Governance and bioeconomy in Adriatic clam fishery (Chamelea gallina)

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Abstract

The research, given the growing attention to sustainable use of natural resources, helps to analyze the management instruments implemented by institutions in clam (*Chamelea gallina*) fishery. This species is commercially exploited with hydraulic dredges along the western coast of Adriatic sea since the 70's and that has led to a depletion of the resource, with serious consequences on the socio-economic framework of Italian fishing.

Starting from the bioeconomic theoretical model, proposed by Gordon and Schaefer in 1954, we analyze through environmental and economic sustainability indicators the impact of political choices in the '90s in Marche Region.

Key words: bioeconomy, governance, Adriatic sea.

Résumé

*Vu l'attention croissante à l'égard de l'utilisation durable des ressources naturelles, la recherche nous aide à analyser les outils de gestion employés dans la pêche des palourdes (*Chamelea gallina*). Cette espèce est exploitée le long de la côte adriatique occidentale depuis les années 70, ce qui a réduit cette ressource avec des conséquences très graves sur la structure socio-économique de la pêche italienne.*

En partant du modèle théorique bioéconomique proposé par Gordon et Schaefer en 1954, on a analysé, par le biais d'indicateurs de durabilité économique et environnementale, l'impact des choix politiques des années 90 dans la région des Marche.

***Mots clés**: bioéconomie, gouvernance, mer Adriatique.*

1. Introduction

Clam fishery is a relevant economic activity for Marche Region. The Northern and Central Adriatic Sea are characterized by an environment that favours the development of many bivalve communities.

The gear most used in Marche region for clam fisheries are hydraulic dredges.

In the past the resource has shown strong signs of depletion and overexploitation calling for immediate management actions (Froglia, 2000). Management tools that have governed since 1992 bivalve molluscs fishing are necessary to ensure a sustainable exploitation over time. Fleet activities are regulated at Fishing District level by Consortium of clam that can add additional rules such as diminishing the daily individual quota or imposition of a rotation of fishing area inside the District.

It is worth mentioning that the depletion of resources, highlighted by the drop in annual landing during the 70s and 80s, has suggested a reduction of overall fishing effort and, between 1996 and 1998, two laws have imposed the withdrawal of licenses in exchange for financial compensation (Hauton et al., 2002).

Indeed, increasingly there have been exceptional reduction in the mass of *Chamelea gallina* (Froglia, 2000) in relation to chemical and physical changes of water and biological phenomena.

Given that sustainability is a three-dimensional concept that evaluates the economic, environmental and social aspects as a whole, it is necessary to identify all factors that contribute to the sustainability of the fishery and therefore models capable of interpreting through biological, economic and social indicators future dynamics of fish stocks and to prevent depletion or establish the social optimum derived from the maximum sustainable production (Antonelli et al., 2005).

The paper proposes, in paragraph 2, a summary of the classic Gordon-Schaefer bioeconomic model and later (§ 3), examines the impact of management policies applied to clam in Marche region in terms of catches and fishing effort by a theoretical and descriptive point of view.

In paragraph 4, we summarize the main bioeconomic models in the international scientific literature that have had practical applications and have been adapted to different fisheries and fishing areas.

2. Gordon and Schaefer bioeconomic model

The theoretical model is the Gordon-Schaefer model developed in the 50's by the economist H. S. Gordon (1953, 1954) and the biologist M. Schaefer (1954), which combines biological and economic aspects establishing a relationship between the reproduction rate of a resource and its exploitation.

The population dynamics is formalised according to the Verhulst[1] logistic equation that expresses the rate of growth

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[1] The logistic function is expressed as $F(X) = rx\left(1 - \frac{x}{K}\right)$: where r is called the *intrinsic growth rate*, x is the stock size and K is yhe environmental *carrying capacity* or saturation level.

(r) in relation to its size and assumes a bell shape, growing until a maximum and then decreasing. To a limited stock of the population will correspond an increase in the rate of natural growth *F(x)*. Subsequently, for a further increase of the population, the mortality rate will increase compared to the birth rate, decreasing *F(x)*.

If the resource is subject to catch by man, the mortality rate becomes a function of fishing effort, measured in different ways (fishing days, number of boats, power, Gross Register Tonnage) and of stock size.

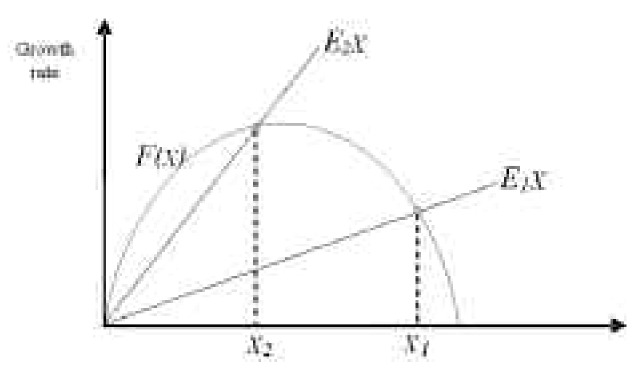
Assuming the hypothesis that the catch per unit effort is proportional to the level of the stock, which is analytically:

$$h = qEx \qquad (1)$$

where h is the catch, q is catchability coefficient equal to 1, E is the effort and x is the population.

Overlapping catch function to the logistic growth function, for constant levels of effort, you get the equilibrium point in which catches coincide with the reproduced biomass (see Fig. 1).

Figure 1 – *Logistic model with constant rate of effort.*



Source: Clark, 1976.

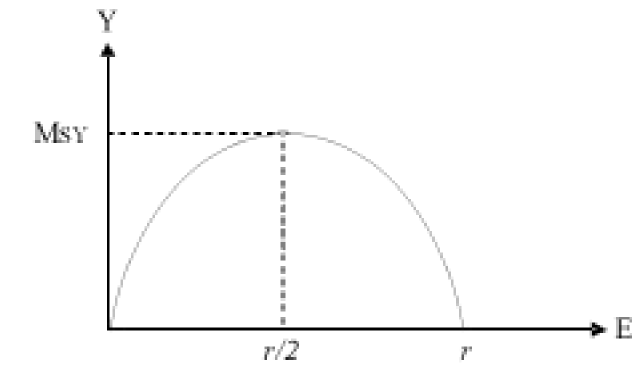
For each level of effort E there is therefore an equilibrium point with the population growth rate .

From the relationship between the effort, the population size and catches, the Sustainable Product for the different effort levels E in the point of equilibrium is given by[2]:

$$Y = Ex_1 = EK\left(1 - \frac{E}{r}\right) \qquad (2)$$

The graph of the equation is the yield-effort curve (see Fig. 2) showing that increasing the level of effort, yield rises smoothly until reaching the maximum level of capture that correspond to the point of Maximum Sustainable Yield (MSY); then, for increasing level of effort, the size of the population decreases and consequently the yield.

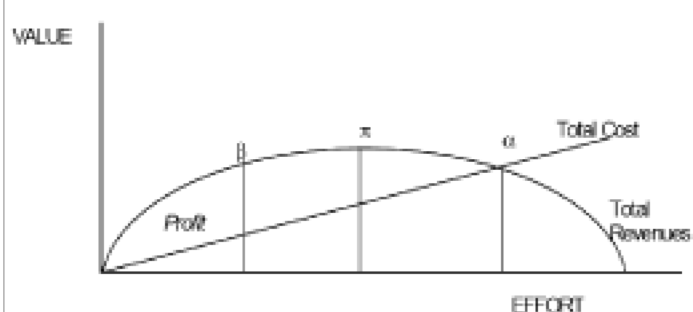
Figure 2 – *Schaefer model: yield-effort curve.*



Source: Clark, 1976.

The relation between the costs and revenues resulting from the exploitation of the fishing resources is obtained transforming the biomass equation in a curve that expresses its economic value.

Figure 3 – *Gordon-Schaefer model.*



Source: Franquesa, 1996.

The Total Revenue curve (TR) is given by the product of catches Y (see Fig. 2) and their unit price, which for simplicity is assumed to be constant.

The Total Cost curve (TC) is expressed as a function of fishing effort assuming that the costs of fishing are proportional to the effort expended. The cost will be given by the product between the price of a unit of effort (man, boat, fishing days, etc.) multiplied by the quantity of effort. The curve of Total Cost will therefore have a constant positive slope. This curve may be more complex because the cost per unit of effort may diminish if there are economies of scale. However, for simplicity, we will consider the simplest hypothesis (Franquesa, 1996).

From an economic point of view three points are relevant: MSY, β and α. MSY is the vertex of the income function and represents the level of effort that simultaneously generates the greater volume of catches and greater income.

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[2] Equation 2 is obtained setting $\frac{dx}{dt} = F(x) - Ex = rx\left(1 - \frac{x}{K}\right) - Ex$ equal to zero. So $x_1 = K\left(1 - \frac{E}{r}\right)$.

The point β maximizes the distance between TR and TC (maximum profit) because the slope of the Cost curve is equal to the slope of Income curve. Profits will attract, in the case of open access, other competitors that will increase the level of effort until the equilibrium point *α,* where cost is equal to revenue. Beyond this point there is no convenience to enter in the sector (Franquesa, 1996).

Given that the current problem is the overfishing of the fishing resource, it is necessary to introduce management tools capable of ensuring the economic and environmental sustainability and to regulate resource exploitation through property rights (Finco and Padella, 2009).

3. Chamelea gallina governance trough management tools

Governance is expressed through a set of measures taken at national and local levels. Since 1992[3] many decrees have regulated fishing for bivalve molluscs and in 1995[4] local Consortia of Clam have been created for the management of that fishery.

The management measures have been strengthened through the development of the I° and the II° «Vongole Plans»[5] with the objective of reducing fishing effort and allowing the recovery of the species. Regulations allow, some in the short other in the medium term, to move from a phase of repeated emergencies to a phase of economic and environmental sustainability.

The management measures have been grouped by different typologies and shown in Table 1.

Table 1 – *Management measures for clam fishery in Marche region.*

Management measures	*Marche's Consortium*
1) Decommission boats	17 dredges
2) Limitation of effort	
number of licences	221
GRT max of 10 tonns	✗
maximum power 150 HP	✓
Close period fishing (2 mounth/year; 1 weekday; holidays)	✓
3) Limitation of production	
max 600 kg/day	✓
4) Limitation fishing tecniques	
clam minimal marketable size > 25 mm	✓
minimum depth of 3 meters	✓
restriction on the use of some equipement	✓

We analyze now in detail the effect of the measures in the Districts[6] managed by Consortia in Marche region. The decommission boats represents a cost for the government but, if adjusted properly, can reduce the effort even if less than proportionally (Franquesa, 1996).

This restriction together with those grouped under the heading «limitation of effort» will determine a change in the shape of the Total Cost curve that will become a perpendicular line to the point of maximum effort allowed.

The introduction of these measures reduces the exploitation and increases the profit margin of those who continue the fishing activity. This generates a situation of extra profit that will determine constant pressure on administration responsible for the restriction.

The application of these restrictions in Marche region has led in 1996 to decommission of 17 boats in the District of San Benedetto del Tronto[7] and the reduction of the number of licenses that became 221[8].

Simultaneously there was a decrease in average Gross Register Tonnage (GRT) over the period 1996-1999; then it was stabilized at a value of 11.2 despite being required by law, with the right of derogation, the maximum limit of 10 GRT per boats (see Table 2).

Table 2 – *Structural data of Marche's hydraulic dredges (1996-2006).*

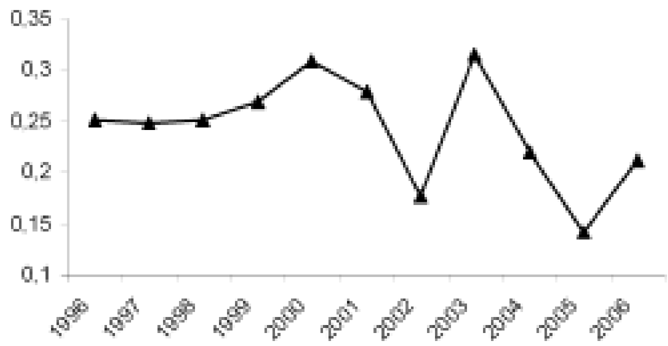
Year	*Dredges (a)*	*Average GRT (b)*	*Average KW (c)*	*Average days (d)*	*Effort (a*b*d/1,000,000)*
1996	245	11,2	106	92	0,25
1997	221	10,9	106	103	0,25
1998	213	10,9	105	108	0,25
1999	215	10,8	105	115	0,27
2000	221	11,1	106	125	0,31
2001	222	11,1	106	113	0,28
2002	221	11,1	106	72	0,18
2003	220	11,1	106	128	0,31
2004	221	11,2	107	89	0,22
2005	221	11,2	107	57	0,14
2006	221	11,2	107	86	0,21

Source: Irepa

Management policies with the aim of reducing effort, calculated on the basis of GRT and average fishing days, should act in parallel on these two parameters. By contrast, in the period under review, there was an inverse relationship between GRT and fishing days (see Table 2): the decrease of GRT has been offset by an increase in fishing days that actually have maintained the effort constant until 2000. From 2001, by maintaining average GRT constant, there was a swinging trend in fishing effort (see Graph 1) due to,

[3] D.M. 29 May 1992 and subsequent amendments for the regulation of bivalve mollusc fishing.
[4] D.M. 12 January 1995 n. 44 (constitution of management consortium) and D.M. 5 august 2002.
[5] I° «Vongole Plan»: National Law n. 107, 28 February 1996. II° «Vongole Plan»: National Law n. 164, 21 May 1998 and D.M. 21 July 1998.
[6] The Management Consortia of clam in Marche region in 2008 are 4: Co.Ge.Vo – Ancona, Co.Vo.Pi - San Benedetto del Tronto, Co.Ge.Mo - Pesaro and Co.Ge.Vo - Civitanova Marche (2002).
[7] D.M. 2 August 1996 «Measures for bivalve community fishery».
[8] D.M. 10 April 1997 (number of dredges for district: Pesaro 65; Ancona 73; S. Benedetto 83). It was abolished by D.M. 21 July 1998.

Graph 1 – *Effort in Marche region.*



Source: our processing on ISTAT and IREPA data.

in 2002, the high mortality of clams and a sensitive reduction of fishing days required by close fishing periods (see Table 3).

After a successful recovery in 2003, the setting up of Civitanova Marche's Consortium with the redistribution of 25 boats of San Benedetto del Tronto has led to an excessive effort in a limited area with consequent depletion of the resource and prolonged stop of activities in 2004 (IREPA, 2004). In 2005, the crisis was due to an abnormal mortality of clams (IREPA, 2005a). Finally, in 2006 the effort was incremented thanks to a superior availability of the product especially in the Districts of San Benedetto del Tronto and Ancona, as a result of the benefits of detentions of previous years (IREPA, 2006).

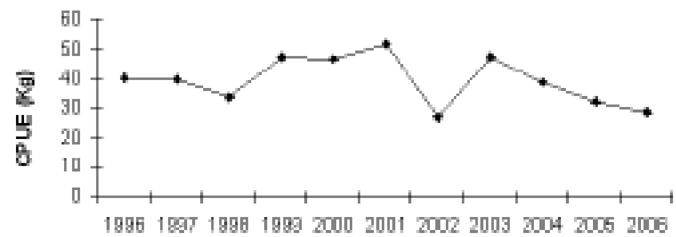
Table 3 – *Fishing stops in Marche region (1999-2004).*

Year	Co.Ge.Mo *Pesaro*	Co.Ge.Vo *Ancona*	Co.Vo.Pi *San Benedetto*
1999	2 months	2 months	2 months
2000	2 months	2 months	2 months
2001	2 months	2 months	2 months
2002	5 months	4 months	5 months
2003	3 months	2 months	n.d.
2004	3 months	3 months	n.d.

Another management technique is the reduction of production (see Table 1 - point 3). The daily fishing quota (600 kg) allows to change the curve of production in a straight line at the point corresponding to the maximum amount of fish catches. Consequently, the equilibrium point (see Fig. 3) given by the intersection of TC curve and TR curve moves at a lower level of effort.

In Marche region this measure has as a result a reduction in catches in absolute terms and in relation to effort unit (see Graph 2).

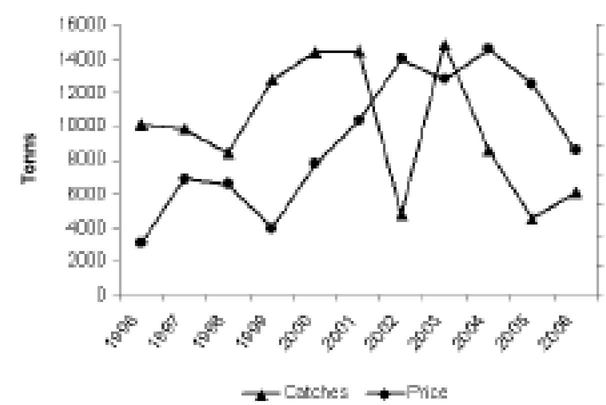
Graph 2 – *Catch per unit effort (CPUE).*



Source: our processing on IREPA data.

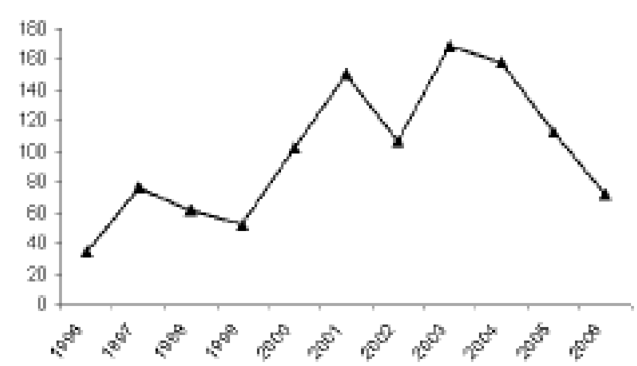
lthough unable to avoid productivity changes, given by the catch per unit effort (CPUE) which passes from 40 kg in 1996 to 28 kg in 2006, the consortia were able to preserve the resource especially in periods of productive stress. Thanks to valorisation policies they have also obtained a greater return of the product despite *Tapes philippinarum* competition (see Graf. 3).

Graph 3 – *Catches and prices time series of Chamelea gallina in Marche region.*



Source: our processing on IREPA data.

Graph 4 – *Economic indicator on the status of clam fishery of Marche region.*



Source: our processing on IREPA data.

The economic sustainability indicator such as average production of effort unit in terms of market value (RPUE), confirms a positive trend recorded up to 2003 while in the last three years, prices could not offset the lower number of catches.

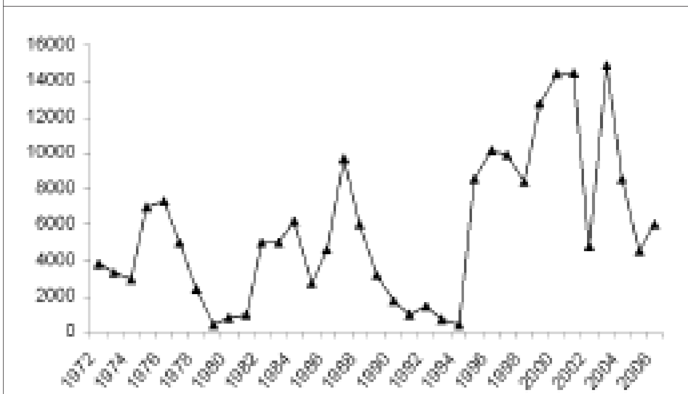
The evolution of the catch is also influenced by the management procedures which are qualitative restrictions, able to prevent overexploitation of the vongola stock. These measures modify the curve of Total Revenues, which becomes lower and the curve of Total Costs assumes a greater slope. That restriction makes effort most expensive and the point of equilibrium will shift to the left.

The local Authorities (Consortia), which are responsible for fishery governance have introduced a fishery closure in June. Then, to prevent landing of undersized clams and to reduce the possible extra mortality induced by dredging on newly juveniles, the Authorities imposed the compliance of clam minimal marketable size of 25 mm (introduced by Italian Law since 1969), the authorization to fish at a minimum depth of 3 meters and a ban on the use of some equipment (see D.M. 22 December 2000).

The effect of these restrictions, applied from 1996, has resulted in a minor fluctuation in annual production compared to previous decades when there was no management by the Consortia (see Graph 4).

Comparing data from CNR on the biomass and commercial catches of two Districts (Ancona and San Benedetto) for which data are available, the curve of the catch was lower in all points than those of biomass except in 2001.

Graph 5 – *Catches time series of Vongola Chamelea gallina on Adriatic Sea Fishing Districts-Marche Region (1972-2006).*

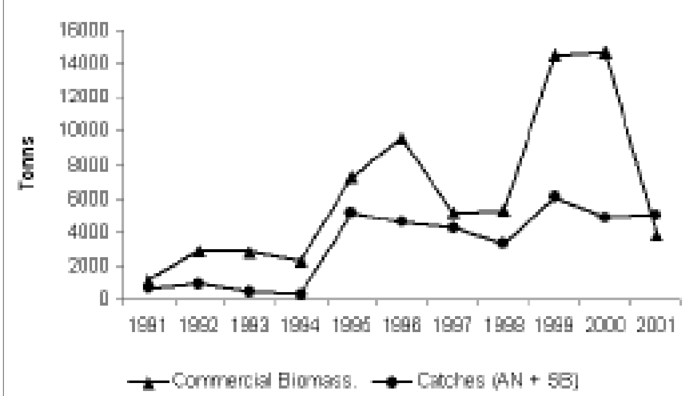


Source: our processing on ISTAT and IREPA data.

Since we have evidence only until 2001, we can suppose that since 1998 the effort in Marche fishing has been placed in the segment of the curve below the MSY (see Fig 2) which also corresponds to a situation of profit for those engaged in fishing activity (see Table 4).

[9] Sub-Group on Economic matters.
[10] Sub-Group on Stock assessment.

Graph 6 – *Commercial biomass and catches time series of Chamelea gallina in Ancona and San Benedetto del Tronto districts.*



Source: our processing on ISTAT and IREPA data.

The analysis conducted in the four Marche's Consortia also showed that fishermen would reduce the minimum size of fishing to 22 mm and would increase the maximum daily fishery. This would result in greater pressure on the population of clams, but would allow an increase in profit.

Table 4 – *Economic indicators of dredges in Marche region (mln euro).*

Year	Revenue	Total costs	Gross Profit
1996	8,65	5,97	2,68
1997	19,01	9,23	9,79
1998	15,40	9,54	5,86
1999	14,15	9,48	4,67
2000	31,47	14,51	16,96
2001	41,94	19,21	22,74
2002	18,86	11,64	7,22
2003	53,32	32,80	20,53
2004	34,76	18,97	15,78
2005	15,92	9,70	6,22
2006	14,53	9,26	5,27

Source: IREPA.

4. Bioeconomic model applications

In order to recreate the conditions in which fishing takes place and consider different scenarios depending on the strategies of governance, the international literature has developed several models that can reproduce the assumptions of the bioeconomic model to estimate effects in the medium and long term.

In table 5 we present a summary of some of the bioeconomic models presented in the final report of the project BEMMFISH (Bio-economic modelling of Mediterranean Fisheries) in 2005 (Maynou, 2005) and the document prepared jointly by SGECA[9] and SGRST[10] (SEC, 2005) which could be applied to clam fishery.

It should first be underlined that the models can be classified into simulation models, which simulate the effects caused by the application of management tools and optimization models, which attempt to determine the optimal solutions identifying the maximum of an objective function (Haraldsson and Arnason, 2005).

The main models applied to fisheries in the Mediterranean are: MOSES (Models for Sustainable Optimal Effort in the Seas) by IREPA that is a catch/effort model for multi-species and multi-gear fisheries built for the Italian context that can be used both for simulation and optimization analysis (Placenti et al., 1992; Placenti and Coppola, 2005) and MEFISTO (Mediterranean Fisheries Simulation Tool) developed by Lleonart and Franquesa (Lleonart et al, 1999) applied in Spain (Lleonart et al. (2003), Maynou et al., (2006)) but also in Italy (Maynou and Silvestri, 2009). It is a bioeconomic simulation model, multispecies, multifleet and multigear. It is developed specifically for Mediterranean Sea fisheries and it simulates the effects of different strategies management for a maximum period of 25 years.

There are also a number of models applied in specific areas and fisheries such as: BEAM 5 (Analytical Bio-Economic Model No. 5) by FAO, developed by Sparre and Willmann, which is a multi-species, multi-fleets dynamic software of a bioeconomic simulation model (FAO, 2001); the BIRDMOD, Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources (IREPA, 2005b; Accadia and Spagnolo, 2006), that is a simulation model that focuses on Italian fishing activities, used for the study of demersal resources; ECOSIMP2, simulation model applied to Barents Sea fisheries, which has two modules combined together, a biological model AGGMULT (Tjelmeland and Bogstad, 1998) and an economic one ECONMULT (Flaaten & Eide, 1998); Icelandic models (as IFMM); models for North Sea fisheries (Haraldsson and Arnason, 2005); models for the study of fishing areas close to Denmark (as TEMAS) and models for English Channel fisheries (as COBAS).

Table 5 – *Some bioeconomic models.*

MODEL	AUTHOR	CHARACTERISTICS	CASE STUDIES
MOSES Models for Optimal Sustainable Effort in the Seas	IREPA	Catch/effort model for multi-species and multi-gear fisheries	Demersal fish in Liguria; Small pelagics fishery in Adriatic Sea
MEFISTO Mediterranean Fisheries Simulation Tool	Lleonart, Maynou and Franquesa	Bioeconomic simulation model, multispecies, multifleet and multigear. It is developed specifically for Mediterranean Sea fisheries.	Hake in Catalonia (western Mediterranean), Red shrimp (Aristeus antennatus) fisheries in the Catalan sea, Small pelagic fishery in North Adriatic (Veneto)
BEAM 5 Bio-Economic Analytical Model No.5	FAO Sparre J. P and Willmann R.	Multi-species, multi-fleets dynamic software of a bioeconomic simulation model	Small pelagic fisheries in the west coast of Peninsular Malaysia
BIRDMOD Methodological Support for a Bio-Economic Model of Population Analysis of Demersal Resources	IREPA, 2005; Accadia and Spagnolo, 2006	Simulation model that is focused on Italian fishing activities	Demersal resources
ECONSIMP2	Tjelmeland e Bogstad, 1998; Eide e Flaaten, 1998	Simulation model which has two modules combined together, a biological model AGGMULT and an economic one ECONMULT	Barents Sea fisheries
IFMM The Icelandic Fisheries Management Model	Based on a previous project HFMM	Simulation model of biological and economic aspects	Icelandic fishery
TEMAS, TEchnical MAnagement measureS	Ulrich et al., 2002a	Simulation model that aims to assess the impact of technical measures for the management, particularly those concerning the ability of the fleet	fishery close to Denmark
COBAS, Cost Benefit Analysis for Sustainability,	Ulrich et al., 2002b	Model that evaluates a number of management options for stocks, with a time horizon of 15 years	Fishing in the western part of English Channel

5. Conclusion

The scientific literature shows that the clam fishery conducted in Adriatic Sea is first responsible for morphological changes involved in the seabed and sensitive changes in the benthic community and second it determines an impact through the introduction of by-catch in the sea.

Most importantly, the new evidence of literature (Morello et al., 2005) underlines that, despite intensive fishing has been going on for decades and a benthic community is typical of a moderately disturbed environment, the effects of fishing on community structure were still discernible above natural variation.

The serious effects of the depletion of fish resource in the seventies and eighties, highlight that the sustainable governance in the clam fishery sector is essential to protect the marine environment, reproduction and biodiversity of species but also from an economic and social point of view because the revenue represents a significant part in the regional economic context. The Consortia of management, through the property rights, have the aim to protect the biomass and to increase the economic revenue of catching production. On the other hand, monitoring of environmental, social and economic indicators and their interpretation through bioeconomic models are crucial to achieve the Maximum Sustainable Yield and the social optimum.

Bio-economicaa models can be able to interpret the different dynamics of the complex system and provide information on management measures related to the specificity of each sector.

The review of the major bioeconomic models proposed in this study has allowed to highlight the commitment of the international scientific research towards the realization of the concept of sustainability in fish, choosing between simulation or optimization models and evaluating the adaptability to different types of specific or mixed fisheries.

In conclusion, starting from the difficulties occurring in our research, we conclude with a recommendation that underlines the urgent necessity to extend the monitoring of biological indicators, economic, environmental and social factors to the Vongole fishing system. At the moment, the indicators have a great difficulty to be identified, for different reasons as the lack of economic resources devoted to research, or the lack of transparency and asymmetric information of the data. The availability of such indicators, is a *conditio sine qua non* for the implementation of the bioeconomic model.

References

Accadia P., Spagnolo M., 2006. *A bio-economic simulation model for the Italian fisheries*, Internazional Conference IIFET, «Rebuilding Fisheries in an Uncertain Environment», Portsmouth, Uk, 11-14 July 2006.

Antonelli G., Bischi G.I., Vigano E. (eds), 2005. *La sostenibilità nel settore della pesca. Modelli, politiche, esperienze in un'area del litorale romagnolo-marchigiano*. Franco Angeli, Milano.

Clark C. W., 1976. *Mathematical bioeconomics: the optimal management of renewable resources*. John Wiley & Sons: USA.

Coppola G., e Placenti V., 2005. *Bioeconomic model for fisheries: A survey (1)*. BEMMFISH project. Final report: 27-40.

Eide A., Flaaten O., 1998. *Bioeconomic multispecies models of the Barents Sea fisheries*. In: Rødseth, T. (Ed.), Models for Multispecies Management. Physica- Verlag, Heidelberg, pp. 141–172.

Fao, 2001. *Report of the bio-economic modelling workshop on the small pelagic fisheries of the west coast of peninsular Malaysia*, Penang, 12-16 febraury 2001.

Finco A., e Padella M. (in press). *I diritti di proprietà come strumento di gestione sostenibile per la risorsa ittica: teoria ed evidenze empiriche per la pesca della vongola (Chamelea gallina)*. Franco Angeli, Milano.

Franquesa R., 1996. *Bioeconomic and political models of fisheries management. An introductory lesson.*

Froglia C., 2000. *Il contributo della ricerca scientifica alla gestione della pesca dei molluschi bivalvi con draghe idrauliche*. Biologia Marina Mediterranea, 7 (4):71-82.

Gordon H. S., 1953. *An economic approach to the optimum utilization of fishery resources*. J. Fish. Res. Bd. Can., 10: 442-457.

Gordon H. S., 1954. *The economic theory of a common property: The fishery*. J. Political Econ., 62(2): 124-142.

Haraldsson G. e Árnason R., 2005. *Bio-economic models: a survey (2): Bio-economic Management Models for the North-Atlantic: An Overview*. BEMMFISH project. Final report: 41-48.

Hauton C., Morello E.B., Howell T.R., Froglia C., Moore P.G., Atkinson R.J.A., 2002. *Assessments of the impact and efficiency of hydraulic dredging in Scottish and Italian waters*. Final Report, EC Study Contract 99/078. pp.475 + Appendices.

IREPA, 2004. *Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2004*. Franco Angeli, Milano.

IREPA, 2005a. *Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2005*. Franco Angeli, Milano.

IREPA, 2005b. *A working proposal for the economic and biological data collection of the small scale fisheries*. Workshop on Small Scale Fisheries. Kavala, Greece 12th -16th September 2005.

IREPA, 2006. *Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2006*. Franco Angeli, Milano.

Laureti L., 2000. *Economia e politica della pesca. Lo sviluppo sostenibile*. Cedam: Padova.

Lleonart J., Maynou F., Franquesa R., 1999. *A bio-economic model for Mediterranean fisheries*. Fish. Econ. Newsletter, 48: 1-16.

Lleonart J., Maynou F., Recasens L., Franquesa R., 2003. *A bio-economic model for Mediterranean fisheries, the hake off Catalonia (western Mediterranean) as a case study*. Sci. Mar., 67(Suppl. 1): 337-351.

Maynou F. (prepared by), 2005. *Final Report of the project Bio-economic modelling of Mediterranean Fisheries.* BEMMFISH (Q5RS-2001-01533).

Maynou F., Sardà F., Tudela S., Demestre M., 2006. *Management strategies for red shrimp (Aristeus antennatus) fisheries in the Catalan sea (NW Mediterranean) based on bioeconomic simulation analysis*. Aquat. Liv. Res., 19: 161-171.

Morello E.B, Froglia C., Atkinson R.J.A., Moore P.G., 2005. *Impacts of hydraulic dredging on a macro-benthic community of the Adriatic Sea, Italy*, Can. J. Fish. Aquat. Sci, 62:2076-2087

Placenti V., Rizzo G., Spagnolo M., 1992. *A bioeconomic model for the optimisation of multispecies, multigear fishery: The Italian case*, Marine resource economics, 74: 275-295.

Placenti V. et al. (IREPA), 2005. *Case Study 4. Demersal fishery in the Ligurian Sea*. BEMMFISH project. Final report

Placenti V. et al. (IREPA), 2005. *Case study 5. North and Central Adriatic small pelagics (1). Estimation of production and cost functions of the North and Central Adriatic pelagic fleet.* BEMMFISH project. Final report

Schaefer M., 1954. *Some aspects of the dynamics of populations important to the management of the commercial marine fisheries*. Bull. Inter-Amer. Trop. Tuna Comm., 1(2): 27-56.

SEC, 2005. *Report of the Joint SGECA - SGRST sub-group meeting on bioeconomic modelling,* Brussels, 4 -6 October 2005. Commission staff working paper, Brussels.

Silvestri S. e Maynou F., 2009. *Application of a bioeconomic model for supporting the management process of the small pelagic fishery in the Veneto Region, northern Adriatic Sea, Italy*. Scientia Marina 73(3), 563-572, Barcelona (Spain).

Spagnolo M., 2006. *Elementi di economia e gestione della pesca*, FrancoAngeli, Milano.

Sparre J.P. e Williams R., 2001. *Bioeconomic Analytical Model n. 5* XIII EAFE Conference, Salerno 18 - 20 April 2001.

Tjelmeland S., Bogstad B., 1998. *Biological modelling*. In: Rødseth, T. (Ed.), Models for Multispecies Management. Physica-Verlag, Heidelberg, pp. 69–92.

Ulrich C., Pascoe S., Sparre P.J., De Wilde J.W., Marchal P., 2002a. *Influence of technical development on bio-economics in the North Sea flatfish fishery regulated by catches- or by effort quotas*, Can. J. Fish. Aquat. Sci. 59 (5), 829- 843.

Ulrich C. B., Le Gallic M., Dunn R., Gascuel, D., 2002b. *A multi-species, multifleet bioeconomic simulation model for the English Channel artisanal fisheries*. Fisheries Research, 58 (3): 379-401.