ISSN: 2086-907X

WORKING PAPER PKSPL-IPB

PUSAT KAJIAN SUMBERDAYA PESISIR DAN LAUTAN
INSTITUT PERTANIAN BOGOR
Center for Coastal and Marine Resources Studies
Bogor Agricultural University

FISHERY RESOURCES APPROPRIATION AS SUSTAINABILITY INDICATOR: AN ECOLOGICAL FOOTPRINT APPROACH

by:

Luky Adrianto

BOGOR
2010

ISSN: 2086-907X

CONTENTS

TABLES

FIGURES

FISHERY RESOURCES APPROPRIATION AS SUSTAINABILITY INDICATOR: AN ECOLOGICAL FOOTPRINT APPROACH

Luky Adrianto[1]

1. INTRODUCTION

It has been widely known that the most fundamental aspect which is underlying most fisheries theory and practice is that of determining the sustainable yield, i.e. a harvest that can be taken today without being detrimental the resources available in future years (Charles, 2001). In recent period, the focus of fishery management has been taken on determining a sustainable yield in the form of total allowable catch (TAC). In this regards, maximum sustainable yield (MSY), i.e. the most fish that can be caught each year, year after year, or a lower catch level has been the important icon in the fishery science and type worldwide. From this, fishery science has evolved as essentially a science of sustainability, with considerable emphasis on the determination of sustainable yields (Schafer, 1954; Beverton and Holt, 1957; Ricker, 1975; and Gulland, 1977).

However, Charles (2000) argued that the more important thing than focus on physical *output* from the fishery is that to focus on the process underlying the fishery. As he has stated :

It has become apparent, particularly in recent times, that a focus on sustainable yield has a major shortcoming in its intrinsic emphasis on physical output from fishery. While balancing of the present and future catches is important, there is also important to pay intention to sustaining the *processes* underlying the fishery.

According to Charles (2000), therefore, the need to pursue *sustainable fisheries* has been introduced which implies attention to the health of aquatic ecosystem, and to the integrity of ecological interactions and human system. At this point, sustainable fisheries refers to the WCED's concept of sustainable development which is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). Using this broad definition of sustainable development, Charles (2000) also argued that there is a wide recognition of the need to view sustainability

[1] Deputy Director, Center for Coastal and Marine Resources Studies/ Graduate School of Coastal and marine resources management, Bogor Agricultural University (IPB)

in integrated manner that includes ecological, economic, social and institutional aspects of the full system – in this case, fishery system.

One of important concept in discussing the sustainability indicator of fishery system is the concept of carrying capacity (Folke, et.al., 1998; Charles, 2001; Nijkamp and Vreeker, 2000). This concept provides possibilities for quantitative sustainability indicators within both the natural and human system. This theme of society-nature interface and interactions actually has been debated within social sciences including in ecological economics (Singh, et.al, 2001; Folke and Jansson, 1992; Costanza, et.al, 1993; and Gunderson and Holling, 2002). The idea of carrying capacity is previously most established and most prominently applied in ecological studies. However, this concept then is applicable for human systems exploiting the resources. In the context of fisheries system, however, the concept of carrying capacity could be seen as the natural environment determines the carrying capacity of the resources, as well as the socio-economic environment (population, consumption patterns, human impacts, etc) affect the carrying capacity of human system (Wackernagel, M. et.al. 1999; Charles, 2001). One of sustainability indicator which represents the above concept is ecological footprint (Charles, 2001).

Per definition, Wackernagel and Rees (1996) defines ecological footprint as the area of ecologically productive spatial areas in various classes (including ocean area) that would be required on continuous basis (1) to provide all the energy and material resources consumed and to absorb all the waste discharged by that population with prevailing technology. In this study, we used this definition according to fisheries system as the area of ecologically productive to provide ocean resources (fish) as consumption supply for population in the area in question. In other words, this ecological footprint analysis can give us the total area required to support that population in consuming fish at its current standard of living. If the total area occupied by the population is smaller than this total area in ecological footprint, the difference in an indicator of the extent that the actual area is insufficient (not sustainable) to support the population (Barker, 2002; Roth, et.al, 2000; Wacknernagel and Rees, 1996; Charles, 2001; Chambers, et.al., 2001; Wackernagel and Yount, 2000).

To date, there are still few numbers of studies focusing on analysis of ecological footprint related to fishery resources. This is because there is little attention on fishery resources as a potential food supply for human being. As Pimentel (1996) stated that it is hardly necessary to include the sea into ecological footprints as the sea provides less than five percent of the total food protein consumed by the world's human population and less than 1 percent of the overall caloric intake. However, in the same time, it has been also globally recognized that fishery resources is the main protein supplier for human being (FAO, 1995). As global population increasing, human pressure on fish resources is also predicted to be increasing. In this regards, it could be argued that ecological footprint analysis for fishery activities has potential growth in its necessity (Charles, 2001). Some previous works which concerned to the application of ecological footprint concept to the aquatic system could be found in for example Folke, et.al. (2000), Warren-Rhodes and Koenig (2001), Jansonn, et.al. (1999), Roth, et.al. (2000), Wada (2002), etc. This chapter aims to assess the sustainability of fishery system in Yoron Island through estimation of marine and coastal area appropriated by fisheries for food consumption using the indicator of ecological footprint. We follow the previous framework on defining the ecological footprint for aquatic system as proposed by Deutsch, et.al (2000) that uses the ecological footprint approach to try to make visible nature's work, i.e. the ecosystems required for the generation of essential ecosystem services that humanity depends upon.

2. THEORETICAL REVIEW

The concept of ecological footprints was introduced to the general public by Wackernagel and Rees (1996) that has premise of that each of human being has real areas of the earth's surface dedicated to our consumption of food and wood products; to the use of land surface for buildings, road, garbage dumps, etc (degraded land footprint); and to forest necessary to absorb the excess of CO2 produced by burning of fossil fuels (energy footprint). The sum of these footprints can be calculated and constitutes as the total ecological footprint (Palmer, 1999).

According to Rees (1996) cited in Wackernagel and Yount (1998), ecological footprint analysis is an area-based indicator which quantifies the intensity of human resources use and waste discharge activity in a special area in relation to the area's capacity to provide for that activity. In the other words, Rees (2000) defines the ecological footprint as "the total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth that land and water may be located". Ecological footprint analysis is based on two assumptions. First, that is possible to keep track of most of the resources that a human population consumes and most of the wastes that the population generates. Second, that these resources and waste flows can be converted to a biotically productive area necessary to provide the resources and to assimilate the wastes (Wackernagel and Yount, 1998). The biotically productive area which performs these functions is termed the "ecological footprint of the human population. A spatial locations (nations, regions, states, watersheds, etc) in which the ecological footprint of the resident human populations is greater than the area which they occupy must be doing at least one of the following : receiving resources from elsewhere, disposing of some of its waste outside of the area, or depleting the area's natural stocks (Wackernagel and Yount, 1998). Furthermore, Wackernagel and Yount (1998) also mention that to deplete natural stocks means to withdraw more ecological services than biotic capacity of the defined area can regenerate; for example by harvesting timber faster than it can re-grow or by discharging sewage at a rate faster than can be assimilated.

The conceptual basis of ecological footprint starts from the premise that people depend on the biosphere for a steady supply of the basic requirements for life; energy for warmth and mobility; wood for housing; furniture and paper products, fibers for clothing; quality of food and water for healthy living; ecological sinks for waste absorption; and many non-consumptive life-support services (Wackernagel and Yount, 1998; Ferguson, 1999; Chamber, et.al., 2000). This human use of nature is termed as ecological footprint. In this concept, ecological footprint is obviously not a continuous piece of land. With the role of international trade, it could be said that the land and water used by most global citizens are scattered all of the earth. Wackernagel and Yount (1998) then suggested that in order to simplify comparisons among various regions of the earth, the occupied space is calculated by adding up the areas (using world average productivity) that are necessary to provide a human population wit al the ecological services it consumes. In practice, ecological footprint quantifies for any given population the mutually exclusive biotically productive area that must be in continuous use to provide its resource supplies and to assimilate its wastes. Area that is in continuous use support one human population cannot simultaneously support another population without depleting natural capital stocks.

As a matter of historical perspectives, ecological footprint is not new concept in assessing nature's capacity to support human life. Cohen (1995) in Wackernagel and Yount (1998) mentioned that apart from the early attempts, much intellectual ground-work of this concept was laid in the 1960s and 1970s. For instances, Howard Odum's emergy analysis that examining systems through embodied energy flows (Odum, 1994), Jay Forrester's advancements on modeling world resource dynamics (Meadows, et.al., 1972), John Holdren's and Paul Ehrlich's I=PAT formula (Holdren and Ehrilch, 1974) or in the context of the International Biological Program, Robert Whittaker's calculation of net primary productivity of the world's ecosystem (Whittaker, 1995). In the last ten years, it has been witnessed a number exciting new developments such as life cycle assessments (e.g. Abe, et.al, 1990), lifestyle energy assessment (e.g. Hofstetter, 1991), environmental space calculations of Johann Opshoor (Buitenkamp, et.al, 1992), human appropriation of net primary productivity (Vitousek, et.al, 1986), regional and industrial metabolism (Ayres, et.al, 1994), social metabolism (Fischer-Kowalski, 1994), resources accounting input-output model (Duchin and Lange, 1994), and ecological footprint (Wackernagel and Rees, 1996; Folke, 1996) amongst other. Their application and representations may vary, but their output mostly the same i.e. quantification of the human use of nature. As most of these approaches are compatible, results from one may strengthens the others (Wackernagel and Rees, 1996).

As a concept, ecological footprint has advantages as well as limitations. It also created some controversies among scholars (Costanza, 2000). The controversy generally comes when one moves from simply stating the results of an ecological footprint calculation to interpreting it as an indicator of something else. The ecological footprint has been proposed actually as an indicator of biophysical limits and sustainability. It can be interpreted as that if ecological footprint of an area is bigger that the area under control then overshoot has occurred and then it could be said that it has exceeded area's sustainable resources uses (Constanza, 2000). Some commentaries on the use of ecological footprint include some argue in favor of its broad use for policy questions about sustainability (Rees, 2000; Templet, 2000; Wackernagel and Silverstein, 2000), while others, acknowledging the ecological footprint's pedagogic value, see a much more limited use for policy making (Ayres, 2000; Opschoor, 2000; van Kooten and Bulte, 2000) or see it as being useful in a different way for policy making (Deutsch, et.al, 2000; Moffat, 2000; Rapport, 2000).

Moffat (2000) for example describe that the major advantage of the ecological footprint concept over some other indicators such as environmental space is that the former concept gives a clear, unambiguous message often in an easily digested form. The clarity of the message is an important function of any indicator for both policy makers and the general public (Moffat, 2000). Furthermore, Moffat (2000) also mentioned that the calculation upon which the ecological footprint is based is relatively easy to undertake and much of the data is available at different spatial scales. The third advantage of this concept is that it also includes trades in its calculation. By including trade, there would be some winners as well as losers (Moffat, 2000). Finally, the concept of ecological footprint also produces a stock value, for example *x* units of land per capita. This make obviously that the area or region supply a flow of goods, information, natural and manmade capital as well as pollution into and out of the region (Moffat, 2000).

As also mentioned by Moffat (2000), several limitations of the usage of ecological footprint concept are also identified. First, as a bald statement of magnitude of the problem facing humankind, it is clear that simple statement of the ecological footprint is not in itself anything more than an important attention grabbing device. Some authors, for example Van den Bergh and Verbruggen (1999), furthermore argued that ecological footprint needs to consider spatial flow of trade in the derivation of indicators of sustainable development. Secondly, the ecological footprint concept is a static measure. It is possible to examine dynamics of this measure by recourse to viewing the ecological footprint through historical time (Haberl, 2000). Such historical studies may unearth the processes leading to unsustainable practices at different spatial scales. More important, however, is the need to develop a dynamic approach for exploring different scenarios of development (Moffat, 2000), at least if we wish for development to be made sustainable. The third limitation is that as in many studies of sustainability, the role of technological change is ignored by ecological footprint concept (Moffat, 2000). Furthermore, Moffat (2000) also addressed that presumably, the ecological footprint could be substantially reduced by several practices. These would include using environmentally friendly technologies, using current technologies more efficiently or reducing the throughput of resources. In this regards, however, Constanza (2000) has pointed out that the importance debate is in the assumption of using current technologies in ecological footprint concept. As he stated that:

The technological optimists would argue that the current path of development is, in fact, sustainable because technology will be able to overcome any biophysical constraints it may encounter. This is true if and only if the underlying assumptions about technical progress are true. If they are not and we pursue policies based on their being true, then we will most likely end up in big, unsustainable, trouble (Constanza, 1999).

Consequently, Constanza (1999) then argued that since we are in a situation of true uncertainty about whether the assumption underlying the technological optimist position are true, we should at least provisionally assume that they are not true (since the costs of their being wrong are potentially so high). The more rational strategy from the point of view of society as a whole is to assume that biophysical limits cannot be overcome, unless and until it can be shown that they can be. This strategy makes the ecological footprint a useful provisional indicator of sustainability at the global scale; as a technologically skeptical indicator (Constanza, 2000).

The next limitation of this concept (the fourth) is that at present the ecological footprint does not consider the oceans and underground resources including water (Moffat, 2000). This limitation, however, has been overcome by several studies on the usage of ecological footprint as sustainability indicators such as Jansson, et.al (1999), Warren-Rhodes and Koenig (2001), Wada (2002). Their studies have included the calculation of ecological footprint for marine resources. Fifthly, the ecological footprint represents a stock measure (Moffat, 2000). It would be useful to integrate the stock measure with the flows into or out of an area. The use of material flows or integrated economic and environmental accounting linked to a dynamic model of sustainable development would help (Moffat, 2000). This argument is also supported by Daly (1977) which stated that reducing the throughput is an important aspect for achieving sustainable development. The sixth limitation is that even if the throughput was reduced and sustainable development was achieved, the thorny ethical problem of an equitable distribution for current and future generations needs to be examined (Moffat, 200). Presently, few measures incorporate the equity problem in their calculation such as the index of sustainable economic welfare (ISEW) proposed by Daly and Cobb (1989). Finally, Moffat (2000) also identified that the ecological footprint concept offers no policy suggestions apart from either including more land, reducing population, or reducing consumption per head which are required to be stated as the policy instruments.

From the brief description on the advantages and limitations of the concept of ecological footprint, it could be said that as a method for raising awareness of the impact of human on the hearth, ecological footprint has been strikingly clear (Moffat, 2000). However, beyond the message of ecological footprint, there is a need to explore the flows into and out of the area in questioned as well as the important problem of intergenerational equity. It has been also suggested that by combining ecological footprint method with more detailed other methods further detailed work of relevance to policy makers will become available. Another important suggestion is that to incorporate a dynamic simulation model so that the spatial and temporal problems of the unsustainable nature of practices can be measured (Moffat, 2000). This issue would be also addressed in this chapter, especially in the next section which describes the dynamic approach application for fisheries appropriation model in the Yoron Island.

3. METHODOLOGICAL APPROACH

As previously mentioned, the sustainability of fisheries system in this chapter is alternatively examined using ecological footprint (Wackernagel and Rees, 1996; Folke, et.al, 1987). However, we also use the framework of Deutsch, et.al (2000) as to use ecological footprint approach for makes nature's work visible. In this regards, we estimate the ecological footprint from a bottom-up perspective using available ecological data and understanding of local and regional ecosystem performance (Deutsch, et.al, 2000).

Meanwhile, ecological footprint indicator or sometimes also called as *ecospace* indicator is basically defined as refer to the question of how large an area of productive land or ocean (as source as well as sink) in order to sustain a given population indefinitely, as its current standard of living and with current technologies (Wackernegel and Rees, 1996; Chambers, et.al., 2001, amongst others).

In this study, two approaches namely static and dynamic approach are used to estimate the ecological footprint of aquatic system in Yoron Island. As previously described, ecological footprint concept is basically a static measure (Moffat, 2000). In approach, a methodology developed by Wada (1999) is used which incorporate a detailed analysis of primary productivity requirements (PPR) for the production of different fish species including the by-catch (Wada and Lathan, 1998). Catch data by fish species were supplied by Yoron Fisheries Cooperative Association (YFCA) for the year 2002.

Theoretically, aquatic system were divided into six system : (1) Open Oceanic System, (2) Upwelling System, (3) Tropical Shelves, (4) Non-Tropical Shelves, (5) Coastal and Coral System and (6) Freshwater System (Pauly and Christensen, 1995). However, for the case of Yoron Island fisheries, only three systems are appropriate i.e. (1) Open Oceanic System; (2) Tropical Shelves (including sub-tropical) and (3) Coral and Coastal System. Each system has its own features called primary productivity (PP) as presented in Table 1 (Pauly and Christensen, 1995). The logic behind this approach is that a particular fish can be caught in different ocean systems such as in open oceanic system, tropical shelves system or coastal and coral system. By knowing from which aquatic system a particular species can be caught, an estimation of PPR therefore could be done. References table on fish groups according to their aquatic system as well as their average tropical level (TL) developed by Pauly and Christensen, 1995) is used (Table 2).

Table 1. Primary Productivity of Aquatic Areas

No	Aquatic Area	Primary Productivity (gC/m^2/year)
1	Open Ocean System	103
2	Upwelling Systems	973
3	Tropical Shelves	310
4	Non-tropical Shelves	310
5	Coastal and Coral System	890
6	Freshwater Systems	290

Source: Pauly and Christensen (1995)

Table 2. Tropical Level of Fishes used in the Case of Yoron Fisheries

Aquatic System	Species Group	Tropic level
Oceanic System	Tunas, bonitos, billfishes	4.2
	Krill	2.2
Tropical Shelves	Small pelagics	2.8
	Misc. teleosteans	3.5
	Jacks, mackerel	3.3
	Tunas, bonitos, billfishes	4.0
	Squids, cuttlefish, octopuses	3.2
	Shrimps, prawns	2.7
	Lobster, crabs, other invertebrates	2.6
	Sharks, rays, and chimaeras	3.6
Coastal and Coral System	Bivalves and other molluscs	2.1
	Misc. marine fishes	2.8
	Herrings, sardines and anchovies	3.2
	Seaweeds	1.0
	Jacks and mackerels	3.3
	Diadromous fishes	2.8
	Shrimps and prawns	2.6
	Crustaceans and other invertebrates	2.4
	Turtles	2.4

Source: Pauly and Christensen (1995)

The formula to estimate the PPR for species *i* is after Pauly and Christensen (1995) as follows :

$$PPR_i = \left(\frac{C_i}{9}\right) \times 10^{(TLi-1)} \quad \text{(1)}$$

where PPR_i = primary productivity required for species *i*, C = catch of species *i*, and TL_i = tropic level of species *i*. The purpose of dividing C by 9 is to convert wet weight into carbon weight (Wada, 1999). (TL-1) represents the average number of tropic level transfers from primary production to catch. Average transfer efficiency of each transfer is 10 % (Pauly and Christensen, 1997; Wada, 1999). Ecological footprint of fishery system (by aquatic system) in Yoron Island then can be calculated by using the following formula (Wada, 1999) :

$$EFa = \frac{\sum PPR_{ia}}{PP_a} \quad \text{(2)}$$

where EFa = ecological footprint of aquatic system a, PPRia = primary productivity required of species a in aquatic system a, PPi = primary productivity of aquatic system a. Then total EF for fishery system could be calculated as the sum of EFa. In this study, we examine the static indicator of ecological footprint for fishery resources use in Yoron Island for the last six years from 1997 to 2002.

4. RESULTS AND DISCUSSIONS

Started with estimation of the biomass production of the main fishes in Yoron Island by the aquatic system. Production of fish in Yoron Island is dominated by *Sodeika* (diamond-back squid) as recorded to be 55.08 % of the total production in 2002 (435,499.9 kg). In the last six years, this domination of *sodeika* in total production of fish in Yoron Island has been increasing since 1997. In 1997, the domination of sodeika was recorded to be 29.02 %, then increased to be 55.07 % in 2002 (see Figure 1). According to aquatic system, fishes from the tropical shelves system are mainly caught as recorded to be 330,495.15 kg in 2002, followed by those which are from the oceanic system (45,119.25 kg) and coastal and coral system (20,039.94 kg).

As previously described in the methodology section, we estimate static ecological footprint of fisheries resources by using ecological data of primary productivity required by aquatic system proposed by Wada (2002). The results of calculation of this indicator for the period of 1997-2002 are

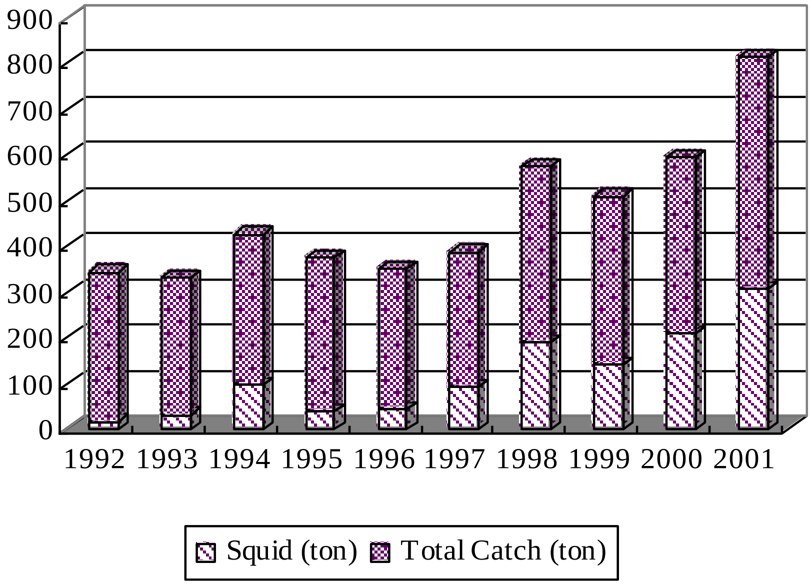

Figure 1. Trend of Domination of *Sodeika* to Total Catch

The summary of ecological footprint results is presented in Figure 2.

As shown in Figure 2, the ecological footprint of fishery sector in Yoron Island seems to be increasing. In 1997, the ecological footprint was estimated to be 0.015 km2 per capita or requires area of about 92.681 km2 and closed to 4.5 times of Yoron Island's domestic land area. After this, ecological footprint of fisheries system in Yoron Island was declining into 57.967 km2 and relatively stable during the following year (1999) which is estimated to be 52.314 km2. In 2000, the ecological footprint increased to be 79.892 and nearly doubling afterwards to 142.235 km2 in 2001. Finally, in 2002 the ecological footprint declined to the level of 92.921 km2. The doubling value of ecological footprint in 2001 reflects the rising level of local catch of fish in Yoron Island. From Figure 7, we also can reveal that Yoron Island obtains ecological deficits for its fishery appropriation. The average appropriated area of fishery is estimated to be 87.168 km2 or 4.254 times of its domestic land area (20.49 km2). However, if we use the productive ocean area of 2.267 km2, Yoron Island obtains ecological surplus due to its appropriated area only 0.0384 times of its productive ocean area.

Compared to other region, Yoron Island has smaller fisheries ecological footprint than for example Hongkong (0.2 km2/capita) or Guernsey Island, UK (1.41 km2/capita). Table 10 presents the comparison of ecological footprint related to fishery between Yoron Island and some regions in the world.

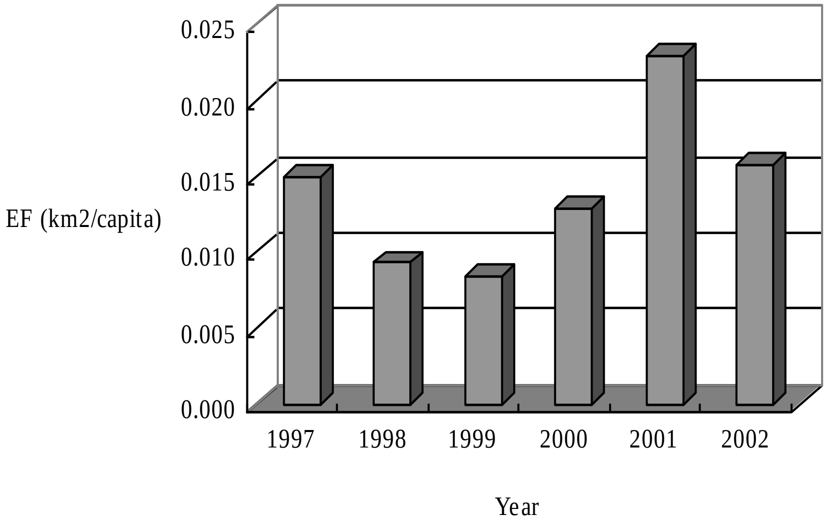

Figure 2. Static Results of Ecological Footprint of Fishery Resources

Table 3. Comparison of Ecological Footprint Related to Fishery Between Yoron Islands and Other Regions

Country/Region/Island	EF related to fishery	Appropriated area
Global resources[a)]	0.3	2.3 billion ha
Hongkong[b)]	0.2	14,220 km^2
Guernsey Island, UK[c)]	1.41	84,600 km^2
Japan[d)]	1.90	n.a.
Yoron Island, Japan	0.014	87.168 km^2

Note : n.a. = not available
Sources :

a) WWF (2002)
b) Warren-Rhodes and Koenig (2001)
c) Chambers, et.al (2000)
d) Wada (1999)

5. CONCLUSIONS

From the results of analysis, it can be cohelube that the appropriate area for sustaining fisheries in Yoron Island is calculated to be 0.014 km^2/ capita or equivalent to 87,168 km^2. It means that the activity of fisheries in this island required more than 3 times of Small Island area.

REFERENCES

Adrianto. L. and Y. Matsuda. 2002. Developing Economic Vulnerability Indices of Environmental Disasters in Small Island Regions. *Environmental Impact Assessment Review* (22) : 393-414

Barker, J.F. 2002. How Many People Can The Earth Support : Ecological Footprints. Available online at : http ://www.population-growth-migration.info/essays/howmany2.html.

Bongaarts, J. 1995. Global and Regional Population Projections to 2025. pp 7-16 in N. Islam (Ed). Population and Food in the Twenty-First Century : Meeting Future Food Demand of An Increasing Population. International Food Policy Research Institute, Washington, DC.

Charles, A.T. 2000. Sustainable Fisheries System. Blackwell Publisher. London, UK.

Charles, A.T. 1998. Living With Uncertainty in Fisheries : Analytical Methods, Management Priorities and the Canadian Groundfishery Experience. *Fisheries Research* (37) : 37-50.

Charles, A.T. 1994. Towards Sustainability : The Fishery Experience. *Ecological Economics* (11) 201-211.

Chambers, N, Craig Simmons, and Mathis Wackernagel. 2000. Sharing Nature's Interest : Ecological Footprint as an Indicator of Sustainability. Earthscan Publication. London, UK.

Chesson, J., H. Clayton and B. Whitworth. 1999. Evaluation of Fisheries Management System Respect to Sustainable Development. *ICES Journal of Marine Sciences* (56) : 980-984.

Environmental Assessment Institute. 2002. Assessing the Ecological Footprint. A Look at The WWF's Living Planet Report 2002. Environmental Assessment Institute. Denmark.

FAO. 2000. World Fisheries and Aquaculture. FAO, Rome.

FAO. 1995. Code of Conduct for Responsible Fisheries. FAO. Rome.

Ferguson, A.R.B. 1999. The Logical Foundations of Ecological Footprint. Environment, Development, and Sustainability 1 : 149-156.

Ferguson, A.R.B. 2002. The Assumptions Underlying Eco-Footprinting. Population and Environment 23 (3); 303-313.

Garcia, S.M., K. Cochrane, G. Van Santen, and Francis Christy. 1999. Towards Sustainable Fisheries : A Strategy for FAO and the World Bank. *Ocean and Coastal Management* 42 : 369-398

Garcia, S.M, D.J. Staples, and J. Chesson. 2000. The FAO Guidelines for the Development and Use of Indicators for Sustainable Development of Marine

Capture Fisheries and An Australian Example of Their Application. *Ocean and Coastal Management* (43) : 537-556.

Haberl, H., Karl-Heinz Erb, and Fridolin Krausmann. 2001. How to Calculate and Interpret Ecological Footprints For Long Periods of Time : The Case of Austria 1926-1995. Ecological Economics 38 : 25-45.

Jansonn, A.A., Carl Folke, Johan Rockstrom, and Line Gordon. 1999. Linking Freshwater Flows and Ecosystem Services Appropriated by People : The Case of The Baltic Sea Drainage Basin. Ecosystem 2 : 351-366.

Mc. Goodwin, J. 1990. Crisis in the World's Fisheries : People, Problems, and Policies. Standford University Press. Standford, USA. 235 pp.

Moffat, I, Nick Hanley and Mike D. Wilson. 2001. Measuring and Modeling Sustainable Development. Parthenon Publishing. Bristol, UK.

Palmer, A.R. Ecological Footprints : Evaluating Sustainability. Environmental Geosciences 6 (4); 200-204.

Roth, E., Harald Rosenthal, and Peter Burbridge. 2000. A Discussion of the Use of the Sustainability Index : Ecological Footprint for Aquaculture Production. Aquatic Living Resources 13 : 461-469.

Takuechi, K and M. Nagahashi. 1993. The Application of System Dynamics to Analyses for Local Timber Production. Journal of Janapese Forest Society : 60-64.

Tai, S.Y., Kusairi Moh. Noh, Ishak Hj. Omar, Nik Mustapha Raja Abdullah, and Yoshiaki Matsuda. 2001. Valuing Fisheries Resources Changes in the Straits of Malacca : Resources Accounting Approach. Working Paper. University of Putra Malaysia. Kuala Lumpur.

Wackernagel, M and J. David Yount. 1998. The Ecological Footprint : An Indicator of Progress Toward Regional Sustainability. Environmental Monitoring and Assessment 51 : 511-529.

Wackernagel, M and David Yount. 2000. Footprints for Sustainability : The Next Steps. Environmental, Development, and Sustainability 2 : 21-42.

Wackernagel, M. et.al. 1999. National Natural Capital Accounting with the Ecological Footprint Concept. Ecological Economics 29 : 375-390.

Warren-Rhodes, K, and Albert Koenig. 2001. Ecosystem Appropriation by Hong Kong and Its Implications for Sustainable Development. Ecological Economics 39 : 347-359.

Van den Bergh, J., and Marjan W. Hofkes. 1998. Theory and Implementation of Economic Models for Sustainable Development. Kluwer Academic Publishers. The Netherlands.

Yoron City Office. 2001. The Development Plan for Yoron Island 2001-2010. Yoron City Office. Yoron Development. Oxford University Press. Oxford. 400 pp.