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EKOSUSTAV MORA KAO FUNKCIONALNA CJELINA

THE MARINE ECOSYSTEM AS A FUNCTIONAL WHOLE

SAŽETAK

Istraživanjima u području zaštite mora i morskog okoliša uočene su različitosti u pristupima ekologiji i povećano razdvajanje pojedinih segmenata njenog izučavanja. Prepoznavanje dijelova pojedinih ekosustava i interakcija unutar njih uzrokuje različite pristupe i ponekad dovodi do prividnog gubitka razumijevanja njihove funkcionalne cjelovitosti.
Cilj ovoga rada je ukazati na funkcionalnu povezanost unutar ekosustava na primjeru sustava u području istraživanja onečišćenja mora i učinkovite zaštite morskog okoliša.
Primjenom metode teorije sustava, prikazom opće prirode interakcija unutar morskih ekosustava, uočavanjem dinamike tijeka energije kroz njih i, s naglaskom na ekološku efikasnost i unutarnje kruženje hranidbenih sastojaka, ukazano je na nužnost sustavnog pristupa izučavanju kroz njihovu funkcionalnu cjelovitost.
Zaključno je naglašena prirodna usmjerenost ekosustava postizanju homeostaze, kao i problem negativnog ekološkog naslijeđa koje neminovno opterećuje cijelu populaciju, te sustavni obrazovni pristup kao moguću odrednicu održivog razvoja.

Ključne riječi: *ekologija, ekosustav, ekološka efikasnost, onečišćenje i zaštita mora*

SUMMARY

Researching into the marine environmental and sea protection field, the diversity of approaches to ecology and the excessive splitting between segments being studied has been noted.
The recognition of the parts of the separated ecosystems and interactions contained between them are the cause of the diversity in approaches and sometimes they lead to a virtual loss of understanding of their functional wholeness.
The aim of this work is to show up the functional ties in the ecosystems exampled by the system of the marine environment and sea pollution and their effective protection.
By applying the system theory method, outlining the general nature of interactions in the marine ecosystems, notifying the energy flow dynamics and highlighting the ecological efficiency and nutrient cycling, the necessity of a systematic approach through a functional whole is pointed out.
To conclude with, the natural tendency of the ecosystems to reach homeostasis, as well as the problem of a negative ecological inheritance that un-doubtfully put the 'weight' on the whole human population, and the systematically educational approach as a possible direction to sustainable development have been accented.

Key words: *ecology, ecosystem, ecological efficiency, marine pollution and protection.*

1. UVOD

Degradacija biosfere naglim industrijskim razvojem i demografskom napučenošću prepoznata je još u prošlom stoljeću. U globalnim razmjerima uočene klimatske promjene posljednjih godina podigle su razinu ekološke svijesti u okruženju, a ekologija je kao znanost postala neizbježna u svim područjima razvoja tako da se danas može reći da se više *ne mogu i ne smiju prihvatiti nova tehnološka rješenja bez uvažavanja i prihvaćanja ekoloških rješenja*, jer su život čovjeka i ostalih bioloških vrsta na Zemlji ozbiljno ugroženi. Presudni utjecaj na promjene ima čovjek (u najvećoj mjeri razvitkom industrije), a razvidno je da se od njega jedino mogu i očekivati aktivnosti u svrhu ublažavanja nastalih posljedica, kao i osiguranje uvjeta za zaustavljanje daljnjeg narušavanja i omogućavanja uspostave ravnoteže unutar pojedinih i između različitih ekosustava.

Razvojem ekologije dolazi do produbljivanja znanja pojedinih područja i sve uže specijaliziranosti ekologa-znanstvenika u njihovom radu.

Iako je, kao znanost, uključena u sve ostale znanstvene discipline, tako nastale podjele uzrokuju i različitosti pristupa podjeli same ekologije. Međutim, različite ekološke poddiscipline nisu uvijek strogo odijeljene jedna od druge, već su usko povezane i često se međusobno preklapaju (pristupi u podjeli ekologije na grane prema: konceptu ili perspektivi, organizmima, staništima ili primjeni, [6, str.13.]).

Da bi se razumjeli razmjeri antropogenog utjecaja na okolišne ekosustave nužno je razumijevanje procesa koji se u njima odvijaju. Aktivnosti u tom smjeru postoje, a nalazi su rezultirali različitim konvencijama o zaštiti i današnjim čovjekovim naporima da se ublaži eksponencijalno rastuća degradacija. Upravo trenutna događanja na svjetskoj razini (skupovi predstavnika industrijskih velesila) ukazuju da je sustavni pristup problemu mogući put prema pronalaženju još boljih rješenja.

Prepoznavanje funkcionalne cjelovitosti ekosustava (na primjeru ekosustava mora) može doprinijeti razumijevanju problema. Stoga se u nastavku do pregleda pokušava doći kroz prikaz opće prirode interakcija unutar ekosustava i uočavanja dinamike tijeka tvari i energije.

1. INTRODUCTION

The degradation of the biosphere caused by extensive industrial expansion and human population growth was well recognized even at the previous century. The globally noted climate changes lasting few decades have raised the level of ecological awareness in our neighborhood and ecology, as a science, became unavoidable in all fields of development, and being told that *'no technological solutions should be accepted without acceptance of the ecological solutions'*, due to the fact that human life and the lives of the other biological kinds on the Earth are 'in danger' seriously. The highest impact on those changes comes from the man (especially from his industrial development), and it is obvious that 'from him only' we could expect activities aiming at diminishing the effects as well as providing the necessary conditions for stopping further degradation and assuring the settling of the balance within particular ecosystems and between them.

The expansion within the science of ecology has caused a high diversity and specializations of the scientists in their works. However, as a science, ecology became the part of all other disciplines of the science and thus caused diversities resulted in her division. But, different ecological disciplines are not strictly separated from each other - they are tightly connected and often partially covered in-between (the approaches to the division of ecology as per: concept or perspective, organisms, biotopes, or use, [6, p.13]).

To understand the extent of the anthropogenic impact on the ecosystems, the understanding of the processes that are involved within became a necessity. The researches in that direction exist, and their findings resulted in different conventions regarding environmental protection and human efforts against exponentially raised degradation. The global events that have taken place recently (meetings of the representatives of industrially highly developed countries) have shown that a system approach to the problem is the possible direction to find even better solutions.

Recognizing the functional wholeness of the ecosystems (exampled by marine ecosystems) might help to understand the subject. Due to this fact, in chapters that follow, there is an attempt to outline the general nature of interactions within and notifying the flow of energy and of nutrients cycling.

2. OPĆA PRIRODA INTERAKCIJA UNUTAR EKOSUSTAVA MORA

U osnovi ekologije kao znanosti jest 'proučavanje odnosa između organizama i biotopa', a ekosustav je 'osnovna prostorna ili organizacijska jedinica organizama i nežive tvari među kojima se stvaraju, kruže i izmjenjuju tvari i energija' [3, str.12.,13.].

Dakle, naglasak je u proučavanju stavljen na međusobne odnose i dinamiku tijeka tvari i energije. Takav pristup zadržao se i danas iako se pojavljuju i nove ideje pri definiranju koncepata ekosustava. Jednu su izložili T.F.H. Allen i Thomas B. Starr (1982) sa Sveučilišta Wisconsin[1] [preuzeto iz 6, str. 245.], prema kojoj se ekosustavi mogu promatrati kroz hijerarhiju trofičkih razina dvojne strukture, odnosno kao dijelovi unutar dijelova, pri čemu svaka razina ima zasebnu vremensku i prostornu skalu. Veća različitost između skala dviju razina, posljedično daje manju vjerojatnost njihove dinamičke povezanosti. Dvojna tendencija se očituje u tome da svaka razina uporno brani svoju individualnost, ali i funkcionira kao integrirani dio veće cjeline.

Ekosustavi su u moru određeni različitim interakcijama između onih elemenata koji ih sačinjavaju. Razumijevanju funkcioniranja može se pristupiti kroz prepoznavanje i objašnjavanje hranidbenih odnosa koji se u njemu formiraju, a to je povezano s dinamikom tijeka energije i kruženjem tvari unutar ekosustava [6, str. 244.].

Ako se isključe središta primarne kemijske sinteze na morskom dnu, početna proizvodnja organskih sastojaka u oceanu ograničena je na plitko eufotičko područje (svjetlodopiruće). U tom je području ugljični dioksid vezan uz fotosintezu, a hranjive tvari sadržane su unutar živućih tkiva. Prevladavajući organizmi koji ostvaruju tu primarnu proizvodnju u pelagijalu su sitni protistički fitoplanktoni (jednostanične planktonske alge). U obalnom području to su bentalske vrste, a neke od njih dosežu i makroskopske veličine (u obliku morskih algi). Jednostanični i manji višestanični fotosintetički protisti zato osiguravaju neposredan izvor hrane za biljojede, dok proizvodnja krupnijih makrofitnih morskih algi i rubnih traheofita u morsko hranidbeno 'tkivo' najčešće ulaze kao detrit ili 'morski snijeg'.

[1] Allen, T. F. H., T. B. Starr, Hierarchy: perspectives for ecological complexity, Chicago, Univ. Chicago Press, 1982.

2. THE GENERAL NATURE OF INTERACTIONS

The ecology as a science is based on 'studying the relationships between the organisms and their biotope' and the ecosystem is 'the basic areal or organizational unit of organisms and nonliving substances, among which are created, circulated and exchanged the nutrients and energy'. [3, pgs.12, 13]

So, the research is accented on the relationships as well as on the nutrients and energy flow dynamics. The same approach exists even nowadays. However, there are new ideas appearing on the definition of the ecosystem concepts. One of such comes from T.F.H. Allen and Thomas B. Starr (1982) from the Wisconsin University[1] [sourced from 6, p. 245.], as per which the ecosystems might be viewed as a hierarchy of trophic levels of dual structures or as a part within the parts, where each level has its own time and areal scale. The higher difference between the scales of the levels causes the lower probability of their dynamic interconnection. The dual tendency is shown when each level tends to preserve its individuality, but in the same time functioning as a part of the whole.

The marine ecosystems are defined with the interactions between the elements contained. To understand the functioning, the approach through recognizing and explaining the food chain relations happening is a possibility, and this is tied with the energy flow dynamics and the nutrient recycling as well. [6, p. 244]

If the centers of primary chemosynthesis on the sea bed were excluded, the initial production of organic compounds in the ocean is confined to the shallow photic zone. In this layer the carbon dioxide is fixed by photosynthesis and the nutrients are incorporated into the living tissues. The dominant organisms achieving this primary pelagic production are the minute protistan phytoplankton. In the littoral zone there are benthic species, some of which attain a macroscopic size (in the form of seaweeds). The unicellular and smaller multi-cellular photosynthetic protists provide, therefore, a direct source of food for herbivorous species, whilst the production of the coarser, macrophytic seaweeds and of the semiterrestrial tracheophytes enters the marine food webs largely as detritus or 'marine snow'.

[1] Allen, T.F.H. and Starr, T.B., Hierarchy. Perspectives for Ecological Complexity. Univ. Chicago Press, Chicago, 1982.

Postoje procjene njihove ukupne biomase koje kažu da ona iznosi 4 x 10^9 t (suhe mase) organskih tvari, a ona godišnje proizvodi oko 55 x 10^9 t (suhe mase) ili oko 14 puta stalnog prinosa (*Tablica 1.*)[1, str. 284.].

There are some estimations of their total biomass on about 4 x 10^9 t (dry wt) of organic matter, and this produces annually about 55 x 10^9 t (dry wt), or about 14 times the standing crop (Table 1.) [1, p. 284]

Tablica 1. Svjetska morska fotosintetička biomasa i produktivnost [1, str. 284.]
Table 1. *World marine photosynthetic biomass and productivity.* [1, p. 284]

	Biomasa (10^9 t) *Biomass* (10^9 *t*)	Produktivnost (10^9 t/god) *Productivity* (10^9 *t/yr*)
Oceanska *Oceanic*	1.0	41.5
Neritička i uzvojna (upwelling) *Neritic and upwelling*	0.3	9.8
Litoralna *Littoral*	2.6	3.7

Najveći dio te primarne proizvodnje konzumiran je u tom području. Trofička povezanost može se prikazati kroz sljedeću strukturu: biljojedni planktoni i oni koji se hrane detritom konzumirani su od strane mesojednog zooplanktona, a istovrsni bentalski mesojedi hrane se konzumentima detrita i osmotrofima, a svi oni čine hranu za nektone koji se nalaze na najvišoj trofičkoj razini morskog hranidbenog lanca. Velika većina nektona su mesojedi, no određene vrste mogu konzumirati i primarne proizvođače, a neki od njih sposobni su se hraniti čak i detritsko/bakterijskim nakupinama [1, str. 285].

Razmatrano po jedinici prostora, površinske vode su najproduktivnija područja, a za primarnu proizvodnju može se reći i da je fenomen površinskih voda. To, posljedično uzrokuje smanjenje sekundarne proizvodnje u ovisnosti o udaljenosti od obale i dubini mora. Na mjestima gdje je duboko more neposredno uz obalu detritski prinos može nastati i na velikim dubinama, no unatoč tomu za ponorni bental može se reći da je najmanje produktivan, najsporije rastući i najduže živući morski sustav. Relativan nedostatak hrane nadoknađen je boljom iskoristivošću. Stoga je tijek tvari u hranidbenom tkivu (za razliku od produktivnosti pojedinih ekosustava) zapravo najučinkovitiji u otvorenim oceanima, na koraljnim grebenima i u dubokom moru. Najmanje učinkovit je u 'uzvojnim' (upwelling) područjima, estuarijima i, općenito, u plitkim vodama.

Procjenjujući ukupnu morsku i kopnenu životinjsku biomasu može se reći da su veličine

Most of this photosynthetic production is consumed in the same zone. The trophic relations are presented through the following structure: herbivorous and detritivorous planktonic organisms are consumed by the carnivorous zooplankton, and equivalent benthic carnivores take the deposit and suspension feeders, and all of them form the food for nekton, which are on the highest level of the marine food chain. The large majority of the nekton is carnivores, although some species can consume the primary producers and even fewer appear to be able to take the detrital/bacterial aggregates. [1, p. 285]

Considering the areal unit, the surface waters are the highly productive regions, and so being told that the primary production is a surface water phenomenon. As a consequence, the secondary production declines with the distance from the coast and with the depth in the sea. Where deep waters lie immediately adjacent to the coast the detrital surplus may occur at great depths, nevertheless the abyssal benthos is known as least productive, slowest growing and longest lived of all marine ecosystems. Relative food shortage is replaced with higher efficiency of utilization. Therefore, the nutrient flow in food tissue (as a difference to the productivity of a particular ecosystem) is most efficient in the open ocean, on coral reefs and in the deep sea. The least efficient is in the upwelling zones, in estuaries and in shallow waters generally.

Estimating the total of the sea and the continental biomass, their values are comparable.

usporedive. Biomasa mora u odnosu na kopnenu proizvodi preko tri puta više organske tvari godišnje. Proizlazi da, iako je primarna proizvodnja mora niža od one kopnene, morska sekundarna proizvodnja (ona na razini konzumenata) je mnogo veća. Razlog tomu je veća učinkovitost trofičkih odnosa u moru (konzumacija primarne proizvodnje u moru je za oko 2,5 puta veća od one na kopnu), a djelomično i ektotermičke prirode morskih potrošača (manje energije hrane potroši se za nadomještanje temperaturne razlike između tijela i okoline). Kao podatak, zanimljivo je navesti da čovjek trenutno koristi oko 77 x 10^6 t mokre mase morske proizvodnje i to gotovo potpuno u obliku mesojednog nektona [1, str. 286.].

The sea biomass, as compared to the continental one, produces more than three times more organic matter per year. It comes out that, although marine primary production is much lower than that on the land; marine secondary production (on the consumers' level) is much greater. This is the result of the greater efficiency of trophic relationships in the sea (the primary production consumption in the sea is about 2.5 times greater than on the land), and partially due to ectothermic nature of the marine consumers (less of the food energy has to be spent for covering the temperature difference between the body and environment). As a tip, it is to be noted that man currently uses 77 x 10^6 t (wet wt) of marine production, almost entirely in the form of carnivorous nekton. [1, p. 286.]

Tablica 2. Pregled nekih pokazatelja produktivnosti mora i usporedba s kopnom. [6, str. 251.]
Table 2. *The list of the productivity parameters of the sea compared with land values.* [6, p. 251]

PARAMETAR / *PARAMETER*	MORE / *SEA*	KOPNO / *LAND*
NPP (g m^{-2} god^{-1}) *NPP (g m^{-2} yr^{-1})*	152	773
NPP (kcal m^{-2} god^{-1})* *NPP (kcal m^{-2} yr^{-1})**	720	3300
Svjetska NPP (10^9 t god^{-1}) *World NPP (10^9 t yr^{-1})*	55	115
Biomasa producenata (kg m^{-2}) *Biomass of the producers (kg m^{-2})*	0.01	12.3
Svjetska biomasa producenata (10^9 t) *World biomass of the producers (10^9 t)*	3.9	1837
Klorofil (g m^{-2}) *Chlorophyll (g m^{-2})*	0.05	1.5
Svjetski klorofil (10^6 t) *World chlorophyll (10^6 t)*	18	226
Konzumacija NPP (10^9 t god^{-1}) *Consuming NPP (10^9 t yr^{-1})*	20.2	7.8
Konzumacija NPP (%) *Consuming NPP (%)*	36.7	6.8
Proizvodnja konzumenata (10^9 t god^{-1}) *Productivity of consumers (10^9 t god^{-1})*	3.0	0.91
Proizvodnja konzumenata / NPP (%) *Productivity of consumers / NPP (%)*	5.5	0.79
Biomasa konzumenata (10^9 t) *Biomass of consumers (10^9 t)*	0.997	1.005
Proizvodnja razgrađivača (detrivora) (10^9 t god^{-1}) *Productivity of detritivores (10^9 t god^{-1})*	2.25	21
Biomasa producenata / biomasa konzumenata *Biomass of producers / biomass of consumers*	3.91	1828
Detrivorna proizvodnja / proizvodnja konzumenata *Detritivores' productivity / consumers' productivity*	0.75	23

* 1 kcal = 4.1868 kJ

U *tablici 2.* prikazan je pregled nekih pokazatelja produktivnosti mora i usporedba s kopnom (prema podacima Whittaker i Likens, 1973[2], a preuzeto iz [6, str. 251.]), gdje su NPP-neto primarna proizvodnja i BB-biljna biomasa, izražene kao suha masa organske tvari.

Slijedeći put hranidbenih tvari od njihove fiksacije do krajnjih potrošača treba uočiti znakovitost kruženja nekih osnovnih elemenata kroz sustave, npr. dušika ili fosfora jer, iako prisutni u ograničenim količinama, izostankom njihova povratka primarnim proizvođačima – proizvodnja će prestati.

Oslobađanje hranidbenih tvari iz njihovih organskih veza odvija se kroz metabolizam životinjskih konzumenata. Amonijak i fosfati potom se izlučuju i raspršuju nazad u vodenu masu, a povlače se natrag kroz bakterije, alge i sl. No, neke hranjive tvari bit će sadržane i u detritnom i fekalnom materijalu koji tone prema morskom dnu. Iako se većina regeneracije hranidbenih tvari događa u samom mjestu nastanka (eufotičkoj zoni), važno je uočiti da postoji i njihovo kontinuirano tonjenje prema dnu.

U plitkim područjima, plimne struje i vjetar uzrokovat će povrat tih hranjivih tvari remineraliziranih u bentalu prema eufotičkoj zoni. No, njihovo tonjenje smanjeno je u područjima položenim preko 'termokline' koja razdvaja eufotičko područje od područja dubokih voda, pa će regenerirane hranidbene tvari ispod termokline nastojati i ostati u tom području. Zato će kruženje tvari, uz konstantnost svih ostalih čimbenika, biti najmanje ograničeno u plitkim vodama i 'uzvojnim' zonama i ta će područja biti maksimalno produktivna iako još uvijek hranidbeno limitirana. Stoga se u vodama s malom zalihom hranidbenih tvari visoka proizvodnja može održavati samo vrlo brzim kruženjem ili prisustvom vrsta sposobnih za fiksaciju atmosferskog dušika [1, str. 287.].

Stalne zalihe hranjivih tvari imaju vrlo malo značenje u ekologiji mora, a fotosintetička je proizvodnja zapravo upravljana veličinom tijeka. Konačna skupina, npr. dušika u svakom trenutku bit će raspodijeljena između živih tkiva. Dok razmjene između dijelova kao što su: rastopljeni neorganski oblici u vodi, rastopljeni organski vezani dušik i zasebni organski dušik u detritima i fekalijama, mogu biti brze ili spore.

[2] Whittaker, R. H., G. E. Likens, Primary production: the biosphere and man. Human Ecol. 1(1973), 357-369.

Table 2 – shows some of the productivity parameters of the sea compared to the land values (referring to Whittaker & Likens, 1973[2], sourced from [6, p. 251]), where NPP – net primary production and PB – plant biomass are presented as dry mass of organic matter.

Following the way of nutrients from their fixation until the end consumers, the importance of cycling some of the essential elements through the systems (in example, nitrogen or phosphorus) is to be noted, because, although presented in a finite amount unless these are cycled through an ecosystem back to the primary producers – the productivity will cease.

Releasing the nutrients from their organic bindings happens through the metabolism of the animal consumers. The ammonia and phosphates are excreted and diffused back in the water mass and withdrawn by bacteria, algae, etc. Nevertheless, some nutrients will be incorporated in the detrital and faecal materials which sink back to the sea bed. Although most of the nutrient regeneration occurs '*in situ*' (in the photic zone), it is to be noted that there is their continual draining towards the bottom. In the shallow regions, tidal currents and the wind will cause the return of the nutrients remineralized by benthic animals into the photic zone. But, their sinking is diminished in the regions overlying the 'thermocline' which separates the photic zone from deep waters, so the nutrients regenerated below the thermocline will tend to remain at depth. Due to that, with all other factors remaining constant, the nutrient cycling will be mostly unconstrained in shallow waters and in the zones of upwelling and these areas will be maximally productive, although still nutrient-limited. So, in the waters with small nutrient stocks, high productivity can be maintained by very rapid cycling only or by presence of species capable of fixing atmospheric nitrogen.

Standing stocks of the nutrients are of very minor importance in the marine ecology and the photosynthetic production is governed by flux rates. The finite pool of, for example, nitrogen at any time will be divided between living tissues. But, the exchanges between compartments as: inorganic forms dissolved in the water, dissolved organically bounded nitrogen and particulate organic nitrogen in detritus and faeces, may be fast or slow. [1, p. 287]

[2] Whittaker, R.H. and Likens, G.E., Primary production: the biosphere and man. Human Ecol. 1: 357-369., 1973

U dosadašnjem dijelu sažet je obrazac kojim ugljik (ili energija) protječe kroz ekosustave mora i naznačeni su razlozi zbog kojih hranjive tvari moraju kružiti, no potrebno je pokušati i količinski odrediti neke od tijekova.

3. PROTIJEK ENERGIJE KROZ EKOSUSTAVE

Za prikaz dinamike tijeka energije kroz ekosustave kao najvažniji pokazatelji ističu se ekološka efikasnost i brzina tijeka.

Organizmi prikupljenu energiju koriste za svoj rast i reprodukciju kao i za obavljanje aktivnosti u okolišu koji ih okružuje. Tu energiju osiguravaju na različite načine u zavisnosti od trofičke razine na kojoj se nalaze. Ipak uravnoteženost sustava omogućena je asimiliranom Sunčevom energijom u primarnim proizvođačima kroz proces fotosinteze. Taj protok upravo započinje u njima i nastavlja se kroz hranidbeni lanac na više trofičke razine koje na taj način preuzimaju dio energije koju su primarni proizvođači asimilirali.

Onaj postotak prijenosa energije s niže trofičke razine na višu predstavlja ekološku efikasnost (još se naziva i efikasnost hranidbenog lanca). Može ju se definirati i kao ‘produkt efikasnosti s kojom organizam iskorištava svoju hranu i efikasnosti s kojom je pretvara u biomasu koja je na raspolaganju sljedećoj trofičkoj razini’ [6, str. 263.].

Biljke kao autotrofni organizmi predstavljaju primarne proizvođače koji kroz kemijsku reakciju fotosinteze (kao najznačajnije reakcije za životne procese na Zemlji) u svom klorofilu iz jednostavnih anorganskih tvari i koristeći Sunčevu energiju sintetiziraju organske tvari uz oslobađanje kisika i vode. U kombinaciji s dušikom, fosforom, magnezijem i sumporom, ti jednostavni ugljikohidrati sekundarno proizvode nizove proteina, nukleinskih kiselina i pigmenata, no izostankom bilo kojeg elementa potrebnog za te procese oni bi se zaustavili.

Dio Sunčeve energije koji primarni proizvođači koriste u tom procesu neznatan je u odnosu na ukupnu količinu koja na Zemlju dolazi od Sunca, no on je još uvijek veći od ukupne količine koju čovjek oslobodi kroz svoje aktivnosti (npr. kroz izgaranje fosilnih goriva).

In the chapter above there is a summary of patterns with which the carbon (or energy) flows through the marine ecosystem and the necessity for nutrients cycling is noted, but there is a need for attempting to quantify some of the fluxes.

3. THE FLOW OF ENERGY THROUGH ECOSYSTEMS

To present the energy flow dynamics through the ecosystems, the ecological efficiency and the fastness of the flow are highlighted as the most representative factors.

The organisms use the collected energy for their growth and reproduction as well as for their activity in the environment. That energy is provided in different ways depending on their trophical level. However, the balance is provided by sun energy being assimilated in the primary producers through the photosynthesis process. The flow is started right in them continuing through the food chain on the higher trophical levels so overtaking the part of energy being assimilated by primary producers.

The percentage of energy transfers from the lower trophic level to the higher one presents the ecological efficiency (also called ‘the food chain efficiency’). It can also be defined as ‘the product of efficiency obtained by the way that organism uses its food and the efficiency food is being converted to its biomass which remains available to the next trophic level’. [6, p. 263]

The plants as autotrophic organisms represent the primary producers which, through the chemical reaction of photosynthesis (as the most important reaction for the living processes on the Earth) in their chlorophylls, from the essential inorganic substances and using the energy of the sun, synthesize the organic substances releasing the oxygen and the water. In the combination with nitrogen, phosphorus, magnesium and sulphur, these simple carbohydrates produce secondarily the files of proteins, nucleic acids and pigments, and unless any of them is missing the processes will cease.

The amount of the sun energy being used by primary consumers in that process is insignificant respecting the total amount coming on the Earth, but it is still greater than the total amount released by human activities (for example through the burning of fossil fuels).

Efikasnost primarne proizvodnje obično se izražava kao količina proizvedene organske tvari po jedinici površne u određenom vremenu. Najznačajniji čimbenici koji utječu na primarnu proizvodnju su intenzitet Sunčeve svjetlosti i duljina dana, pa je stoga i primarna proizvodnja ljeti nekoliko puta veća negoli zimi.

Fotosintezom proizvedene organske tvari primarni proizvođači mogu iskoristiti za vlastiti rast i metabolizam ili ih pohraniti u obliku npr. škroba koji će postati izvorom hrane za više trofičke skupine (heterotrofne organizme) ili se one mogu razgraditi pod djelovanjem razgrađivača (mikroorganizmi) do jednostavnih anorganskih tvari. Heterotrofni organizmi iz viših trofičkih skupina nisu sposobni direktno proizvoditi hranu već troše produkte primarne proizvodnje. Na tim višim trofičkim razinama mogu se uočiti različite skupine konzumenata: najniža su herbivori koji ujedno predstavljaju sekundarnu proizvodnju i hranu za karnivore kao sekundarne konzumente, te tercijarni konzumenti (grabežljivci).

Na taj način zatvoren je slijed organizama u kojima se prenosi energija u obliku hrane od proizvođača preko konzumenata do mikroorganizama koji nazivamo hranidbenim lancem.

Dakle, u ekosustavima se istodobno s procesom primarne organske proizvodnje odvijaju procesi potrošnje i razgradnje čime je zatvoren krug protjecanja tvari i energije unutar ekosustava, a ekološka efikasnost predstavlja onu količinu energije koju na kraju dosegne svaka trofička razina.

Brzina tijeka energije, drugi je pokazatelj dinamike, a najčešće je iskazana kroz ‘vrijeme zadržavanja’ na pojedinoj trofičkoj razini što zapravo predstavlja njenu inverznu vrijednost. Što je duže vrijeme zadržavanja energije unutar neke trofičke razine veće je i njezino pohranjivanje u obliku biomase i detrita.

Ponekad se vrijeme zadržavanja umjesto s energijama računa s masama, pa se tada naziva ‘omjerom akumulacije biomase’. Prosječno vrijeme zadržavanja u vodenim ekosustavima je kratko i iznosi 24 dana (u planktonskim zajednicama svega 9 dana), dok je u kopnenim znatno duže i iznosi oko 16 godina [6, str. 265.].

U *tablici 3.* prikazano je prosječno vrijeme zadržavanja energije biljne biomase (biomasa/neto primarna proizvodnja) za reprezentativne ekosustave (prema: Whittaker i Likens, 1973[3], a preuzeto iz [6, str. 266.]).

[3] Whittaker, R. H., G. E. Likens, Primary production: the biosphere and man, Human Ecol. 1(1973), 357-369.

The efficiency of primary production is usually defined as the quantity of organic matter produced on the areal unit in a specified time. The most influent factors on the primary production are the sun light intensity and the length of the day, so the primary production is few times higher during summer than during the winter season.

The organic matters produced by photosynthesis the primary producers may use for their own growth and metabolism or they can be stored as, for example, starch that will be used as a food source for the higher trophic groups (heterotrophic organisms) or they can be decomposed by the activity of decomposers (microorganisms) to essential inorganic matters. The heterotrophic organisms from the higher trophic levels are not capable of direct food production but use the products of primary production. On these higher trophic levels different groups of consumers can be noted: the lowest ones are herbivores representing the secondary production and food for the carnivores as the secondary and tertiary consumers (the predators).

In that way the linkage of organisms is closed and in which the energy is transferred in the form of food from the producers, over the consumers, to the microorganisms and is being called ‘the food chain’.

Therefore, in the ecosystems, at the same time with the primary production process, there are consuming and decomposing processes being conducted thus closing the nutrient and energy flow contained, and ecological efficiency represent the quantum of energy reached by each level.

The rapidity of energy flow is the other representing factor and most often it is defined through ‘residence time’ on the specified trophic level that, in fact, is its inversion value. The longer is the energy residence time within any trophic level, the higher is its storage in the form of biomass and detritus. Sometimes, the residence time, instead with energy is calculated with mass, and then it is called ‘the biomass accumulation ratio’. The average residence time in the aquatic ecosystems is short and lasts 24 days (in the plankton families 9 days only), while on the land is quite longer and lasts for about 16 years. [6, p. 265]

Table 3 – shows the average energy residence time of the plant biomass (biomass/ net primary

Tablica 3. Prosječno vrijeme zadržavanja energije biljne biomase za reprezentativne ekosustave. [6, str. 266.]
Table 3*. The average residence time of the plant biomass energy for representative ecosystems*. [6, p. 266]

EKOSUSTAV *ECOSYSTEM*	Neto primarna proizvodnja (g m^{-2} god^{-1}) *Net primary production (g m^{-2} year^{-1})*	Biomasa (g m^{-2}) *Biomass (g m^{-2})*	Vrijeme zadržavanja (godine) *Residence time (year)*
Tropske kišne šume *Tropical rainforest*	2000	45000	22.5
Umjerene listopadne šume *Moderate deciduous forests*	1200	30000	25.0
Borealne šume *Boreal forests*	800	20000	25.0
Umjereni travnjaci *Temperate grasslands*	500	1500	3.0
Pustinjsko grmlje *Desert shrubs*	70	700	10.0
Močvare *Wetlands*	2500	15000	6.0
Jezera i rijeke *Lakes and rivers*	500	20	0.04*
Naselja alga i grebeni *Algal domains and reefs*	2000	2000	1.0
Otvoreni ocean *Open oceans*	125	3	0.024**

* 15 dana / *15 days*; ** 9 dana / *9 days*

Iz *tablice 3.* može se razlučiti da se većina energije u morskim ekosustavima rasprši unutar nekoliko tjedana. Onaj dio tijeka koji prolazi kroz predatorski hranidbeni lanac može se u njemu zadržati i mjesecima, a u organskim sedimentima na dnu čak i godinama.

Proučavajući različite potencijalne obrasce protijeka energije kroz hranidbeno tkivo za općeniti pelagički i bentički sustav na kontinentalnim grebenima, postavilo se određene pretpostavke i pojednostavnjenja kako bi se došlo do modela koji bi mogli biti reprezentativni za izvođenje zaključaka. Kombinirajući različite skupine varijabli pri pretpostavljanju učinkovitosti prijenosa energije između trofičkih skupina unutar promatranih sustava, došlo se do šest različitih realističnih obrazaca protijeka energije. Iako postavljeni modeli nisu kompletni, oni su do sada najrealističniji, a pokazuju da su procjene primarne proizvodnje i/ili ekološke učinkovitosti vrlo niske. Međutim, ukoliko se ti modeli 'pročiste' i nadopune novim istraživanjima i rezultatima oni bi mogli kvantitativno opisati: kako neritičko/grebensko hranidbeno tkivo, tako i široka oceanska područja, a mogli bi

production) for the representative ecosystems (referring to Whittaker & Likens, 1973[3], sourced from [6, p. 266]).

It is to be distinguished from *Table 3* that most of the energy in the marine ecosystems disseminates within few weeks. The part of the flow passing the predator's food chain might be held within for a few months and in the organic sediments on the sea bed even for years.

Studying the potential various patterns of energy flow through the food web of generalized pelagic and benthic systems over any continental shelf, there are some estimations and simplifications being made to come out with the models that might be representative for withdrawing the conclusion. Combining the various groups of variables in the estimation of energy transfer efficiency between trophic levels within the observed systems, the six different realistic patterns of the energy flow were yield. Although the stated models are incomplete, they are among the most realistic, yet devised, ones and they indicate that the estimates of either prima-

[3] Whittaker, R.H. and Likens, G.E., Primary production: the biosphere and man. Human Ecol. 1: 357-369., 1973

poslužiti za predviđanje učinaka promjena u tim sustavima relativno jednostavnim laboratorijskim simulacijama.

Ipak, znakovito je primijetiti da bilo koji od postavljenih modela ekosustava jest onoliko dobar koliko su dobre pretpostavke na kojima je zasnovan i onoliko realističan koliko su realistični podaci koji se u njega unose [1, str. 295.].

4. KRUŽENJE HRANIDBENIH TVARI U EKOSUSTAVU

Kruženje hranidbenih tvari usko je povezano s tijekom energije kroz ekosustave. Biogene elemente, koji su najznačajniji za organizme, može se podijeliti na: *makroelemente* (ugljik, vodik, kisik, dušik, kalcij, fosfor, sumpor, silicij, magnezij, natrij, kalij, klor, željezo) koji stvaraju 99% suhe težine organizma, *mikroelemente* (mangan, molibden, bakar) koji se pojavljuju u mnogo manjim količinama, te na *ultramikroelemente* (tragovi bora, nikla, vanadija) koji su važni pri aktivaciji određenih enzima [3, str. 27.].

Povezanost kruženja hranidbenih tvari i tijeka energije kroz ekosustave jasno je izražena kroz oksidoredukcijske reakcije. Oksidirajući agensi (oksidansi) tijekom procesa primaju elektrone od reducirajućih agenasa (reducensi), pa se može kazati da bi se reducirao oksidans mora primiti energiju, a analogno, da bi se oksidirao reducens mora osloboditi energiju. Iako svaka supstanca može poslužiti kao oksidirajući ili reducirajući agens, može se uočiti da zapravo jaki oksidansi vrlo čvrsto drže elektrone, pa su oni uvijek slabi reducensi, i obrnuto.

To se može razjasniti na primjeru oksidacije ugljika s kisikom pri čemu se oslobađa energija, dok se kod fotosinteze događa obrnuta reakcija i ugljik se fiksira uz dovođenje energije (Sunčeva svjetlost). Tijekom kruženja kroz ekosustav, svaki element slijedi svoj jedinstveni put koji je određen njegovim specifičnim kemijskim transformacijama i prelazi kroz različite oblike, pri čemu procesi prelaska iz jednog oblika u drugi moraju biti uravnoteženi s procesima njegovog povratka u prvobitnu formu. Kako je većina energetskih transformacija povezana s oksidacijama i redukcijama ugljika, kisika, vodika, dušika, fosfora i sumpora, praćenjem ciklusa tih elemenata prikazuje se na koji način hranjive

ry production or of the ecological efficiency (or both) are too low. However, if these will be refined and modified by future researches and results, they will be able to describe quantitatively either neritic/shelf food web or larger oceanic regions, and they can also be used to predict the effects of disturbances of these systems by a relatively simple laboratory simulations.

Nevertheless, it is to be noted that any of such yielded ecosystem models is only as good as the assumptions on which it is based and as realistic as the data fed into it. [1, p. 295]

4. THE NUTRIENT CYCLING WITHIN ECOSYSTEM

The nutrient cycling is tightly connected with the flow of energy through ecosystems. The biogenic elements, that are the most important for the organisms, might be divided as: *macro elements* (carbon, hydrogen, oxygen, nitrogen, calcium, phosphorus, sulfur, silicone, magnesium, sodium, potassium, chlorine, iron) that form 99 % of the organisms' dry weight; *microelements* (manganese, molybdenum, copper) that appear in much minor quantities, and *ultra-microelements* (the traces of boron, nickel, vanadium) that are important in the activation of particular enzymes [3, p. 27].

The interconnection between the nutrient cycling and the flow of energy is clearly presented through oxidation-reduction reactions. The oxidation agents accept the electrons during the process from reducing agents, so to say: to be reduced – the oxidant has to accept the energy, and analogically, to be oxidized – the reducer has to free the energy. Although each substance could be used as an oxidation or reduction agent it is to be noted that strong oxidants keep the electrons tightly, so they are always week reducers and vice versa.

It can be explained in the case of oxidation of carbon with oxygen when there is a freeing of energy, while in photosynthesis there is an inversing of the reaction and the fixation of carbon happens by employing the energy of the Sun. Cycling the ecosystem, each element follows its unique path specified by its own specific chemical transformations, passing through different forms, so the passing processes from one to another form have to be balanced with the processes of returning to the original form. As most of the energetic transformations are tvari kruže kroz sustav i posredno upućuje na procese tijeka energije.

Promatranjem kruženja ugljika u vodenim i kopnenim sustavima može se uočiti da postoje tri glavne grupe procesa, [6, str. 272. – 274.]:

1. Asimilacijske i disimilacijske redoksne reakcije ugljika u procesima fotosinteze i respiracije koje čine najvažnije transformacije u živom svijetu.
2. Fizikalne izmjene CO_2 između atmosfere i hidrosfere. Upravo svojstvo lakog otapanja CO_2 u vodi omogućava izmjenu kroz granicu voda-zrak i ta izmjena povezuje cikluse ugljika između kopnenih i vodenih sustava.
3. Otapanje i taloženje ugljikovih spojeva kao sedimenata (vapnenac, dolomit). Ova grupa procesa odvija se znatno sporije od prvih grupa, pa je izmjena između sedimenata i vodenog stupca gotovo beznačajna za kratkoročno kruženje ugljika u ekosustavu.

No, u atmosferu dolazi i iz drugih izvora. Današnjom povećanom potrošnjom fosilnih goriva, ugljik se u obliku oksida vraća u atmosferu i u sinergiji s grupom drugih plinova (CFC, CH_4, NOx, ...) uzrokuje ‘efekt staklenika’. Važno je uočiti da u toj sinergiji CO_2 sudjeluje s više od 60%.

Ciklus kisika može započeti njegovim obnavljanjem i oslobađanjem u atmosferu kroz proces fotosinteze (nastaje najvećim dijelom u eufotičkim morskim područjima), a troši se u procesu respiracije i ulaskom u veliki broj reakcija.

Vodikovo je kruženje najvećim dijelom vezano uz kruženje vode u biosferi. Isparavanjem, voda u obliku vodene pare zajedno s krutim česticama u zraku stvara oblake, a potom se u obliku padalina vraća na površinu Zemlje. Ukupne zalihe su najvećim dijelom sadržane u oceanima (čak 97%). Oko 75% zaliha pitke vode sadržano je u podzemnim vodama, te vječnom snijegu i ledu čija se održivost uslijed evidentnih klimatskih promjena dovodi u pitanje. Kako je ona osnova životnih funkcija svih organizama i značajan čimbenik stabilnosti ekosustava posljedično je i njihova opstojnost upitna.

Za razliku od ugljika primarni proizvođači ne mogu izravno uzimati molekularni dušik N2 iz atmosfere. Za njegovo kruženje u atmosferi presudno je sudjelovanje nekoliko skupina bak-

tied with oxidations and reductions of carbon, oxygen, hydrogen, nitrogen, phosphorus and sulfur, by following the cycles of these elements, the way of the nutrient cycling through the system can be shown and indirectly referred on the energy flow processes.

Observing the carbon cycling in aquatic and land systems, three main groups of processes are to be noted [6, pgs. 272-274]:

1. Assimilation and dissimilation red-ox reactions of carbon in the processes of photosynthesis and respiration that are the most important transformations among the living planet;
2. Physically interchange of CO_2 between the atmosphere and the hydrosphere. It is just the propriety of CO_2 that is soluble in water which makes the exchanging between the water-air boundary possible, and this exchange connects the carbon cycles between the land and the aquatic systems.
3. Dissolving and sedimentation of carbon compounds as sedimentary rocks (limestone, dolomites). These groups of processes are slower respecting the first ones, so the exchange between the sediments and the water column is almost insignificant for the short-time cycles of carbon in the ecosystem.

However, it also appears in the atmosphere from other sources. By a higher consumption of fossil fuel, nowadays, the carbon is returning to the atmosphere in the form of oxides and in the synergy with some other gases (CFC, CH_4, NOx …) causes the ‘greenhouse effect’. It is to be noted that CO_2 contributes in the synergy with more than 60%.

The oxygen cycle starts within the regeneration and is releasing into the atmosphere through the process of photosynthesis (yielded mostly in the photic zones of the sea), and is consumed within the respiration process entering into a large number of reactions.

The cycling of hydrogen is mostly connected with the cycling of water within the biosphere. Evaporating, the water in the form of steam and with solid particulars (dust) in the air form the clouds and then as precipitation returns to the surface of the Earth. The total supply of water is mostly contained in the oceans (even 97%). About 75% of fresh water is locked up below the ground and in glaciers which existence is doubtful respecting the evidential climate change. The fresh water is essential for all terija koje su sposobne fiksirati atmosferski dušik i pretvoriti ga u one kemijske oblike koje primarni proizvođači mogu iskoristiti (nitrati i amonijak). Biljne stanice pretvaraju topljive nitrate u aminokiseline (asimilacija nitrata), a iz njih nastaju specifični proteini koje životinje kroz hranu sintetiziraju u animalne proteine. Konačno, dušik se izlučuje iz organizma u obliku mokraće ili mokraćne kiseline.

U mnogim kemijskim reakcijama dušik sudjeluje i u obliku amonijaka NH_3 koji u biosferi može nastati razgradnjom uginulih i ubijenih organizama ili električnim pražnjenjem i kozmičkim zračenjem. Nastali amonijak bakterije oksidiraju do nitrata za koje je već naznačeno da su osnova iz koje biljne stanice sintetiziraju potrebne aminokiseline i specifične proteine. U tom složenom ciklusu dušika uočava se i skupina denitrificirajućih bakterija koje prerađuju nitrite i nitrate do molekularnog dušika N_2.

Kruženje fosfora – u obliku fosfata on sudjeluje u svim metaboličkim procesima organizma i izgrađuje složene spojeve poput nukleinskih kiselina i fosfolipida. Najveće zalihe nalaze se u litosferi u obliku slabo topljivih željeznih i kalcijevih fosfata iz kojih se polako otapa pod djelovanjem slabe dušične kiseline nastale nakon denitrifikacije. Velike količine erozijom se ispiru iz zemljišta i završavaju u moru. U današnje vrijeme se upotrebom deterdženata pojavljuje dodatni unos fosfora u ekosustave s količinom dostatnom za ugrožavanje ekosustava neposredno zahvaćenim takvim prilivom. U proces kruženja uključene su neke grupe bakterija koje ga mogu prevesti do topljivih fosfata u obliku $CaHPO_4$, koji sudjeluje u sintezi biljnih proteina ili se istaloži u moru u obliku čvrstog sedimenta $Ca(PO_4)_2$, a u sličnom kemijskom obliku izgrađuje kosti životinja ili ljušture nekih organizama.

Sumpor se u prirodi nalazi u obliku sumporovodika H_2S, sulfita SO_3 i sulfata SO_4, a u organizmu stvara disulfidne veze značajne za tercijarnu strukturu proteina i diobeno vreteno. Organski sumpor iz biljnih i životinjskih stanica razgrađuju neke bakterije do sumporovodika koji može oksidirati u amonijev sulfat $(NH_4)_2SO_4$. Značajni izvor sumpora u atmosferi dolazi i izgaranjem fosilnih goriva koji ga u sebi sadrže. Pri tomu nastaju sumporni oksidi, a spajanjem s vodom i sumporna kiselina. Povećanom koncentracijom u atmosferi, između ostalog, sumporni i dušični oksidi zajedno s fi-

living functions of all organisms and an important factor of the ecosystems stability, as a consequence, their existence is doubtful also.

As it is different with carbon, the primary producers cannot use the molecular nitrogen N2 from the atmosphere directly. For its cycling in the atmosphere, crucial is the participation of several groups of bacteria that are able to fix the atmospheric nitrogen and convert it into chemical forms that those primary producers can use (nitrates and ammonia). Plant cells convert soluble nitrates into amino acids (nitrate assimilation), and they form specific proteins that animals can synthesized through the food into animal proteins. Finally, nitrogen is excreted from the organism in the form of urine or uric acid.

In many chemical reactions the nitrogen is involved in the form of ammonia NH3, which may occur in the biosphere by decomposition of dead or killed organisms or with electric discharge, and cosmic radiation. The resulting ammonia is oxidized by bacteria to nitrates, which has already been indicated as the basis on which plant cells synthesize the required amino acids and specific proteins. A group of denitrification bacteria, that process nitrite and nitrate to molecular nitrogen N_2, can be observed within this complex cycle of nitrogen.

The phosphorus cycling - in the form of phosphate, it participates in the whole metabolic process of the organism and builds up complex compounds such as nucleic acids and phospholipids. The largest reserves are located in the lithosphere in the form of poorly soluble iron and calcium phosphate from which slowly dissolves under the influence of weak nitric acid formed after denitrification. Large amounts are washed from the land with erosion and ending in the sea. Today, the use of detergents appears to be an additional input of phosphorus in the ecosystems with the amount sufficient to endanger the ecosystem directly affected by such influx. In the cycling process a group of bacteria is included which can carry it up into soluble phosphate in the form of $CaHPO_4$, that participates in the synthesis of plant proteins, or sediments on the sea bed in the form of solid sediment $Ca(PO_4)_2$, and in a similar chemical form builds animal bones or shells of some organisms.

Sulfur is found in nature in the form of sulfur-hydrogen H_2S, sulphite SO_3, sulphate SO_4, and it produces disulphide links in the organism that are important for the tertiary structure of proteins and mitotic spindle.

nim česticama sulfata i nitrata uzrokuju 'kiselu' suhu ili vlažnu depoziciju ('kisele kiše').

U oceanima kao cjelini, jasno dominantno kruženje jest povezivanje u organske tvari, tonjenje u dubinu i ponovno vraćanje u površinske slojeve 'uzvijanjem'. U stvarnosti, svaki od atoma navedenih elemenata može u eufotičkoj zoni proći kroz mnoga kruženja tipa: fiksacija → potrošnja → izlučivanje → fiksacija, prije nego što konačno potone u afotične dubine. Time se zadire u područje njihovog 'okretanja' unutar ekosustava u kojem su, do sada, izvršena određena mjerenja i procjene brzine recikliranja, no za postavljanje općenitih postavki potrebno je prikupiti veće skupine reprezentativnih podataka, što indirektno upućuje u buduća istraživanja.

5. INTERSPECIFIČNA KOMPETICIJA I KRITIČNA TOČKA

Štetni antropogeni utjecaj na ekosustave općenito danas je neupitan. Iz 'Principa kompeticijskog isključenja' (koji je tako nazvao Garret Hardin 1960[4] [6, str. 135.]). prema kojem: 'dvije vrste ne mogu koegzistirati na istom ograničenom resursu', (gdje je izraz 'ograničen' istaknut zato što kompeticija dolazi do izražaja jedino ukoliko se resurs smanjuje konzumacijom i ograničava rast populacije) može se analogno postaviti pitanje opstanka ljudske populacije u sadašnjim uvjetima čovjekovog odnosa prema prirodi. Interspecifična kompeticija prepoznaje se kao kompeticijski odnos jedinki različitih vrsta koja može uzrokovati nestanak jedne od populacija koje su u kompeticiji (za razliku od intraspecifične kompeticije[5]). Vjerojatno sam antropogeni štetni utjecaj i nije bio ranije prepoznat, dijelom i zbog manjeg učinka kompeticije u odnosu na predaciju koju čovjek sa svoje visoke trofičke razine nije odmah uočio, iako je njen koncept od samog početka bio dio ekologije.

Velikim i naglim industrijskim razvojem i povećanjem ljudske populacije svjedoči se sve većoj potrebi za energijom i posljedično sve većem onečišćenju s obzirom da se, u sadašnjim

[4] Hardin, G., The competitive exclusion principle, Science, 1960.,131, 1292 – 1297.

[5] Intraspecifička kompeticija jest kompeticija između jedinki iste vrste, a ona vodi k stabilnoj regulaciji veličine populacije u granicama koje su određene okolišem. [6, str. 133.]

Organic sulfur from plants and animal cells is decomposed by some of the bacteria to sulphur-hydrogen which can oxidize the ammonium sulfate $(NH_4)_2SO_4$. A significant source of sulfur in the atmosphere comes from the combustion of fossil fuel, which contains it. Sulfur oxides are formed as a result, and, merged with water, form the sulfuric acid. The increased concentration in the atmosphere, among other things, of sulfur and nitrogen oxides with fine particles of sulfate and nitrate, cause the 'acid' dry or wet deposition ('acid rain').

In the oceans as a whole, the clearly dominant circulation is connecting into the organic matter, sinking to the depths and upwelling to the surface layers again. In practice, each atom of these elements in the photic zone may pass through many cycles of fixation → consumption → excretion → fixation, before it finally descends into the aphotic depths. This enters the area of their 'turnover' in the ecosystem in which, until now, some measurements have been made and estimations of the rapidity of recycling, but much larger series are required to support generalizations, so there is the necessity of gathering large groups of representative data, which indirectly point to the future researches.

5. INTERSPECIFIC COMPETITION AND CRITICAL POINT

Harmful anthropogenic impact on ecosystems in general is unquestionable nowadays. From 'The competitive exclusion principle' (which is so called by Garrett Hardin 1960[4] [6, p. 135]) according to which: 'the two kinds cannot coexist at the same restricted resources', (where the term 'restricted' is enhanced because the competition becomes noticeable only when the resource is restricted with consumption thus limiting the population growth) arises, analogically, the question of the human population survival in the current conditions of the human relationship to nature.

Interspecific competition is recognized as a competitive relationship between individuals of two different species that can cause the disappearance of one of the populations that are in

[4] Hardin, G., 1960., The competitive exclusion principle, Science 131: 1292 – 1297.

okvirima, do nje najviše dolazi izgaranjem fosilnih goriva. Pri tome se pod onečišćenjem podrazumijevaju „nepoželjne promjene u fizikalnim, kemijskim ili biološkim svojstvima zraka, zemljišta ili voda koje mogu ili će štetno djelovati na: čovjeka ili druge organizme, njihove uvjete života, industrijsku proizvodnju, kulturno-povijesne spomenike ili mogu uništiti sva prirodna bogatstva" [3, str. 47.].

Ekološka istraživanja rezultirala su prepoznavanjem antropogenog utjecaja i podizanjem ekološke svijesti u razvijenim zemljama (poglavito dostupnošću njihovih rezultata javnosti). Time su zahtjevi za pronalaženjem tehnoloških rješenja pojačani. Iako su neka od trenutno dostupnih rješenja već u uporabi, njihova raširenost nije zamjetna. Kao i kod svake nove tehnologije i ova, povezana s ekologijom, nije iznimka u visokoj cijeni koštanja. No, za očekivati je da će se značajnijom proizvodnjom i uporabom cijena smanjiti, pa tako učiniti dostupnijom. Kako vlasnici kapitala nisu skloni izlaganju troškovima, postoji otpor prihvaćanju. No, do 'kritične točke' (u smislu prihvaćanja nužnosti smanjenja onečišćenja, primjene postojećih i pronalaska još boljih ekološko prihvatljivih tehnoloških rješenja) se već dolazi, i izvjesno je da će se do nje doći, zbog sve većeg svakodnevnog pritiska javnosti u tim zemljama da se međunarodnim propisima i zakonskim sredstvima osigura smanjenje negativnih utjecaja i omogućavanje održivog razvoja.

competition (as opposed to intraspecific competition[5]).

The harmful anthropogenic impact was not recognized earlier, probably due to the lower effect of competition respecting the predation that man has not recognized at first from the higher trophic level he belongs to, although its concept was a part of ecology from the very beginning.

A large and rapid industrial development and the increasing human population testify to the growing need for energy and, consequently, due to the increasing pollution, in the present framework, it mostly comes from fossil fuel combustion. In doing so, the pollution include "undesirable changes in physical, chemical or biological properties of the air, land or water that may or will adversely affect: a man or other organisms, their living conditions, industrial production, cultural and historical monuments, or may destroy all the natural wealth". [3, p. 47]

Ecological researches have resulted in the detection of anthropogenic impact and raising environmental awareness in the developed countries (especially the public availability of their results). In doing so, the demands on finding technological solutions strengthened. Although some of the currently available solutions have been already used, dissemination of their use is not evident. As with any new technology, as well as with this one, associated with ecology there is no exception in its cost price. It is still expensive. But, it is to be expected that rising significantly in the production and implementation, its price will be cut, thus making it more accessible. As the owners of capital are not attracted to cost exposing, there is a resistance to the acceptance. However, the 'critical point' (in terms of adopting the necessity for reducing pollution, the implementation of the existing solutions and finding even better environmentally sound technological solutions) is already there, and certainly this will come to it, because of the daily growing public pressure in these countries to ensure, with international regulations and legal means, the reduction of negative influences and to facilitate sustainable development.

[5] Intraspecific competition is competition between individuals of the same species, and it leads to a stable regulation of the size of the population within the limits of that particular environment. [6, p. 133]

6. ZAKLJUČAK

Zajedničko svojstvo svih ekosustava jest da oni uvijek nastoje biti uravnoteženi (postizanje homeostaze). Čovjek razvojem i uređenjem tehnoloških sustava, svjesno ili često nesvjesno, narušava ravnotežu svoga okoliša.

Kako su procesi koji se u ekosustavu odvijaju uglavnom spori, i odgovor sustava na te promjene je vremenski dug. Pojedini organizmi u promjenama zahvaćenim sustavima nemaju mogućnosti dovoljno brze prilagodbe, pa im se populacije rapidno smanjuju, a neki su gotovo nestali. Znanstvenim uvidom u neke od tih promjena raste svijest o *'ekološkom dugu'*. Zavaran početnim kapacitetom apsorpcije okolišnih ekosustava čovjek je previdio činjenicu da je samo dio u hranidbenom lancu (vjerojatno iz razloga što se nalazi u višoj trofičkoj strukturi). Djelujući na način da ugrožava opstanak ostalih trofičkih skupina razvidno dovodi u pitanje i svoj.

Pristup osviješćenju čovjeka kroz kataklizmička predviđanja možda jest trenutno učinkovit, ali je sasvim sigurno bolji onaj kroz edukaciju do razumijevanja problema i prepoznavanja čovjekove pozicije u prirodnom ustroju. Edukacija bi trebala započeti u najranijoj dječjoj dobi i nastaviti se kroz trajni sustav obrazovanja i aktivnog ljudskog djelovanja u svim područjima znanja i zanimanja. Takav pristup već je prihvaćen u nekim najrazvijenijim zemljama (npr. Skandinavija), jer se nameće kao logičan put traženja rješenja.

Širenje spoznaje o štetnom antropogenom utjecaju na ekosustave je nezaustavljiv proces i pitanje dostizanja kritične točke i pritiska na vladajuće strukture najrazvijenijih zemalja je stvarnost. Tehnološka rješenja koja mogu doprinijeti zaštiti postoje, iako su neka još uvijek prilično skupa. Vrijeme pokazuje da će svjetski kapital u svojim troškovno-korisnim analizama morati prepoznati veće vrijednosti na strani korisnih čimbenika u tim analizama. No, do naglog obrata vjerojatno može doći jedino uz neki katastrofični događaj ili pronalaženje pozitivnog financijskog učinka među najbogatijim zemljama.

Istraživanja u ovim tematskim područjima svakako doprinose ukupnom znanju, no propusti u pozicioniranju dobivenih rezultata unutar cjeline nalažu nužnost redovite obnove cjelokupne slike uvažavajući funkcionalnu cjelovitost svih ekosustava, pa tako i ekosustava mora.

6. CONCLUSION

The common property of all ecosystems is that they always strive to be balanced (the achievement of homeostasis). The man, with the development and the designing of technological systems, often, consciously or unconsciously, distorts the balance of those in their environment.

As the processes running in are mostly slow, the response of the systems to these changes is a timely long. Some organisms within the systems affected with changes are not able to adapt fast enough, so their population is rapidly decreasing, and some have almost disappeared. The scientific insight into some of these changes is the growing awareness of the 'ecological debt'. Fooled with the initial capacity of the absorption of the environmental ecosystem, the man overlooked the fact that he is only a part of the food chain (probably due to this fact he belongs to a higher trophic structure). Acting in a way of threatening the survival of other trophic groups, shows prejudice to its own.

Approaching the man awareness through cataclysmic predictions might be currently effective, but it is certainly better to approach through the education to understand the problem and to identify the human position in the natural structure. Education should begin in the early children's age and continue through the permanent education system and the ongoing human action in all spheres of his profession. Such an approach has been adopted in some developed countries (i.e. in, Scandinavia), because it imposes a logical way to seek solutions.

The dissemination of knowledge about the harmful anthropogenic impact on the ecosystems is an unstoppable process and the issue of reaching a critical point and the pressure on the governing structure of most developed countries is a reality. Technological solutions that can contribute to the protection exist, although some are still quite expensive. Time shows that the world capital in its cost-beneficial analysis must recognize the higher value on the side of the beneficial factors in this analysis. However, a sharp reversal might be probably reached by a catastrophic event only, or by finding a positive financial impact within the richest countries.

Researches in these thematic areas certainly contribute to the overall knowledge, but fails in the positioning of the results within the whole require the necessity of regular updates of the total picture, taking into account the functional integrity of all ecosystems, the marine ecosystem included.

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