Trophic levels and ecological pyramids

Three hundred trouts are needed to support a man for a year. The trout, in turn, must consume 90,000 frogs, which must consume 27 million grasshoppers living from 1,000 tons of grass. - G. Tyler Miller, Jr., American chemist (1971) In this lesson, we will reply to the following questions: What is the efficiency with which energy is converted from the trophic level to the trophic level? Ã, what are the differences between the efficiency of assimilation, net efficiency and ecological efficiency? How do ecosystems differ in the amount of biomass or number of organisms present at any time, and generated over time, at each trophic level? Ã, how many energy is available for humans and how much do we use? Are the main controls on the function of the ecosystem? Go to: [Introduction] [Energy transfer] [Example of fox and hare] [Pyramid models] [Human energy consumption] [Summary] Ã, 11/02/2005 Format for printing Introduction In our latest conference we examined the creation of organ question IC by primary producers. Without autotrophes, there would be no energy available for all other bodies that lack the ability to set light energy. However, the continuous loss of energy due to metabolic activity puts limits on how many energy is available for higher levels (this is explained by the second law of thermodynamics). Today we will look like and where this energy moves through an ecosystem once incorporated into organic matters. Most of you are now familiar with the concept of trophic level (see figure 1). It is simply a power level, as often represented in a food chain or food. The primary producers include the lower trophic level, followed by primary consumers (herbivores), then secondary consumers (carnivores who feed on herbivores), and so on. When we talk to moving "on" the food chain, we are speaking figuratively and mean that we move from plants to herbivores to carnivores. This does not take into account the decomposers and detritives (organisms that feed on death organic substances), which constitute its own very important trophies. Figure 1: Trophic levels. The transfer of energy to higher tropics what happens to the NPP produced and then stored as a vegetable biomass? On average, it is consumed or decomposed. Know you already the equation for aerobic breathing: Ã, $C_6H_{12}O_6$ + 6 O_2 -------- 6 CO_2 + 6 H_2OÃ ¢ In the process, metabolic work is made and energy in chemical bonds is converted into energy Thermal. If NPP has not been consumed, it accumulates somewhere. Usually this does not happen, but during the periods of earth history as the carboniferous and the Pennsylvanian huge quantities of excess consumption accumulated in swamps. It was buried and compressed to form coal and oil deposits that ours today. When we burn these deposits (same chemical reaction as above except that there is greater energy produced) we release the energy to guide the machines of industry and, of course, CO_2 enters the atmosphere as greenhouse gas. This is the situation we have today, where the excess of CO_2 to burn these deposits (excess NPP) is going into the atmosphere and accumulate over time. But let's go back to a balanced ecosystem or in "stationary status" ("balance"), where the total annual breathing scale the total annual GPP. Because the energy passes from the trophic level to the trophic level, the following rules apply: only an energy fraction available at a trophic level is transferred to the next trophic level. The rule of the thumb is 10%, but this is very approximate. Typically the numbers and biomass of organisms decrease as the food chain is ascended. An example: the fox and the hare for it These rules, we must examine what happens to energy within a food chain. Suppose you have some quantity of plants consumed by hares, and hares are consumed by the foxes. The following diagram (Figure 2) illustrates how it works in terms of energy energy at every level. Ã A hare (or a population of hares) ingests plant material; we will call this ingestion. Some of this material is processed by the digestive system and used to make new cells or tissues, and this part is called assimilation. What can not be assimilated, such as perhaps some parts of the plant stems or roots, leaves the body of the hare and this is called excretion. So we can make the following definition: = Assimilation (ingestion - excretion). The efficiency of this process of assimilation in animals varies from 15-50% if the food is plant material, and by 60-90% if the food is animal material. The hare uses a significant fraction of the energy assimilated. a hare - maintain a high, constant body temperature, synthesize proteins, and hopping. This energy used (lost) is attached to the cellular respiration. The rest goes to make biomass more hare from growth and reproduction. The conversion of energy assimilated into the new tissue is called the secondary production in consumers, and is conceptually the same as the primary production of plants or NPP. In our example, the secondary production of the hare is the energy available to the foxes eating rabbits for their needs. Clearly, because of all the energy costs of hares involved in normal metabolic activity, the energy available for the foxes is much less than the energy available for hares. When we calculated the efficiency of assimilation above, we can also calculate the efficiency of net production for any body. This efficiency is equal to the production divided by the assimilation for animals, or NPP divided by the GPP for plants. The "production" here refers to more growth playback. In equation form, we have efficiency = Net production (production / assimilation) or = plants (NPP / GPP). These ratios measure the efficiency with which an organism converts the energy assimilated into primary or secondary production. These efficiencies vary between organisms, largely due to widely different metabolic requirements. For example, on average vertebrates utilize about 98% of the energy absorbed by the metabolism, leaving only 2% for growth and reproduction. On average, invertebrates only use 80% of the energy assimilated for the metabolism and thus exhibit increased efficiency of net production (~ 20%) compared to vertebrates. Plants have the greatest efficiencies of net production, ranging from 30-85%. The reason that some organisms have an efficiency of net production is that they are so low homeotherms or animals that maintain a constant internal body temperature. What it requires much more energy than is used by Poikilotherms, which are organisms that do not regulate their temperatures internally. Just as we can build our understanding of a system from the individual to the population to the community, we can now examine whole trophic levels calculating eco-efficiency. Eco-efficiency is defined as the supply of available energy for the trophic level N + 1 divided by the power consumed by a trophic level n. You could think of it as the efficiency of hares in converting plants in Fox Food. In equation form for our example, eco-efficiency = (Production of Fox Production / Production of the hare). Think ecological efficiency brings us to our first rule for the transfer of energy through trophic levels and food chain. Overall, only about 10% of the energy consumed by a level is available for the next. For example, if the Feide consumed 1000 kcal of energy plant, they may be capable of forming 100 kcal of the new fabric hare. For the population of hare to be in stable condition Increased nor a decrease), every year's consumption of fox hares should equal approximately the production of each year of biomass of hare. So the foxes consume about 100 kcal of hare biomass and convert perhaps 10 kcal in a new fox biomass. In fact, this ecological efficiency is quite variable, with homeOtherms on average 1- 5% and POKILOTHERMS with an average average The overall loss of low energy to higher levels is important to set the absolute number of tractory levels that any ecosystem can contain.ã, from this understanding, should be obvious that the mass of foxes must be less than the mass of hare, And the mass of hares less than the mass of plants. Generally this is true, and we can represent this concept visually building a pyramid of biomass for any ecosystem (see figure 3). Figure 3. A pyramid of biomass showing producers and consumers. Pyramids of biomass, energy and numbers A pyramid of biomass is a representation of the amount of energy contained in the biomass, at different levels tractures for a given point over time (figure 3, above, below figure 4b). The amount of energy available for a trophic level is limited by the quantity stored from the lower level. Because the energy is lost in the passage from one level to another, there is energy subsequently less total, as you move to trophic levels. In general, one would expect the higher trophic levels would have total biomass less than those in a row, because less energy available for Them.a we could also build a pyramid of numbers, which as its name implies represents the number of organisms in each Level trophic (see figure 4a). For oceans as shown in Figure 4, the lower level would be rather large, due to the enormous number of small algae. For the other ecosystems, the pyramid of the numbers could be inverted: for example, if a vegetable community of a forest was composed of only a handful of large trees, and yet there have been many millions of insect herbivores who ate the plant material. Just as with the inverted pyramid of numbers, in some rare exceptions, there could be an inverted pyramid of biomass, in which the biomass of the lower trophic level is less than the biomass of the level immediately higher trophic. The oceans are such an exception because at any point over time the total amount of biomass microscopic algae is small. So a pyramid of biomass for oceans can appear inverted (see figure 4b). Now you should ask "how can it be?" If the amount of biomass energy at a level sets the biomass energy limit to the next level, as it happened with hares and foxes, how can you have less energy at the lower trophic level? This is a good question, and can be resolved considering, as we discussed in the last lesson, the aspect all the most important of the "time". Although the biomass can be small, the speed to which new biomass is produced can be very large. Thus over time, it is the quantity of new biomass that is produced, from whatever the stocking stock of biomass could be, which is important for the next trophic level. We can examine this additional building a pyramid of energy, which shows production rates rather than standing crops. Once done, the figure for the ocean would have the characteristic pyramidal shape (see figure 4c). Algali populations can double in a few days, while zooplankton feed on them reproduce more slowly and could double in numbers in a few months, and fish feed on zooplankton could only reproduce once a year. Thus, a pyramid of energy takes into account the rotation rate of the organisms, and it can never be reversed. Ã, Figure 4: Pyramids of numbers, biomass and energy for the oceans. We see that the thought about pyramids of time energy and turnover is similar to our time discussions of elements. But here we are talking about the time of permanence of "energy". The time of permanence of energy is equal to the energy in the biomass divided for net productivity, RT = (biomass energy NET PRODUCTIVITY). If we calculate the time of permanence of energy in the primary producers of the various ecosystems, we find that the time of stay range from about 20-25 years for forests (both tropical rainforests and boreal forests), up to ~ 3-5 years for the Prayers, and finally down for just 10-15 days for lakes and oceans. This time difference between between And the terrestrial ecosystems are reflected in the pyramids of the biomass, as discussed above, and is also very important to consider in the analysis of the way these different ecosystems would respond to a disturbance or in which scheme could be used better to manage the resources of the 'ecosystem. Human beings and energy consumption All animal species on earth are consumers, and depend on the producing bodies for their food. For all practical purposes, they are the productivity products of the earth's plant that support humans. What fraction of the terrestrial NPP employs humans, or, "appropriate"? It turns out to be a surprisingly large fraction. We use our knowledge of ecological energetic to examine this very important problem. (Why NPP? Because only the energy "remained" from plant metabolic needs is available to feed consumers and decomposers on Earth.) We can start looking at the inputs and outputs: inputs: NPP, calculated as an annual harvest. In a croundland and the annual collection take place in the same year. In the forests, the annual harvest can overcome the annual NPP (for example, when a forest is reduced the harvest is many years of growth), but we can still calculate medium annual. Outputs: 3 scenarios, how many NPP human use directly, such as food, fuel, fiber, timber. This provides a low estimation of the human property of the NPP. The total productivity of the lands dedicated entirely to human activities. This includes Total Cropland NPP and also the energy consumed in the firing setting to cancel the earth. This gives a central estimate. A high estimate is obtained by including the lost productive capacity resulting from the conversion of the open land towards cities, pasture forests, and due to desertification and another overflow use. This is an estimate of the total human impact on terrestrial productivity. Unit: We will use the PG or the whirlwind of organic matter (= 1015 g, = 109 tons, = 1 "gigaton") (1 ton of metric = 1,000 kg). Table 1 provides the world's total NPP estimates. There is a certain possibility that the NPP lower than the ground is underestimated, and in the same way the marine NPP can be underestimated because the contribution of smaller Plankton cells is not well known. Total = 224.5 pg Ã ¢ Table 1: surface of the surface by cover type and total (from Atjay et al. 1979 and De Vooys 1979). Surface area of the type of ecosystem (X 106 km2) NPP (PG) Forest forest 31 48.7 Boschi, Prati and Savannah 37 52.1 Deserts 30 3.1 Arctic-Alpine 25 2.1 Ground land 16 15.0 Human area 2 0.4 Other Terrestrial (Chapparral, Bogs, Marshes, marshes) 6 10.7 10.7 subtotal terrestrial 147 132.1 lakes and flows 2 0.8 marine 361 91.6 subtotal Aquatic 363 93.4 Total 510 264.5 1. The low calculation: (see table 2) Ã ¢ (a) vegetable material directly consumed = 5 billion of People x 2500 kcal / person / day x 0.2 (to convert kcal - organic matter) = 0.91 pg organic matter. If we assume that 17% of these calories derived from products for animals, humans directly consume 0.76 pg of plant substance. The estimate of the human crop of cereals and other plant crops is 1.15 pg per year. This implies loss, deterioration or waste of 0.39 pg or 34% of the total harvest. (b) Livestock consumption: estimates range from 2.8 to 5 pg, and there seems to be some uncertainty here. Our low estimate uses 2.2 pg. (c) Forests: The wood harvest for construction and fiber is well known. Amount used for firewood, especially in the tropics, is not. The table dies a low estimate. (D) Fish collection: 0.075 pg wet weight = 0.02 pg dry wt. If we assume that the average fish is two trial transfers (@ 10% each) above the primary producers, the NPP to produce those fish was 2 pg a year. Total: humans consume 7.2 of organic matter directly every year. This is about 3% of the annual total biosphere NPP.Ã ¢ Table 2: Quantity of NPPs used directly by human and pets Source NPP NPP used (PG) Cultivated land, food 0.8 pets lining 2.2 Construction of Wood Products, FiberFirewood 1.2 1.0 Fishing (0.020 Wt Dry. Harvest) 2.0 Total 7.2% NPP (7.2 / 224.5) 3.2 Ã, Ã, The intermediate calculation: (see table 3), we add to the low calculation the quantity of NPP co-opted by humans. This is: (a) All Cropland NPP (B) All the spent that was converted by other types of ecosystem, NPP consumed by livestock on the natural land to pasture and human fires-set (C) a number of uses of the forestry earth (D) Human occupied areas included meadows, parks, golf courses, etc. The total is 42.6 pg of NPP per year, or 19% of the world NPP. Table 3: Intermediate calculation of NPP co-opted by Humans Source NPP co-opted (PG) Earth cultivated 15.0 Grassland Land: Converted pastures consumed to Naught lands to pasture burned on natural land at subtotal pasture 9.8 0.8 1.0 11.6 Forestry land : killed during collection, not used Shifting Cultivation Land Clearing Forest Plantivity Plantivity Forest Subtotal Collection 1.3 6.1 2.4 1.6 2.2 13.6 Areas occupied by man 0.4 subtotal terrestrial 40.6 Aquatic ecosystems 2.0 Total 42.6% co-opted (40.6 / 132.1) 30.7% Aquatic Co-opted (2.0 / 92.4) 2.2 Ã, 3. The high calculation: (see table 4) For high estimate, now we include both NPP co-opted that the NPP potential have lost as Consequence of human activities: Ã, (a) the cultivated lands are probably less productive than natural systems that replace. If we use production estimates from savannah grasslands, it seems that the production of cultivated lands is less than 9 pg. (b) Conversion of the forest to the pasture: about 7 million km2 of forest converted in pasture represents a loss of 1.4 pg. (c) Excessive use: Some 35 million km2 of land were rendered more arid and less productive due to human excessive use, about 15 million km2 severely so. Using NPP Dry Savanna estimates, the global NPP has been reduced by 4.5 pg. (D) Conversion of the land: assuming that the 2 million km2 of land in the city, motorways, etc. They had a productivity equivalent to natural forests, 2.6 pg of NPP is Foregone. The total for high estimate is 58.1 pg of NPP used, CO -Pato or lost. We must also add the potential NPP to the estimated NPP world before calculating the appropriate fraction from humans. This gives us 58.1 / 149.6 or almost 40% of the potential terrestrial production (about 25% of terrestrial + aquatic production). WARNING: These estimates are based on the best data available and are approximate. They probably give the correct order of magnitude. Ã, Table 4: High calculation of NPP was cooperated by humans. Added to table 3 from processes that co-opt or degrade the amount of the process process (PG) Previous Terrestrial Total (Table 3) 40.6 Decrease in NPP in Agriculture 9 Forest conversion to pasture 1.4 Desertification 4.5 Loss to human areas 28.1 percentage terrestrial co-opted or lost (58.1 / 149.8) 38.8 percent plus aquatic terrestrial co-opted or lost [60.1 / (149.8 + 92.4)] 24.8 Ã, WILDING: what we can conclude from from Analysis of which above the fate of the net primary production of destiny in our world? (a) Human use of marine productivity is relatively small. Also, although the main fish stocks are strongly caught, and many coastal areas are strongly polluted, the human impact on the seas is lower than the ground. (b) On the ground, a species, Homo Sapiens, commands about 40% of the total terrestrial NPP. This probably never happened first in the history of the earth. (C) There are many consequences of this tankness of NPP by humans. The consequences include environmental degradation, species extinctions and altered climate. (d) Human "transport capacity" on earth is difficult to estimate, because it depends on the turnout of a population and technology to support the population. But to current levels of turnout and technology, a population from 50 to 100% bigger than what we have to push today Our use of land NPP at over 50% of the available production and the attending degradation of Earth ecosystems (eg water and water pollution) would be of great concern. Therefore the deselected growth limits must be very close. Note that the lowest "we will feed" on the trophic chain, more efficient the web of life becomes - - Animals eating animals eating plants is a very inefficient use of solar energy. Checking the function ecosystem now that we have learned something about how ecosystems are put together and like the materials and the flow of energy through ecosystems, we can better face the question of "what controls the ecosystem function"? There are two dominant theories of ecosystem control. The first, called bottom-up control, states that it is the supply of nutrients for primary producers that in the end we control the ecosystem function mode. If the supply of nutrients is increased, the increase in autotrophe production is propagated through the food network and all other trophic levels will respond to the greater availability of food (energy and materials will be fast cycle) .ã, the second theory, Called top-down control, states that predation and grazing from high levels of tractors on lower trophic levels, it finally controls ecosystem function. For example, if you have an increase in predators, this increase will translate into fewer herbivores, and which decreased herbivores will in turn translate primary producers in turn, because less than them are eaten by herbivores. So the control of the population and the total number of "waterfall" productivity from the higher levels of the food chain up to the lower trophic levels. So that theory is correct? Well, as often the case in which there is a clear dichotomy to choose from, the response lies somewhere in the middle. There are evidence provided by many ecosystem studies that both checks operate to a certain extent, but nor the control is complete. For example, the effect of "top-down" is often very strong at trophic levels near predators, but the control weakens while moving lower in the food chain. Similarly, the "bottom-up" effect of nutrients usually adding primary production, but the stimulation of secondary production upstream of the food chain is less strong or is absent. So we find that both these controls are operating in any system at any time, and we must understand the relative importance of each check, in order to help us to predict how an ecosystem will behave or change in different circumstances, as in the face of a Change climate. A summary only one fraction of the energy available at a trophic level is transferred to the next trophic level; The fractions may vary between 1-15%, with an average value of 10%. Typically the number and biomass of organisms decreases as rising in the food chain. We can build biomass, energy and numbers pyramids to represent the relative size of the tractory levels in ecosystems. Pyramids can often be "inverted" as a consequence of high production rates at low levels.ã, trophic the human diet is derived from vegetable material. Human beings can consume, co-opt or make available up to 40% of the total terrestrial NPP of the earth for food, land, and for other uses. The function of the ecosystem is mainly controlled by two processes, "top-down" and "bottom-up" controls. Review of the main terms and concepts of this conference. Recommended readings Wessells, N.K. and J.L. Hopson. 1988. Biology. New York: Random House, CH. 44 Townsend, C.R., J.L. Harper, and M. Begon. 2000. Essential ecology elements. Blackwell science.