OPEN ACCESS
Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) |ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/haya/

Original Research Article

Mapping Human Appropriation of Net Primary Production in the Greater Jakarta Bay Large Ecosystem

Dr. Robin[1,2*], Rahmat Kurnia[3], Kadarwan Soewardi[3], Isdradjad Setyobudiandi[2], Arya H. Dharmawan[4]
[1]Student of Coastal and Marine Resources Management Study Program FPIK-IPB, Jawa Barat 16128, Indonesia
[2]Southeast Asian Regional Center for Tropical Biology, Jawa Barat 16128, Indonesia
[3]Department of Aquatic Resources Management FPIK- IPB, Jawa Barat 16128, Indonesia
[4]Department of Communication Science and Community Development (SKPM) FEMA-IPB, Jawa Barat 16128, Indonesia

***Corresponding author:** Dr. Robin
| **Received:** 02.03.2019 | **Accepted:** 15.03.2019 | **Published:** 30.03.2019
DOI:10.21276/haya.2019.4.2.1

Abstract

This study aims to look at the rate of primary productivity utilization in Jakarta waters by fisheries activities which are divided into two main zones using the Human appropriation of net primary production approach and the primary production recquirement. The fishery zone is divided based on the type of vessel weight size, namely zone I for ships with sizes <5GT and zone II for 5-10GT vessel sizes. The method used in calculating PRRi is to use the approach of Pauly and Chirstensen (1995) while for HANPP we transform the approach of Erb *et al.* 2009 to the Djau 2013 approach to see the value of HANPP fisheries. From the analysis, it can be seen that the PPR value for zone I is equal to 1,63 x 10^8 $kgC.y^{-1}$ while for zone II amounting to 1,44 x 10^8 $kgC.y^{-1}$. For HANPP value for zona II is equal 5,12 x 10^{10} kj and zone I 4,04 x 10^{10} kj. Total value (zona I dan II) PPRo = 9,88 x10^{10} , PPRh = 7 x 10^9 kj, and HANPP total = 9,17 x 10^{10} kj. The conclusion from this analysis is shown that harvesting rate of primary productivity by fisheries in Jakarta waters reaches more than 95% of total energy availability it means that the fisheries activities has given considerable pressure to the waters.
Keywords: HANPP, PPR, Jakarta Bay, Ecological Footprint.

INTRODUCTION

Large-scale (industrial) and small-scale (artisanal) impacts on benthic habitats and fauna communities have attracted much attention and attention throughout the world during the last war. Overall, the ability to use tools that cause damage to benthic habitat has been extensively investigated by people involved, management and sustainable use of resources. Trawll and other basic fishing tools, can have direct and indirect effects on the physical characteristics of marine habitats, including hard or soft bottoms (eg sediment surface roughness, sediment resuspension, removal of large rocks, removal of large epifauna species), and composition , diversity and productivity of related benthic communities. Artisanal fishing is characterized as a local fleet using manual or manual fishing gear on a 15 m long vessel which produces relatively low catches per vessel [1, 2], but according to the Republic of Indonesia fisheries law small-scale fisheries are defined as fishing activities that only serve to fulfill the lives of fishermen with a ship size of 0-10 GT. Small-scale fisheries activities have become the activity of most of the world's fishermen and provide more than half of the seafood sources captured in the world. This fishery is expected to have a low ecological impact on marine ecosystems and lower annual catches compared to large-scale fisheries [1, 3]. Artisanal fisheries target a variety of commercial species including demersal fish and deep pelagic fish and usually use nets, lines and traps, as well as coastal invertebrates (such as mollusks) caught with mechanical and traditional fishing gear. Although most research on the ecological impacts of fisheries in the marine environment comes from industrial fisheries studies.

The waters of Jakarta or what is known as The Greater Jakarta Bay Ecosystem has been a fishing ground for centuries. At present the pressure on the Jakarta bay ecosystem is very large because it is caused by the many uses of the bay for shipping activities, tourism and the biggest is the change in the use of coastal land (coastal reclamation) which all the above activities intersect directly with fishing ground fishermen. Some results of the study state that the results of catching fish in Jakarta in general continue to experience decline, especially the catches of small-scale fishermen (5 GT - 10 GT), but there are several types of fish that still have high catch, namely anchovy, rebon and crab so attractive for fishermen who live along the coast of Jakarta but also fishermen from outside Jakarta. In 2017 there are more than

30,000 fishermen families who live in the coastal area of Jakarta, most of which are small fishermen who depend on fishing activities.

Robin *et al.*, [4] explains that the condition of the Jakarta aquatic ecosystem has experienced a decrease in environmental quality, this is characterized by an ecological footprint and biocapacity ratio that reaches 10:1 or in other words the burden on the environment has exceeded the bioproductive capacity of the DKI Jakarta marine area. Besides that, it was explained that the area of the sea which was still able to support the fishing activities of the fish was only around 30% of the total area of Jakarta's waters. The question as to the extent to which the pressure of taking fishermen on primary productivity potential has not been explained in detail so that further research is needed regarding human appropriation of net primary production as an illustration of the process of land use by fishermen for fishing activities in Jakarta waters. The purpose of this study is to calculate and mapping the value of the human appropriation of net primary production of fisheries activities in Jakarta waters and it relation to Primary production Recquired approach.

Human Appropriation of Net Primary Production

Up to 83% of the global terrestrial biosphere except Greenland and Antarctica are considered to be under direct human influence [5]. About 36% of Earth's bioproductive surface has been classified as "fully dominated by humans" [6]. Changes in terrestrial ecosystems generated from land use act as drivers of global environmental change [7]. It is increasingly recognized that the results of land use in sustainability challenges are equally important and urgent as potential threats resulting from changes in the atmosphere and global climate [8, 9]. There is a growing recognition that an integrated socio-ecological approach is needed to understand the challenges of sustainability arising from changes in global land systems [9]. Land is used by human society for at least three core functions or services [10, 11]: (1) Supply of vital materials and energy resources such as fossil fuels, minerals, water, biomass and others. One important difference that is useful here is that between "renewable" resources taken from current biogeochemical cycles (biomass, water, hydropower or wind, etc.) and "non-renewable" resources taken from geological deposits (fuel fossils, minerals, etc.). Land use produces changes in the flow of biomass in ecosystems which can be monitored using indicators symbolized as Human Appropriation of Net Primary Production (HANPP). Two interrelated processes are reflected by HANPP: (1) Changes in land use that modify the NPP of vegetation compared to undisturbed (potential) vegetation. The first component of HANPP is denoted as $\Delta HANPP_{LC}$ (change in NPP resulting from land conversion). $\Delta HANPP_{LC}$ Defined as the difference between NPP potential vegetation [12] denoted as NPP0, and NPP of the vegetation currently in effect, denoted as NPPact. (2) Extraction or destruction of a small portion of NPP for human purposes, for example through biomass harvesting or livestock grazing. This stream is denoted as NPPh. HANPP is defined as the sum of $\Delta HANPP_{LC}$ and NPPh and is an indicator for human-caused changes in the availability of annual trophic energy in ecosystems [13, 14]. So HANPP is a land-use intensity indicator that explicitly links nature to socio-economic processes, resulting in an integrated picture of socio-ecological conditions in land systems [15]. NPP is a central parameter of ecosystem function that determines the amount of trophic energy available to transfer from plants to other levels in tropical tissue in the ecosystem. Many aspects of ecosystem functions such as nutrient cycles, accumulation of organic matter on the ground or in ecosystem compartments above ground, are very dependent on this energy flow. Thus, NPP is strongly related to ecosystem resilience and their capacity to provide services to humans, such as supplying biomass through agriculture and forestry, but also buffering capacity or absorption capacity for waste and emissions [16, 11].

Ecological Footprints

Ecological Footprints analysis is carried out with the aim to see the ecological load magnitude of small-scale fisheries capture fisheries. Ecological Footprint analysis in this study was measured in the Primary Production Requirement (PPR) magnitude compared with the primary productivity rate of fishing round and the results will be compared with the value of biocapacity in supporting fishing activity. The greater the ecological burden due to an activity carried out in a feeding system the potential to exceed the biocapacity value will also be greater in other words the carrying capacity of the environment will also decrease.

The ecological footprint was first introduced by William Rees in 1992. Ecological Footprint is a measure of how much biologically productive land and water that an individual population needs to produce all the resources it consumes and to absorb the waste produced. The Ecological Footprint approach is intended to show human dependence on the environment they use and also to provide natural resources for humanity in the future. The ecological footprint consists of 4 (four) basic parameters, namely; population, land and sea, productivity (product / ha) and indicators (ha / capita), and this calculation will be part of the environmental carrying capacity equation to determine the resilience of natural resources and the environment.

Pauly and Christensen [17] introduced a calculation approach to predict the sustainability of fisheries resources in an ecosystem, where the main base is Primary Production Requited (PRR) ($kgC.y^{-1}$) compared to the primary productivity level (PP) ($kgC.m^{-2}.year^{-1}$). The concept of PPR comes from the fact that, for existing exploited species to be able to replenish, they must have a minimum supply of organic energy. Simply put, this energy comes from solar energy captured by autotrophic species (eg phytoplankton), passes to secondary producers (eg zooplankton, suspension feeders), planktivorous species and eventually becomes a predator through trophic webs. At each of these stages, only a small portion of the energy consumed (after metabolic costs) is passed on to the growth of individuals or populations (through gonadal development). The fraction used for individual or population growth is called transfer efficiency. This transfer efficiency depends on many factors, such as the effort needed to hunt food, overcome metabolism and the efficiency of assimilation of organisms from organic carbon from food [18].

HANPP and Ecological footprints

The approach to ecological footprint analysis and HANPP is an analysis of the utility of resources both land and waters by humans. Both of these approaches recognize the importance of surface area for ecological processes that are related to land use and metabolism of an area [19, 14].

Table-1: Comparisson betwen ecological footprints approach and HANPP

Item	Harbel et al. 2004: Djau 2013 [19, 14]	
	EFA	HANPP
Research Question	How large is the bioproductive area needed to maintain the socio-economic metabolism of a particular population, using applicable technology?	Which proportion of the original NPP remains in the ecosystem on land is defined, with current land cover patterns and land use practices?
Units	Global Hectare; that is, acres of bioproductive land and sea area, with global average productivity	Joule, kilograms of dry matter biomass or kilograms of carbon
Underliying Asumsion	Humans depend on the availability of bioproductive areas; too often uses spent natural capital (‘‘ overshoot ’)	The percentage of NPP adjusted by humans is the right measurement for " human domination " of the ecosystem. The high level of HANPP is a potential risk to biodiversity
Relevance for sustainability	A comprehensive ecological account to compare the size of the human economy to the size of the supporting ecosystem. This allows one to detect ecological overshoot By also converting ecological distribution conflicts	Assessment of land use in the national area. Show intensity of the use of a country's terrestrial ecosystem The current assessment does not identify 'clear' sustainability boundaries' Large reductions in productivity (low NPP compared to NPP0) indicate inefficient land management

Research Methods

The research data was obtained from Analysis of the condition of coastal resources begins with the collection and preparation of data base based on socio-ecological data.

Table-2: Data needed Human Appropriation of Net primary Production

Main Component	**Colleting data method**	**Data Source**	**Type of data**
Fish catching area/Fishing Ground	Survey, Interview	Fishermen dan Community	Primer (First Hand data)
Energy Content of Fish	Internet	wholefoodcatalog.info	Secondary
Trophic Level of Fish	Internet	Fishbase.org	Secondary
Fish Production data	Survey, Interview	Fishermen, Fishingport, Food Security, Marine and agriculture services of DKI Jakarta	Primer (First Hand data) & Secondary data
Type of fish catched by fisherman	Survey, Interview	Fishermen, Fishingport, Food Security, Marine and agriculture services of DKI Jakarta	Primer (First Hand data)

Ecological Footprints Base on Primary Production Recquired

To measure a single system unit of ecological footprint, We use a more aplicable equation based on Pauly & Christensen [17]; de Leo *et al.*, [20], its called Marine Ecological Footprints (MEF):

$$MEFa = \frac{PPRia}{PPa} \quad \text{...} \quad (1)$$

MEF_a = Ecological footprint for aquatic systems a (km^2/y), PPR_{ia} = *Primary Production Required* for spesies a on aqatic system a ($tC.y^{-1}$). PP_a = Primary Productivity for aquatic systems a ($tC.km^{-2}.year^{-1}$).

$$PPRi = CC * DR * (\frac{1}{TE})^{(TL-1)} \ldots (2)$$

PPRi is primary productivity needed for species i ($tC.y^{-1}$), CC adalah *carbon content* per unit weight of species i (1/9 Pauly and Christensen 1995) [17], DR adalah *discard rate of bycatch* (1,27 Pauly dan Christensen 1995) [17] TL is a trophic level for species taken from fishbase.org or other sources.

Human Apropriation on Net primary Production

HANPP, by our definition, can be interpreted from a community perspective and an ecological perspective. From a community perspective, HANPP is the overall effect of changes in productivity resulting from land conversion and use of PNPPLC and harvesting of NPPh biomass. From an ecological perspective, HANPP measures human impacts on energy availability in the ecosystem; namely the difference between a potential vegetation (NPPo) and part of the NPP of vegetation that currently applies NPPact remaining in the ecosystem after harvest (NPPt) and available for all other heterotrophic organisms:

$$HANPP = \Delta NPPlc + NPPh = NPPo - NPPt \ldots (3)$$

HANPP can be expressed in absolute numbers as kilograms carbon per year (kg C/yr), as kilograms dry matter biomass per year (kg DM/yr) or as energy flow (Joules per year, J/yr). As a rough proxy one may assume that 1 t DM is equivalent to 0.5 t C and that the calorific value of dry matter biomass is around 18.5 Megajoules per kilogram (MJ/kg, 1 MJ=10^6 J). In this study we transform HANPP notation into fisheries HANPP notation based on Djau [14] notation as follows:

HANPP is the primary productivity requirement for fisheries; PPRo is a potential primary productivity requirement obtained from PPR of fish species calculated based on the formulas of Pauly and Christensen [17] multiplied by energy per fish species (kj / 100g) obtained from Djau 2013 and wholefoodcatalog.info, where the energy of each fish is divided by weight the body is multiplied by 100 to get energy per 100g of fish weight. PPRh is the production of each type of fish (Volume of Landing) multiplied by the energy of a fish species. Furthermore, efficiency is calculated by comparing the value of HANPP and PPRh.

Results and Discussion

To calculate Primary Production recquired (PPR) values in the waters of the bay of Jakarta, we conducted a survey of the most common types of fish caught by fishermen in DKI Jakarta by dividing the types of catches based on fishing areas by fishermen. Fish catchment areas are usually influenced by the type of boat and the time or fishing trip. In this study the surveyed fishermen were <5GT size fishermen with a one day trip system (Zone I) and 5GT - 10GT vessel size (Zone II) with a 7 day fishing time per trip. The types of fish caught by fishermen are around 17 species of fish with 14 species generally caught by ships 5-10 GT and 3 types captured by ships <5GT [4]. In the calculation of PPR and HANPP we only use 8 types of fish out of a total of 17 species, due to the limited data related to the energy value of fish.

PPR Calculation

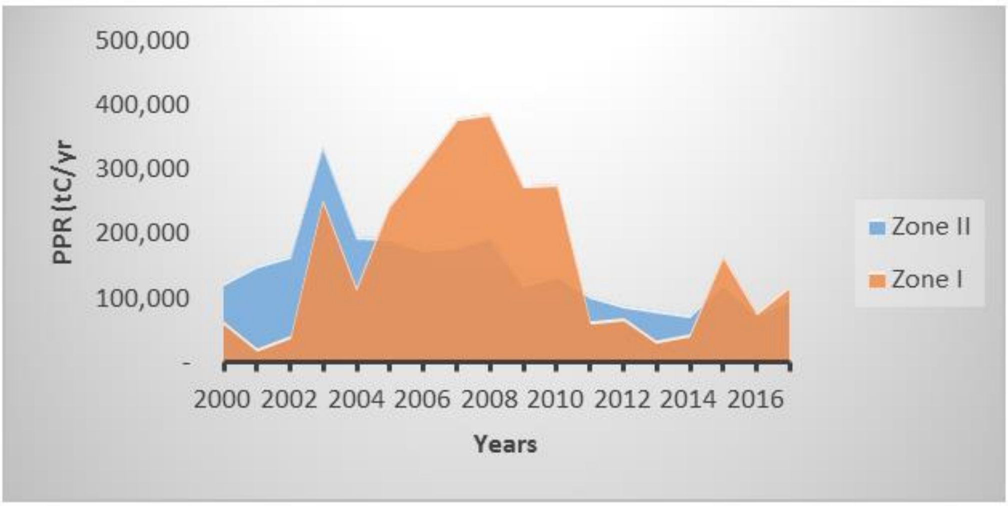

Fig-1: PPR value for past 17 years at Jakarta water ecosystem

From the calculation of the PPR value for 17 years, the average value is 144,877 $tC.yr^{-1}$ for zone II and 163,499 $tC.yr^{-1}$ for fishing in Zone I. Analysis of PPR is done to see how much primary productivity concentration is needed in this is carbon harvested from the waters and how much carbon is available in these waters to support the sustainability of fish resources. PPR is a product of the mass of the carbon catch being converted and the conversion ratio for the trophic level of each taxa involved. For example, PPR is needed to produce one metric ton of red snapper or Kwee fish significantly greater than the metric ton of sardines because the position of snapper and kwee is much higher in the food chain (see table), or in other words to produce 17,434 tons fish required PPR of 308,376 $tC.yr^{-1}$ while the gross primary productivity value in Jakarta waters was only 6,708 $tC.yr^{-1}$ and net productivity was only 155 $tC.yr^{-1}$ obtained from water productivity data in Jakarta according to Siregar and Koropitan [21] which is then processed according to approach de Leo *et al.*, [20]; Robin *et al.*, [4] to get the annual productivity value.

Table-3: Human Appropriation of Net Primary production

Zone II Type of Fishing Vessel 5-10GT										
NO	**Local Name**	**TL**	**Global Name**	**Volume (kg.y-1)**	**PPR kgC.y-1**	**Energy Kj/100 g**	**PPRh**	**PPRo**	**HANPP**	**Colony efficiency (%)**
1	Kakap Merah	4	Indonesian snapper	2.012.078	75.893.562	365	735.253.154	27.733.013.730	26.997.760.575	97,35
2	Kwee	4	Giant trevally	820.939	30.964.994	414	339.868.700	12.819.507.495	12.479.638.795	97,35
3	Tembang	3	Fringescale sardinella	3.849.667	13.200.507	439	1.689.575.926	5.793.555.850	4.103.979.924	70,84
4	Bentrong	4	Big eye Scad	1.477.800	5.067.376	228	336.483.692	1.153.802.581	817.318.889	70,84
5	Kembung	3	Indian mackerel	5.633.656	19.317.805	494	2.785.529.691	9.551.581.312	6.766.051.620	70,84
6	Alu-alu	5	Great Barracuda	126.344	433.235	371	46.915.904	160.874.634	113.958.730	70,84
Total				13.920.483	144.877.479		5.933.627.068	57.212.335.601	51.278.708.534	70,84
Zone I Type of Fishing Vessel <5GT										
7	Rebon	3	Acetes	3.822.128	144.166.838	276	1.054.102.608	39.759.696.278	38.705.593.670	99,83
8	Rajungan	3	Swimming Crabs	512.522	19.331.826	95	48.777.977	1.839.856.515	1.791.078.538	97,35
Total				4.334.650	163.498.663		1.102.880.585	41.599.552.793	40.496.672.208	99,72
Total Semua				18.255.133	308.376.142		7.036.507.653	98.811.888.394	91.775.380.742	95,62

Note: [a]Table sources base on research except the energy value obtained from Djau 2013 and wholefoodcatalog.info
[b]Zone of fishing base on fishing vessel
[c]All research variable that have to calculate

HANPP Calculation

Human activities in utilizing ecosystem services forever have a significant impact on the ecosystem itself. The use of natural and environmental resources has an ecological impact on the sustainability of resources and the environment and the ecosystem so that their activities can take place sustainably. To understand the scale and potential impacts of human activities on ecosystems, an approach is called the human appropriation of net primary production (HANPP). HANPP is a human use of clean primary productivity that is utilized from existing land uses or existing ecosystems [14]. Halbert *et al.,* [13] suggested that HANPP is a parameter indicator of the use of the area and its intensity by humans. Therefore in this study try to elaborate on the HANPP approach which is generally widely applied in terrestrial ecosystems to aquatic ecosystems, the purpose of which is to measure the extent or intensity of fisheries resource use in this case fisheries production.

The results of the calculation of fisheries HANPP presented in the table are referred to as exosomatic energy calculations. There are several steps in calculating HANPP in Jakarta bay, namely 1) by calculating the potential of primary productivity needs, (2) actual production (production of each species of fish (landing volume) (3) energy content of each type of fish. In the table it can be seen that the calculation of the average value of exosomatic energy in the waters of the bay of Jakarta from 2000-2017 reached 5.12 x 10^{10} kj for fisheries activities in zone II with colony efficiency of 70.84%, while for fisheries activities in zone I reached 4.04 x 10^{10} with colony efficiency reaching 99.72%.

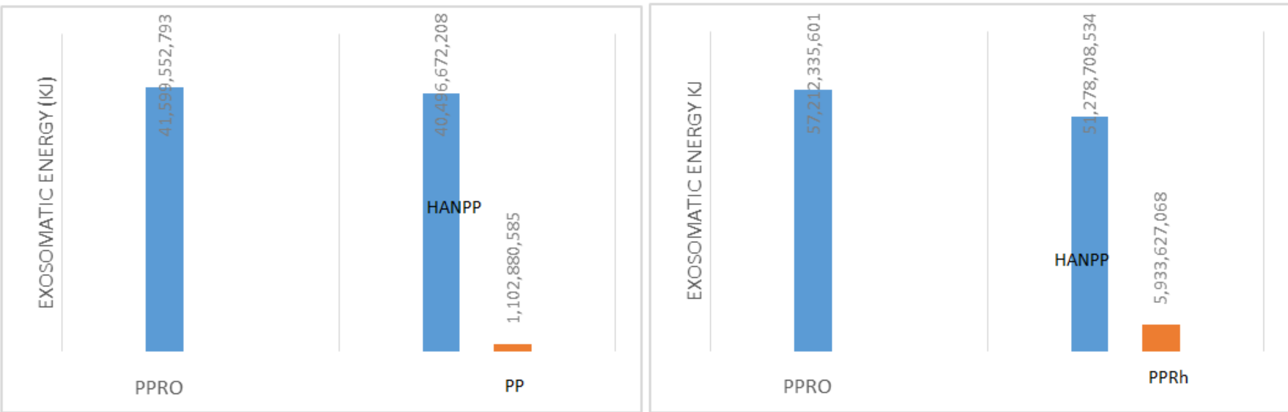

Fig-2: Comparison of the values of PPRo, PPRh and HANPP in zones I (a) and Zone II (b)

In the picture above, it can be seen that the harvest rate of primary productivity which is indicated by the HANPP value in zone I is seen to be higher than zone II. This condition shows that in zone I the utilization of primary productivity is greater than zone II. This is due to the high fishing activity, especially the capture of *rebon* (Acetes) and rajungan (swimming crab) around the coastal area, with harvesting efficiency reaching 99.72%, which means that crab and rebon fisheries are potentially unsustainable. This is quite reasonable when seeing the trend of catching both species is quite high. From the results of the observations of the majority of fishermen in the area of Muara angke (kali adem is the size of the crab caught in the bay of Jakarta, small in size far below the size limit that is permitted to be captured according to fisheries minister regulation No. 2 of 2015.

CONCLUSIONS

After analyzing the human appropriation and primary production recquirement, a number of things can be concluded:

- PPR aproach shown the value of primary production that recquired to produce tonnes or kilogram biomass of fish, whereas HANNP approach is focused to measure how much the ammount of energy that used to harvest the primary production.
- Harvesting rate of primary productivity by fisheries in Jakarta waters reaches more than 95% of total energy availability.
- Fisheries activities especially those carried out in zone I look much more intensive compared to fisheries activities in zone II.

Acknowledgment

We would like to express our deepest gratitude to Southeast Centre for Tropical Biology (SEAMEO BIOTROP) for financing this research and also to all fisheries authorities of DKI Jakarta province, in this case, the food, marine, and agricultural security services for their assistance in providing secondary data and access to fishermen in the Bay of Jakarta.

REFFERENCES

1. Berkes, F., Mahon, R., McConney, P., Pollnac, R., & Pomeroy, R. (2001). Managing Small-scale Fisheries: Alternative Directions and Methods. *International Development Research Centre* (IDRC), Canada. 320.
2. FAO. (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome (ITA). Licence: CC BY-NC-SA 3.0 IGO.
3. Pauly, D. (2006). Major trends in small-scale marine fisheries, with emphasis on developing. countries, and some implications for the social sciences, *Marit. Stud. (MAST)*, 4(2): 7-22.
4. Robin, R. K., Kadarwan, S., Isdradjad, S., & Arya, H. D. (2018). A Regional Fisheries Ecological Footprint of Jakarta Bay (An analysis of carrying capacity based on primary production requirement). Publication on IOP Proceeding Conference Series of Integrated Coastal Management and Marine Biotechnology (ICM-MBT).
5. Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V., & Woolmer, G. (2002). The human footprint and the last of the wild: the human footprint is a global map of human influence on the land surface, which suggests that human beings are stewards of nature, whether we like it or not. *BioScience*, *52*(10), 891-904.
6. Hannah, L., Lohse, D., Hutchinson, C., Carr, J. L., & Lankerani, A. (1994). A preliminary inventory of human disturbance of world ecosystems. *Ambio*, 246-250.
7. Turner, I., & Jolly, P. (1990). The Effect of Dielectric Properties on Microwave Drying Kinectics. *Journal of microwave power and electromagnetic energy*, *25*(4), 211-223.
8. Andreae, M. O., Talaue-McManus, L., & Matson, P. A. (2004). Land, Coastal, and Atmospheric Systems as Threats to the Functioning of the Earth System. *Earth system analysis for sustainability*, 245-264.
9. Erb, K. H., Krausmann, F., Gaube, V., Gingrich, S., Bondeau, A., Fischer-Kowalski, M., & Haberl, H. (2009). Analyzing the global human appropriation of net primary production—processes, trajectories, implications. An introduction. *Journal Ecology Economic.* 69: 250-259.
10. Dunlap, R. E., & Jr, W. R. C. (2002). Which function (s) of the environment do we study? A comparison of environmental and natural resource sociology. *Society & Natural Resources*, *15*(3), 239-249.
11. Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-Being-Our Human Planet. Summary for Decision Makers. Island Press, Washington, D.C.
12. Tuxen, R. (1956). Die huetige potentielle naturliche Vegetation als Gegestand der Vegetationskarierung. *Angewandte Pflanzensozioligie*, *13*, 5-42.
13. Haberl, H., Erb, K. H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., ... & Fischer-Kowalski, M. (2007). Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences*, *104*(31), 12942-12947.
14. Djau, M. S. (2013). Analisis keberlanjutan sistem perikanan di kawasan konservasi laut daerah (KKLD) olele dan perairan sekitarnya kabupaten bone bolango provinsi gorontalo. Thesis Sekolah Pascasarjana. Institut Pertanian Bogor.
15. Krausmann, F., Haberl, H., Erb, K. H., Wiesinger, M., Gaube, V., & Gingrich, S. (2009). What determines geographical patterns of the global human appropriation of net primary production?. *Journal of Land Use Science*, *4*(1-2), 15-33.
16. Daily, G. C., Alexander, S., Ehrlich, P. R., Goulder, L., Lubchenco, J., Matson, P. A., & Mooney, H. A. (1997). Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology 2: 1-16. *ANDREW P. DOBSON*, *154*.
17. Pauly, D., & Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature.* 374 (6519): 225-257.
18. Knight, J., Lina, S. O. N. G., & Gunatilaka, R. (2009). Subjective well-being and its determinants in rural China. *China economic review*, *20*(4), 635-649.
19. Herbel-Eisenmann, B., Lubienski, S. T., & Id-Deen, L. (2004). One Teacher, Two Curricula: How And Why Does Her Pedagogy Vary?. *North American Chapter of the International Group for the Psychology of Mathematics Education October 2004 Toronto, Ontario, Canada*, 903.
20. De Leo, F., Miglietta, P., & Pavlinović, S. (2014). Marine ecological footprint of Italian Mediterranean fisheries. *Sustainability*, *6*(11), 7482-7495.
21. Siregar, V., & Koropitan, A. F. (2013). Primary productivity of Jakarta Bay in a changing environment: anthropogenic and climate change impacts. *Biotropia*, *20*(2), 89-103.