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The Impact of Harvesting of Perch on the Trophic Structure of a Marine Ecosystem

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Abstract: The objective of this work is the realization with the software Ecopath with Ecosim a new ecosystem model, with new data and supplemented to allow representation of the functioning of a marine ecosystem more consistent with what we know the fish population. Then we show through this model, the impact of harvesting of perch on the trophic structure of this marine ecosystem.

Keywords: Ecopath with Ecosim; Marine ecosystem; Impact of perch; Accumulation biomass; Predation mortality; Catch.

2010 MSC. Primary Mass-balance modelling, Multiple-species models, Parameter estimation; **Secondary** Fisheries management, Harvesting strategies, Marine ecosystems.

I. Introduction

The marines ecosystems are fragile ecosystems impacted by both global changes, such as global warming (S.C. Doney et al., 2012), or more local pressures such as fisheries, agricultural or industrial waste (D. Smith et al, 2006). Indeed, human activities such as fishing can lead to major imbalances in trophic structures, which can cause a depletion of the ecosystem (D. Pauly et al., 2001). This can result in a loss of biodiversity, decreased abundance of fauna and flora; see a decline in catches and fishing activity. Fisheries management is therefore now focusing an ecosystem approach to protect ecosystem structure while preserving fisheries (K.J. Dame et al., 2006).

To understand the impact of current anthropogenic pressures on ecosystems as a whole, knowledge of these trophic structures are needed. The objective of this work is the realization with the software Ecopath with Ecosim a new ecosystem model, with new data and supplemented to allow representation of the functioning of a marine ecosystem more consistent with what we know the fish population.

The first step will be an analysis of the trophic structure of the marine ecosystem considered in this work, and identify key pathways. Sensitivity analyses of the parameters give an idea of the strength of this model and the fragility of the tropic structure. This will also analyze the relevance of the findings and their sensitivity to these parameters. The impact of harvesting perch on the trophic structure of the marine ecosystem can then be analyzed in more detail precisely through EcoTroph model.

II. Materials and methods

1. The study site

The study area is defined in terms of geographic coordinates as the area of the Atlantic Ocean that corresponds to the hosting of the central stock of Moroccan area (Figure 1). This area is related to the:

(a) zone A: between Safi and Sidi Ifni (32°30'N, 29°30'N). This zone is fished exclusively by the Moroccan fleet. The number of purse seiners operating in this zone is around 150 during the fishing season (May-September). The fishing effort of these purse seiners which have the same characteristics as those that operate in the Northern Zone(between Cape Spartel and Eljadida 35°45'N, 32°N), is progressively decreasing (in terms of positive trips). The catches have also been declining since the beginning of the 90s.

(b) zone B: between Sidi Ifni and Cape Bojador (29°30N, 26°30'N). Since 1983 the Moroccan fishing fleet has become quite important in Zone B following the transfer of a part of the fleet that operated in Zone A to the new ports of Tan Tan, Laâyoune and Tarfaya, which were opened respectively in 1982, 1989 and 1994. From 1990 to 1999 the total number of active vessels in this zone was around 200, with a gross tonnage of between 50 and 55 tones and an HP of between 250 and 300. The average annual catch of the fleet was 350 000 tones.

The Spanish fleet, composed of purse seiners, has traditionally fished for sardine between the Straits of Gibraltar and Cape Juby. Part of this fleet, coming from peninsular Spain, fished in the zone north of Casablanca, while the other part of the fleet, based in the Canary Islands, fished in Zone B. In 1976 the total number of vessels was forty purse seiners with an average gross tonnage of 130 and around 400 HP engines. Since then there has been a progressive decline in the size of the fleet.

(c) and zone C: between Cape Bojador and Southern extent of species (26°30'N-Southwards). Two types of fleet operate in Zone C: the purse seiners (Moroccan and Spanish) and the pelagic trawlers (Russian, Ukrainian and others). The Moroccan fleet is composed of approximately ten purse seiners operating in the Dakhla zone. The Moroccan catch from this zone has been increasing since 1996. In 1983 the fleet that began working in Zone C was made up of thirty vessels with a gross tonnage of 214 tones and 659 HP on average. Smaller vessels were replaced by larger ones, but always within the limits established by the fishing agreements signed by Morocco and the European Union. In 1995 the fleet had been extended by eleven vessels of which 70% were between 250 and 500 GRT. Since 1996 the fleet of Spanish purse seiners has only fished in Zone C following a transfer of effort imposed by the last fishing agreement between Morocco and the EU which was signed in 1995. The conditions of this agreement made provision for an annual closure to fishing during February and March and that the fishing zone which had originally been established at two nautical miles from the coast be moved to fifteen miles from 1998.

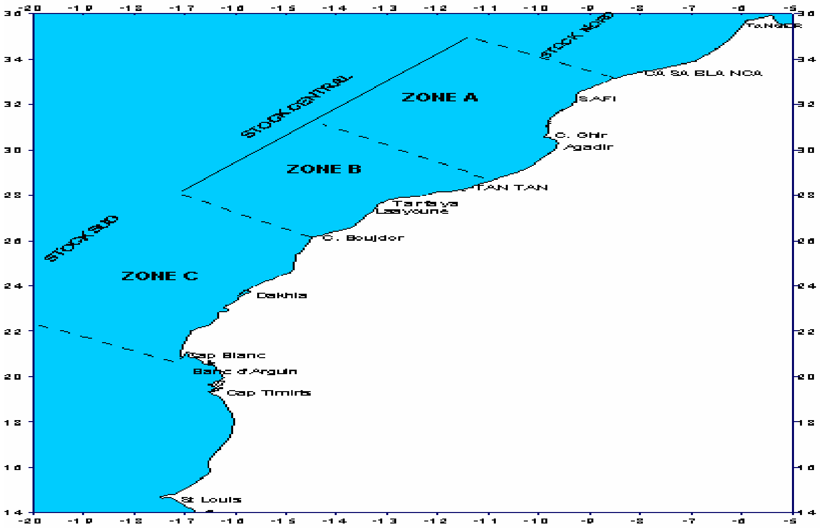

Figure 1 : Representation of the distribution of exploitation's zones of perch in the three zones.

2. Ecopath and EcoTroph models:

2.1. General Principles of the Ecopath with Ecosim (EwE)

The EwE software (EwE 6.3) allows the rapid construction of a model that is a representation of a balanced aquatic ecosystem (V. Christensen et al., 2004). The biotic community is divided into several functional groups, each comprising species with habitats, diets and traits lives as similar as possible. These groups may contain one or more species, or species of cohorts.

EwE calculations are based on assumed system equilibrium (V. Christensen et al, 2005). The Ecopath resulting model is balanced when the production of a group is equal to or greater than the power of this group by predators.

The production of a group is equivalent to the sum of its biomass accumulation, flow to predators (predation mortality) and fishing (fishing mortality), and what is called his other mortality (mortality due to age or disease, where even to secondary predators are not included in the model):

Production = Accumulation biomass + predation mortality + catch + other mortality

The term net migration is usually considered. Here we consider the site ecosystem as closed and the zero migration. This assumption seems reasonable in view of the importance of resident species (whitefish and perch mostly) (K. Riede, 2004).

This same production group is also equivalent to consumption when the part will be used for respiration, i.e. maintenance or basal metabolism of the group and the share is removed which will not be considered by the group, i.e. losses. It generally presents this equation in the form:

Consumption = production + respiration + unassimilated mass

2.2. Basic parameters of the model

Basic parameters characterizing the operation and dynamics of consumption and production of each group within the ecosystem. For each functional group, a minimum number of parameters is required so that the software can estimate the other. Thus, most groups have input biomass (B), a report on biomass production (P/B), a report on consumer biomass (Q/B) and a mass ratio of non-assimilated consumption (U/Q). The software then calculates the output ratio of consumption (P/Q), and ecotrophic group efficiency (EE).

The ecotrophic efficiency is the main parameter calculated which is marked by steady hypothesis. It is the share of production that is consumed by predators and fishing. Consequently, it is necessarily less than 1 if the ecosystem is in equilibrium. This setting often reveals estimation errors and corrects the model.

Thus, with the assumption of equilibrium and input data, the software can calculate and identify each biomass flows between functional groups.

2.3. The outputs of the model with EwE

The EwE can calculate a number of statistics and values that characterize the ecosystem represented.

These indices can characterize productivity, complexity and efficiency of the food web, and the effectiveness of the fishery. They also assess the maturity of the system. This is the state to which the system operates, and wherein the maximum biomass. A mature system is characterized by an almost complete utilization of energy for maintenance, limiting opportunities for development (E.P. Odum, 1969).

In other words, our ecosystem, primary production and production groups are used for breathing. The utilization efficiency of the production of each group is maximum.

(a) Total Flux: The amounts of consumption, exports, breaths and contributions to detritus groups are calculated for the entire ecosystem. The sum of these parameters is the total flux of the ecosystem. This total flux can also be seen as the "size" of the ecosystem (R.E. Ulanowicz, 1986).

The EwE also calculates the sum of all productions.

(b) The primary production rates: A ratio of the total primary production (PP) and total respiration (R) is calculated. It describes the maturity of the ecosystem (E.P. Odum, 1971, Christensen, 1995). Early in the development of the ecosystem, the production will be much higher than breathing. In mature ecosystems, in thermodynamic terms, the amount of energy is set at roughly the cost of maintenance. PP/R ratio is then close to 1 in some polluted systems, this ratio can be as low as 1 (V. Christensen et al., 2005).

Similarly, the ratio of the total primary production and total biomass will depend on the maturity of the ecosystem. In an ecosystem developing, immature, production will be greater than breathing. The system therefore accumulates biomass, and PP/B ratio will decrease. In a mature ecosystem, production equals respiration, and total biomass varies so little. The report therefore remains constant.

(c) Net production system: A net production of the system can be calculated. It represents the production or accumulation of biomass energy system. An immature ecosystem will be a high net production. In a mature ecosystem, production groups will eventually be almost entirely used for breathing other. The energy balance is close to equilibrium. The rate of net production will then tend towards 0.

(d) Report of the biomass system on the total system flow: Available feeds the system supports the total biomass. In a mature system that supported biomass is maximized. The B/total flow is expected to increase with the maturity of the system.

(e) Characterization of the food web: The software establishes a EwE omnivory index (OI). It measures the distribution of trophic relationships. More OI, the stronger the network is less complex and trophic relationships are linear. It also gives an idea of the potential of an ecosystem to withstand a decline in abundance or extinction of a species through trophic relationships remaining capacity.

The Mixed Trophic Impact function (MTI) also assesses the impact of a group on each other. An impact is said "positive" when the increase in biomass of a group results in an increase of biomass of another group. Groups generally have a negative MTI on themselves due to intragroup competition for resource (V. Christensen et al., 2005). This function also evaluates the impact of an increase in catches of fishing on each group. The importance of each group in the trophic structure indices is also calculated. The index of "keystoness" reflects the concept of keystone species, or "keystone" (S. Libralato et al., 2006). This index reflects the impact of the group on the rest of the trophic structure relative to its biomass. A group of "keystone" will have a relatively low biomass, but a strong impact on other groups and trophic structure, and its index of "keystoness" will be close to 0 Groups at high biomass and relatively low impact will strongly negative indices. We can also analyze the impacts totals that measure the impact of the group on all other groups in relation to biomass.

(f) Reliability index model: An index, the Ecopath Pedigree Index reflects the fit of the model to local data. For parameters of biomass production rate (P/B), consumption rates (Q/B) and diets, it indicates where the input values are. Each type of data source is assigned a value between 0 and 1 indicating the degree of certainty. Thus, data from the literature have generally lower as data from literature on the ecosystem studied index and data from in situ measurements have the highest index.

We can therefore observe the reaction of the index to the input of new data from the preliminary model.

2.4. EcoTroph package (ET)

To analyze the response of the ecosystem to some change, EcoTroph package available for use on R was used. This package is based on a representation by Ecopath trophic level model to analyze the impact of the fishery on the ecosystem represented (D. Gascuel et al., 2009).

The EcoTroph package creates a spectrum for each food group. Thus, all biomasses, productions, consumption, etc. is distributed along the trophic levels. These continuous representations of groups based on the assumption that all individuals are different, and therefore occupy trophic levels distributed around the average level of the group.

The software models a biomass flow through trophic levels using data from predation and ontogeny (D. Pauly et al., 2001, D. Gascuel et al., 2008). Loss of biomass levels are calculated with fishing mortality, natural mortality other than predation, and losses due to metabolism (respiration and excretion in particular). The equations of biomass flows from one trophic level dependent flows at lower levels. This introduces a built bottom-up flow control biomass.

The speed parameter stream to a trophic level (K) of biomass depends on the speed of the renewal thereof. In other words, K can be estimated as equivalent to the rate of production (P/B) in Ecopath (D. Gascuel et al., 2008). When mortality changes, the rate P/B and the flow velocity K therefore also changing. And a top-down control is introduced because predation is a major source of mortality.

To analyze the impact of the fishery, the ecosystem is divided into two compartments, one open to the fishery, the other not (D. Gascuel et al., 2011). The software takes into account that exploited species generally have characteristics and traits very different from non-target species life. This is especially true for species of lower trophic levels such as zooplankton; the turnover rate is very high compared to that of fish species.

Through modeling of the biomass flows through the trophic levels, so the software estimates the impact of different amounts caught on the entire ecosystem.

3. Calibration of the model

3.1. Basic estimates for the model

Most of our data, outside the biomass of perch and some diets, were obtained using the EwE. According to the acoustic measurements that were previously performed, biomass of perch can reach 15 t/km^2 in August in some years during the heaviest biomass, and the annual average would be between 5 t/km^2 and 10 t/km^2. The biomass of perch is largely underestimated by a factor of about 50 to 100. These additional measures were used as input for the construction of model data.

3.2 Functional Groups

The fish fauna (ichthyofauna) studied is composed of about fourteen species. Of these, the main ones whitefish and char, perch, roach, pike, tench, trout, burbot, and common carp (cyprinus carpio) (ONEMA 2007).

In order to make the necessary model functional groups, we are brought together various cyprinids such as common carp and Chub (Leuciscus cephalus) in the same group.

Functional groups for zoobenthos, zooplankton, phytoplankton and macrophytes are also included in the model.

Groups such as predatory birds or bacteria were not included because of lack of data. This also allows for a simple model as possible, the main groups are the fish species of interest.

3.3 Basic parameters of fish fauna

- Biomass

Data for the amateur and professional fisheries are harvested and used to estimate the relative biomass of the species caught. Biomasses are also adjusted to balance the EwE model. The first condition is to have $EE<1$.

Biomass and Q/B of Whitefish and Trout groups were calculated by the EwE software. The entries are biomass and Q/B older cohorts groups, the cohort mortality rate and the growth parameter K of Von Bertalanffy function of the species. The multi-function cohort software then calculates the missing parameters some cohorts through growth function.

- Growths

The equation was used to calculate the growth parameter K of Von Bertalanffy of whitefish and trout species is: $K = -\,Ln(1-L_m/L_\infty)/t_m$. The growth parameters, the asymptotic size (L_∞ in cm) size at maturity (L_m in cm) and age at maturity (t_m years) were calculated using the proposed empirical relations for several groups fish such as salmonids, cyprinids or perciformes (R. Froese et al., 2000). Asymptotic size was calculated according to the equation: $Log(L_\infty)=0.044+0.9841\ log(L_{max})$, where L_{max} is the maximum size of fish caught. Size at maturity was obtained by the equation: $Log_{10}(L_m)=0.898Log(L\infty)-0.0782$. The last parameter t_m was estimated according to different values found in the literature.

- Production / Biomass (P/B)

The parameter P/B, difficult to measure, can be likened to a total mortality Z in the case of the balanced model EwE. Natural mortality was calculated from the sum of natural mortality and fishing mortality $Z = F + M$. Fishing mortality F was calculated from fisheries data collected by a performance report on biomass. Natural mortality could be calculated from an empirical relationship (M.L.D. Palomares et al., 1998): $M = K^{0,65}\ L_\infty^{-0.279}\ T_c^{0,463}$ where T_c is the average water temperature in degrees.

- Consumption / Biomass (Q/B)

An empirical equation was used to calculate the Q/B functional groups (M.L.D. Palomares et al., 1998).

Log (Q/B) = 7,964 – 0,204logWinf – 1,965T + 0,083A + 0,532h + 0,398d.

The Winf parameter is the asymptotic weight group. T is the annual temperature (in degrees Celsius) average of the water expressed with the formula T=1000/(Tc+273.15). A is a value representing the shape of the tail of a species. It is calculated from $A=h^2/S$ (h: the height of the fin; and S the surface). The parameter h is a variable expressing the diet group, 1 for herbivores and 0 for the carnivores and scavengers. The last parameter, d, is also an expression of the diet, and is 1 for scavengers and 0 for herbivores and carnivores.

- Catch

The fisheries catch data were collected from commercial and recreational fishermen. Average catches between 1986 and 2014 were calculated for the realization of our model. Amateur and professional fishermen who catch and very different management systems, they were separated into two different fisheries for the model.

3.4 Basic parameters of the other compartments

- Zoobenthos

The total biomass of zoobenthos has been estimated from density measurements of the most abundant species and measures specific individual weights: $B = \Sigma(d*S*W)$.

The density of the benthic community was estimated at d = 451 ind/0,1m². The surface S of benthic substrate was estimated 27,4 km². The individual mass of different species was found in the literature (Stevens et al., 2001, Donald, 1977).

The P/B of zoobenthos was calculated from those of the main species (Jorgensen, 1979). It has been estimated at 5.2 years^{-1}. For this functional group, Q/B was calculated by EwE, and we entered the P/Q in the data. Thereof was set at 0.2 (V. Christensen et al., 2000).

- Zooplankton

The biovolume was used to calculate a zooplankton biomass (G. Balvay, 1987).

Weight Fee = 187.96 * Volume. The P/B was estimated at 19 years^{-1} (S.E. Jorgensen, 1979). The P/Q zooplankton was set at 27.5%, which is intermediate between that of carnivorous zooplankton and herbivorous zooplankton (P. Reyes-Marchant et al., 1993). The EwE then calculates the Q/N.

- Phytoplankton

Phytoplankton concentration is measured. It was used to calculate the biomass. Primary production measurements that have been made (D. Gerdeaux et al., 2002) were used to calculate the P/B ratio.

- Benthic primary producers

Studies on benthic vegetation are few. No direct estimate of biomass was available. Primary production of macrophytes unit area is assumed to be the same as that of phytoplankton (P. Reyes-Marchant et al., 1993). Macrophytes are present up to 15 meters deep, which represents 13.7% of the surface. Total production has been estimated at 3 614.5 tonnes. This production was then brought to a production km² dividing by the surface. A P/B average 10 years^{-1} is set (P. Reyes-Marchant et al., 1993). It takes into account the relatively rapid turnover of small agencies with respect to macrophytes. It is intermediate between a P/B of zooplankton and zoobenthos.

The biomass was then calculated from the ratio P/B and the total macrophyte production.

- Detritus

Biomass detritus (D) was calculated from an empirical formula (Christensen et al. 2005):
Log (D) = 0.954 * log (Pp) 0,863log + (E) - 2,41, Where Pp is the primary production and E is the depth of the photic zone (14.85 meters).

3.5 Diets

The diets of species caught by anglers were estimated in followed by professional fishing. For other groups, such as groups of younger cohorts, power supplies were estimated based on data from similar ecosystems or food for older cohorts as illustrated in Table 1.

	Prey\predator	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Pike														0.264
2	Burbot	0.008													0.080
3	Arctic char	0.076	0.018												0.911
4	Trout	0.034													0.237
5	Trench	0.076													0.241
6	Perch	0.169	0.059	0.129	0.040										2.557
7	Whitefish	0.181	0.059	0.129	0.040										3.281
8	Cyprinids	0.089	0.009	0.065	0.016			0.052							1.246
9	Roach	0.042	0.077	0.200	0.064		0.078	0.312							6.681
10	Zoobenthos	0.169	0.048	2.043	0.638	0.668	6.227	1.715	0.601	12.832					25.755
11	Zooplankton		0.091	0.662	0.000	0.000	1.439	8.317	3.483	0.000	30.341				229.613
12	Phytoplankton					0.000			0.781	4.816	30.341	297.496			
13	Macrophytes					0.007				4.977	30.341				
14	Detritus								1.141	9.696	30.341	297.496			
15	Import														
16	Sum	0.844	0.360	3.228	0.797	0.675	7.745	10.397	6.006	32.321	121.366	594.993			270.865

Table 1: The diets of ecosystem functional groups.

III. Results and discussion

1. Basic Estimates calculated by Ecopath

The model estimates the missing parameters for each compartment. This is in most cases efficiencies ecotrophic. Estimates based on the model are shown in Table 2.

	Group name	**Trophic level**	**Biomass (t/km²)**	**P/B (/year)**	**Q/B (/year)**	**EE**	**P/Q**
1	Detritus	1.00	3.200	**-**	**-**	**0.348**	**-**
2	Macrophytes	1.00	3.200	8.351	**-**	**0.333**	**-**
3	Phytoplankton	1.00	11.038	82.862	**-**	**0.365**	**-**
4	Zooplankton	2.00	8.605	18.603	69.145	**0.309**	**0.269**
5	Zoobenthos	2.25	**4.880**	6.072	**24.870**	**0.950**	**0.244**
6	Roach	2.50	2.492	0.435	12.970	**0.800**	**0.034**
7	Cyprinids	2.71	0.485	0.539	12.383	**0.828**	**0.044**
8	Whitefish	3.06	**4.036**	0.516	**2.576**	**0.423**	**0.200**
9	Perch	3.21	**2.155**	0.543	3.594	**0.139**	**0.151**
10	Trench	3.24	0.250	0.651	2.700	**0.350**	**0.241**
11	Arctic char	3.29	**1.045**	0.474	**3.089**	**0.465**	**0.153**
12	Trout	3.37	0.350	0.356	2.277	**0.381**	**0.156**
13	Burbot	3.59	0.115	0.437	3.134	**0.833**	**0.139**
14	Pike	3.92	0.456	0.430	1.851	**0.516**	**0.232**

Table 2: Basic estimates for the model. The values in bold are the values estimated by EwE, others are input values.

The first observation of the results presented in Table 2 is that it is possible to build a balanced ecosystem model with a very high perch biomass. Indeed, the EE are all between 0 and 1, and P / Q reporting are mostly between 0.034 and 0.269. This high perch biomass was accompanied by a strong EE (0.139). Almost three-quarter of the production of this group is consumed by predators.

The EE obtained for zoobenthos and zooplankton (0.950 and 0.309 respectively) have less contrast. The EE values of these two groups are strong, very strong view on zoobenthos. The largest part of the production of these groups is consumed by predators. Phytoplankton and macrophytes, however, have relatively low EE. Just over half of the production of these groups to share litter. In this model, there is still very important remark ecotrophic efficiency for burbot, whitefish juveniles, roach and cyprinids.

P/Q is generally between 0.05 and 0.3 (V. Christensen et al., 2005).

2. Indices ecosystem.

Modeled ecosystem statistics are given in Table 3. The net primary production of the ecosystem is 1119.325 t/km²/year.

The index Gross efficiency is the capture volume achieved in relation to primary production. It is a marker of efficiency of the fishery to operate primary production.

The index of reliability of our model is 0.139.

	Group name	Flow to detr. (t/km²/year)	Net efficiency	Omnivory index
1	Pike	0.264	0.290	0.158
2	Burbot	0.080	0.174	0.228
3	Arctic char	0.911	0.192	0.082
4	Trout	0.237	0.195	0.074
5	Trench	0.241	0.301	0.015
6	Perch	2.557	0.189	0.010
7	Whitefish	3.281	0.250	0.017
8	Cyprinids	1.246	0.054	0.239
9	Roach	6.681	0.042	0.374
10	Zoobenthos	25.755	0.305	0.188
11	Zooplankton	229.613	0.336	-
12	Phytoplankton	-	-	-
13	Macrophytes	-	-	-
14	Detritus	-	-	-

Table 3: Key indices of the model.

3. Food web analysis

A representation of the food web of the ecosystem, based on biomass of each compartment and flows between them, can be done (Figure 2). The highest trophic level is the Pike, equal to 3,92.

Figure 2 is a diagram representative of the organization of the ecosystem trophic network. The compartments are represented by circles whose surface is proportional to the biomass of the compartments. The links between the circles represent the trophic links.

A description of a trophic level flow is presented in Tables 4 and 5. Table 4 shows the distribution of flows between different trophic levels. We observe that the Level I and II focus by far the bulk of the flow (62% for Level I and 32% for level II). The volume flow decreases rapidly to higher trophic levels. Flows to trash are the most important. This is almost entirely due to the first two trophic levels. The flows to predators are less significant along the trophic levels.

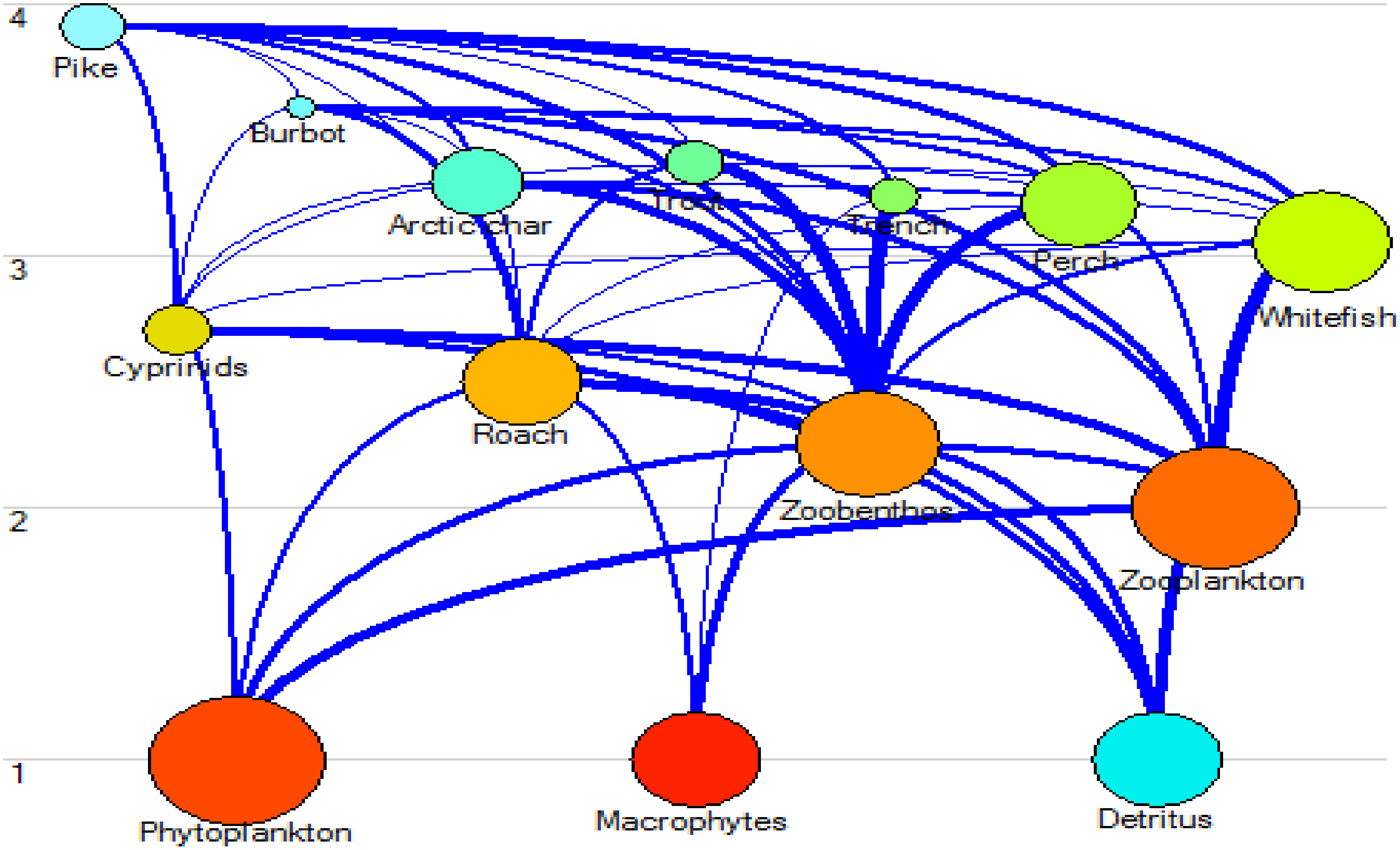

Figure 2: Diagram of the organization of the ecosystem food web.

Trophic Level\ Flow	Predator consumption	Export	Flow to detritus	Respiration	flow
4	0.357	0.237	3.798	8.558	12.95
3	12.95	0.921	56.82	109.2	179.9
2	179.9	0.0172	515.9	472.7	1168
1	1168	527.4	505.3	0	2201
Sum	1361.207	528.575	1081.818	590.458	3561.850

Table 4: Distribution of flow trophic levels

Table 5 shows that the flows from primary producers account for about half of total flows that are eaten by predators. Rubbish, are responsible for the other half flows eaten by predators, and to the highest trophic level. This shows the importance of litter for the functioning of the ecosystem.

Trophic Level\ Flow	Predator consumption	Export	Flow to detritus	Respiration	flow
4	0.181	0.124	1.935	4.354	6.594
3	6.594	0.499	29.54	57.23	93.86
2	93.86	0.0086	271.9	248.2	614
1	614	0	505.3	0	1119
Sum	714.635	0.6316	808.675	309.784	1833.454

Table 5: Distribution of flow from primary producers

Transfer efficiencies of each level, data in Table 6, can also be analyzed. It characterizes the ability of a trophic level to transmit a biomass flows from the lower level to the upper level. The total transfer network efficiency is 8.2%, which is quite low compared to what can be seen in the literature. The effectiveness of lake systems that have been modeled are usually closer to 10% (V. Christensen et al., 1993). It is also noted that the effectiveness of ecotrophic Level II is relatively strong and that higher levels is, it is relatively low. The high transfer efficiency level II is explained by the high EE, zoobenthos, roach and cyprinids. However, trophic levels III and IV have very low transfer efficiencies.

Biomass source \ Trophic Level	II	III	IV
Producers	15.3	7.6	4.6
Detritus	15.5	7.9	4.6
Flows from the two source	15.4	7.7	4.6

Table 6: Transfer efficiency of different trophic levels

It is also shown the efficiency of the system by the variation of the biomass, Production/Biomass, Consumption/Biomass and Ecotrophic Efficiency according trophic levels within the ecosystem as shown in Figures 3-6.

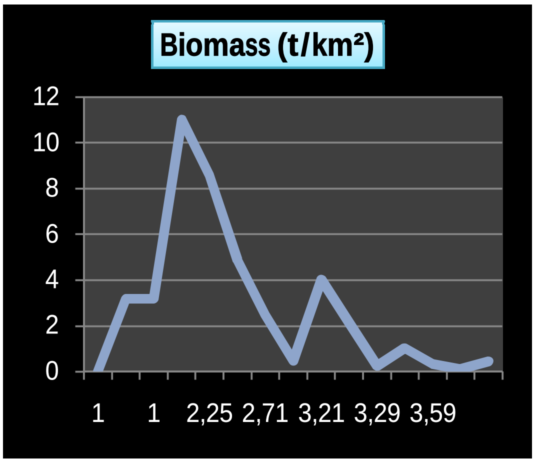

Figure 3: Variation of the biomass according trophic levels within the ecosystem.

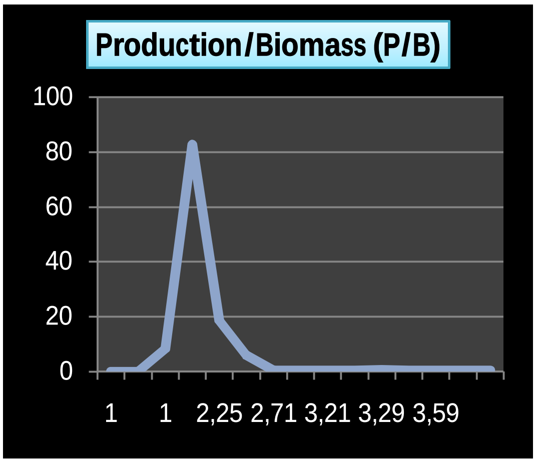

Figure 4: Variation of the Production/Biomass (/Year) according trophic levels within the ecosystem.

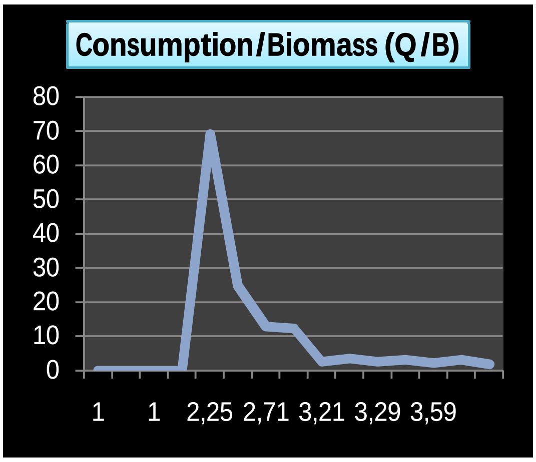

Figure 5: Variation of the Consumption/Biomass (/Year) according trophic levels within the ecosystem.

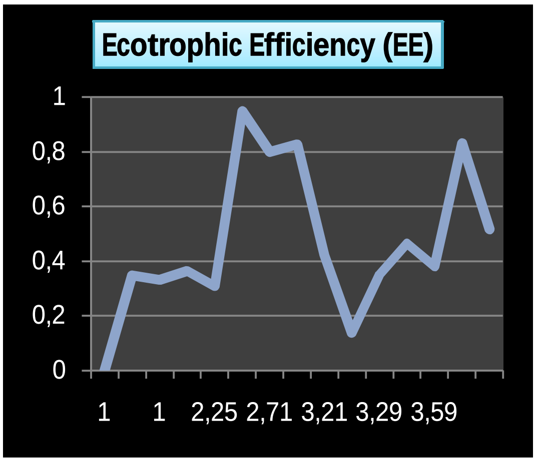

Figure 6: Variation of the Ecotrophic Efficiency according trophic levels within the ecosystem.

We can, again, observe the low efficiency in trophic level III from the level II. Indeed, the flow through the level 3 is small while the biomass of Level II and III are strong.

The tool Mixed Trophic Impact (MTI) identifies the impact of each group on other ecosystem groups (Figure 7).

The importance of zooplankton and zoobenthos even more apparent to the ecosystem in this figure. They have a significant positive effect on many groups of higher trophic level 2. We also see the important role of Pike has a strong negative impact on these groups.

The group has a negative effect on him many groups. It also has a positive effect on Pike groups, including trout and perch.

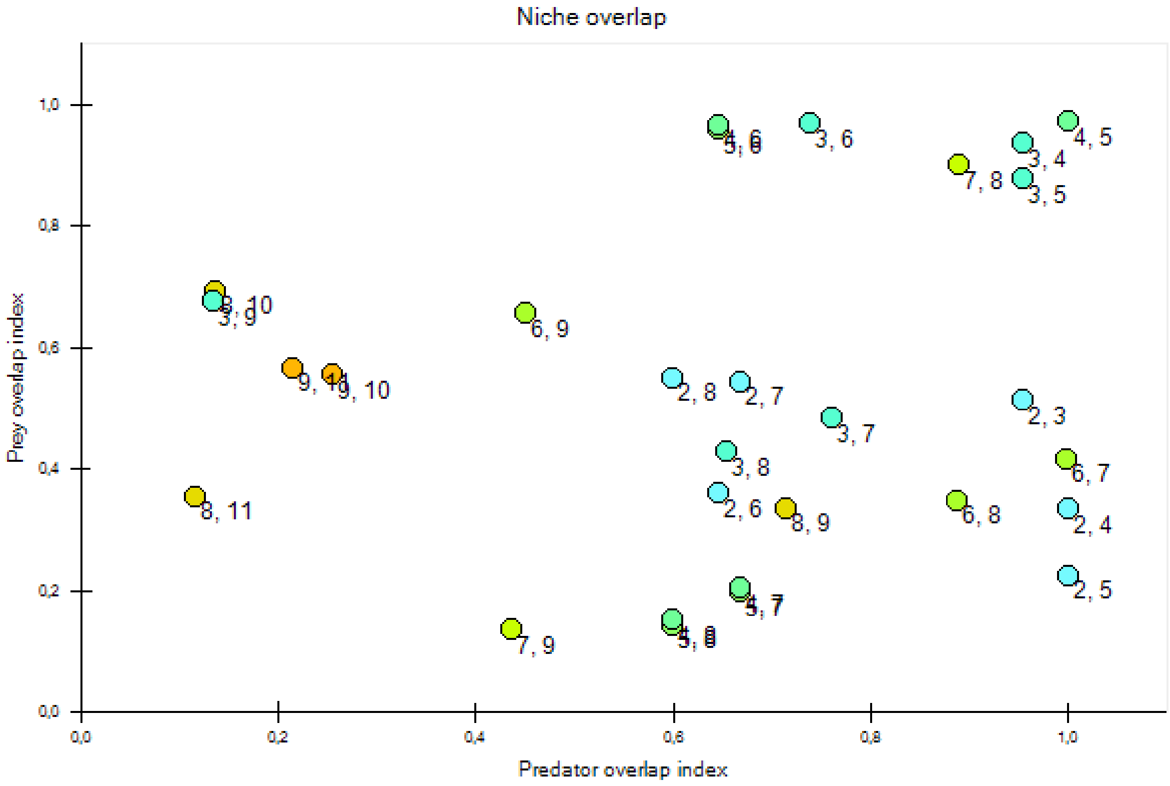

Figure 7: Representing the impact of each group within the ecosystem.

Indices *keystoness* or importance of high impact groups on trophic structure are presented in Table 7. Index groups of *keystoness* which is close to 0 and high relative impact are secondary producers and the Roaches, who are the first operators of that secondary production in the food web. Pike also has a very important role in relation to its biomass. Its large predator role is indeed very important for ecosystem structure.

group	zoobenthos	pike	zooplankton	perch	roach	char	perch
Index keystoness	0.0499	-0.0506	-0.194	-0.242	-0.238	-0.245	-0.258
total relative impact	1	0.68	0.581	0.482	0.458	0.44	0.433

Table 7: Keystoness indices of groups in the trophic structure.

4. Sensitivity analysis of the model and its parameters

4.1. Sensitivity of the model to predation on perches

The results obtained by varying the proportion of Perches in the predator feeding are given in Figure 8.

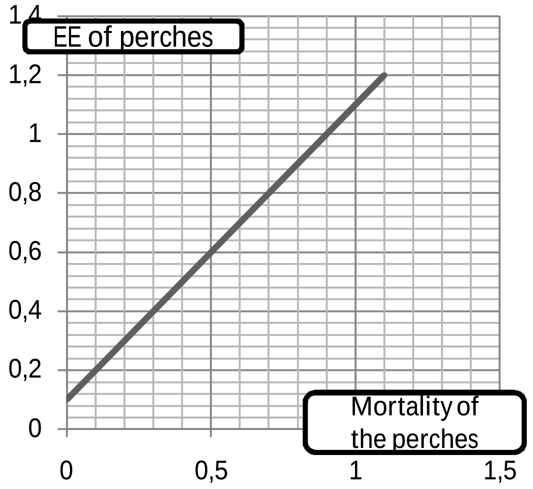

Figure 8: Variation of EE of perches according to the intensity in predation.

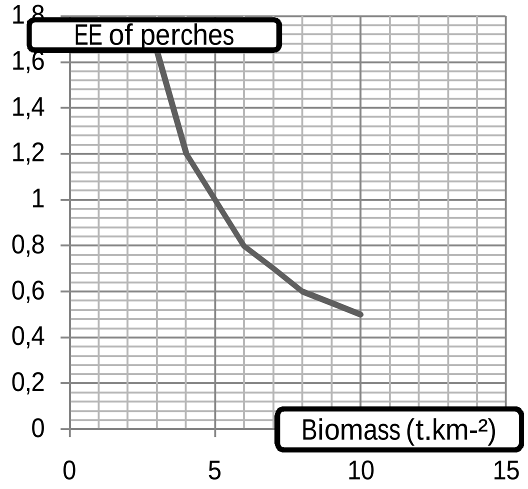

Figure 9: Influence of biomass on EE of Perches.

Predation mortality of adult Perches and trout on Perches is the share of the production of Perches that is consumed by these predators. Perch drop in diets causes a decrease in the use of the group's production by the higher trophic levels. EE therefore increases linearly with predation. It decreases to 0.318 for an overestimation of 25% from the boom in the diets of trout and perch. This value would remain one of the strongest of all functional groups. An increase in the share of 10% is sufficient to have an EE higher than 1 and unbalance the model. The variability of EE is very important. By varying diets and predation mortality, total level transfer efficiency is 6.2 (M=0.21); 8.2 (M=0.85), with 7.7 for the model.

4.2. Sensitivity of the model to biomass of the perches

The variation of the input value of perch's biomass leads to in a change of the estimation of EE parameter that group as illustrated in Figure 9.

The range of uncertainty of the perch’s biomass is between 5 t/km² and 10 t/km², would set the EE of the perches between 1 and 0.494. The group thus has a more or less EE, but still strong. Beyond a biomass value =9 t/km for the perches, EE of zooplankton exceeds 1, which would tend to show that beyond this level of biomass production zooplankton cannot bear predation of the perch's group. Given these limitations, the EE of the perch group would be between 1 and 0.549. The transfer of the overall effectiveness of the trophic level III also varies. It ranges from 8.2 for an abundance of 5 t/km² to 6.8 an abundance of 9 t/km².

Conclusion

A coherent model has been created, representing an ecosystem with sufficient capacity for large biomass observed perches (Guillard et al., 2006). This ecosystem appears to be relatively mature in the light of studies on other lake ecosystems (M.Y. Janjua et al., 2009, P. Reyes-Marchant et al., 1993, E. Halfon et al., 1993, P.D. Walline et al., 1993). According to the model achieved, the functional group of Perch undoubtedly a key role in the secondary transfer production to high trophic levels, including to perch, pike and char exploited by professional and amateur fishermen. It seems that the biomass variations of this group have therefore an important impact on the entire food web. An increase would result in an abundance of zooplankton consumption, and decreased rapidly cause or a change of predatory regime, a decrease in abundance for lack of prey.

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