sixty operations, requires a noticeable investment in time, men and materials. However, this significant effort makes it possible to obtain reliable results of known precision and low statistical variability, generally under 20%.

At the end of two or three seasons' fishing exercises, a fairly accurate diagnosis of the nature and the importance of the fish resource is available for the pond managers in the form of a series of indices of abundance output for each species, associated with confidence intervals. In parallel, data is also available about the structure of the major populations as well as on their spatial distribution. The combination of this information with the physical configuration and the biological characteristics of the water-body makes it possible to interpret the differences in densities observed are different systems. However, in order to be complete, this method requires a typological reference frame (which is currently being developed).

In its current form, this method, which could be improved in the near future, is particularly appropriate for the estimation of the fishing potential of water-bodies, with a surface area up to 2 000 ha. For an optimal analysis of the fish resource of a lake, and then for a follow-up of any changes, the periodicity for the optimal application of this protocol after the tri-seasonal initial operation is at least one autumnal sampling programme every 4 or 5 years.

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