The Stock Concept Applicability for the Economic Evaluation of Marine Ecosystem Exploitation

Lars J. Ravn-Jonsen

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Lars J. Ravn-Jonsen
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Tel.: +45 6550 4208
Fax: +45 6550 1091
E-mail: lrj@sam.sdu.dk

Abstract

Stock models, in which production is interpreted as if it were the population growth of a stock, have been the preferred tool for fishery economics since Clark and Munro (1975) introduced capital theory in these models. Ravn-Jonsen (2009*c*) applied capital theory to a model in which the production in the ecosystem is a consequence of predator–prey interaction and the somatic growth of the predator as a result of this interaction. By deducing the results of Clark and Munro anew, the assumptions of the stock model are clarified. Four different biomass measures are introduced in the ecosystem model as stocks. The optimum point found with the stock model approach is compared with the optimum point found in the ecosystem model with the capital value calculations of the occurring rent flow. A comparison shows that the stock model fails to generate the correct optimal point. The assumptions behind the use of stock models for species population models are discussed. The population stock model corresponds to a holistic community view, which has in fact failed to explain various phenomena.

The production of the marine ecosystem cannot be reduced to a model *as if* the production were a consequence of the growth of a stock. The concept of a stock is rather an illusion, as is the concept of an optimal stock level. It is essential to liberate fishery economics from a simplified view of population and communities.

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1 Introduction

The introduction of capital theory within fishery economics in a proper setting is normally attributed to Clark and Munro (1975). Many analyses related to the economics of the fishery are cast along the concepts and methods introduced in that article, and Clark and Munro's golden rule is well known by most fishery economists. Ravn-Jonsen (2009*b*) introduced an size-based ecosystem model with quite a different model concept, and this model is analysed in the context of capital theory in Ravn-Jonsen (2009*c*). As the golden rule of Clark and Munro is so well known in fishery economics, a natural question is: How do the optimum points found by Ravn-Jonsen in the ecosystem model relate to the golden rule? The short answer will be that Ravn-Jonsen is an ecosystem model, while Clark and Munro is a population model. The models therefore explain two different concepts with different positions in Nature's organisational hierarchy. Therefore, the findings from the two models cannot be compared.

Such a conclusion will, however, be too superficial. The article of Clark and Munro does not explicitly define the model as a model for a population of a specific species, but simply analyses a model of a population. The only link to indicate that the model may be a species population model is in the reference to Schaefer (1954) regarding the natural rate of increase as a function of the stock (Clark and Munro, 1975, equation (2.1)). The analysis of Schaefer is related to the fish population in general (that is, without a reference to species), but it is applied to the Pacific halibut fishery and the California sardine fishery, and, therefore, through its application, it is interpreted as a species population model. The population in the article of Clark and Munro is therefore probably meant to be a population of a specific species, but by not being explicit regarding where the model does and does not apply, there is a risk of applying the model's concept of stock to issues that are not species population problems. An example is marine protected areas that are proposed as ecosystem management tools; however, the models used for analysing the economic consequences are nevertheless often stock models (Armstrong and Skonhoft, 2006; Sanchirico et al., 2006). So, whether or not Clark and Munro intended to apply the concept of stock models to anything but the population of a particular species, the concept of stocks is so much a part of the fishery economics mindset that many researchers will apply it in this way.

In this paper, the results related to the population model of Clark and Munro (1975), seen as ecosystem models, are compared with the results of the ecosystem production model of Ravn-Jonsen (2009*b*,*c*). As the two models are cast over different concepts, in order to make the comparison, the golden rule first has to be deduced in another way than in how it was found in Clark and Munro (1975). This is done in order to see what kind of assumptions have to be made in order to move from the ecosystem model of Ravn-Jonsen to the stock model of Clark and Munro.

2 Capital theory

Faustmann (1849) introduced the present value of expected rent flows as the value of capital: The capital value $\mathbb{C}$ is defined as:

$$\mathbb{C} = \int_0^\infty \mathrm{e}^{-\rho t} \pi(t)\,\mathrm{d}t \tag{1}$$

where $\pi(t)$ is the expected rent from the capital, ρ is the discount rate and t is time. As a natural consequence, Pressler (1860) introduced[1] the maximisation of the capital value as the management objective:

$$\text{Objective:} \quad \max_{\boldsymbol{y}} \mathbb{C} \tag{2}$$

where $\boldsymbol{y}$ is a vector of all possible management controls.

The first order conditions for (2) are:

$$\frac{\partial \mathbb{C}}{\partial y_i} = 0 \tag{3}$$

That is:

> In optimum, the change in capital value will be zero for all marginal changes in controls.

When (3) is applied to evaluate a management action there is no need to calculate the total capital value (1), but only to evaluate the changes in rent flow, and hence capital value, as a consequence of a management action.

The management theory based on Faustmann (1849) and Pressler (1860) is known within forestry as the “Bodenreinertragslehre”, which in Ravn-Jonsen (2009*c*) is translated into ground rent theory. The term “ground” is used to indicate that the resource under management is based on the nutrition, wind, soil, etc., and the pool of genetic information. The generated rent is ultimately founded based on the ground.

The present value calculation as a concept for capital valuation entered general economic theory through Fisher (1906). Clark and Munro (1975) states that the objective of “capital theory” is to maximise the present value of rent derived from fishing estimated by a stock model. This approach is identical to the ground rent theory

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[1] See Viitala (2006) for a review of present value calculations and management objectives before Faustmann (1849) and Pressler (1860).

if the stock model accounts for all changes with respect to future rent based on the ground. The difference is that in the Ravn-Jonsen analysis, the objective is subjected to a ecosystem model, while the objective in Clark and Munro is subjected to a stock model.

To gain deeper insight into the assumption behind the stock concept, I shall derive the Clark and Munro golden rule, departing from the general formulated objective (2). The first step is to divide the rent flow into two periods. In order to get the capital value, the discounted rent flow from the first management period has to be added to the discounted rent flow from the second period. For the expectation value of the second period rent, I shall use the symbol $\mathbb{C}^{+}$. In the present analysis, the management action under evaluation is an extra harvest h at $t = 0$. The first period is therefore a point in time, the discount factor is one, and the rent flow of the period is hp, where p is the net value of the harvested items, that is, revenue minus variable costs. The second period expectation value is then:

$$\mathbb{C}^{+} = \lim_{a \longrightarrow 0} \int_{a}^{\infty} \mathrm{e}^{-\rho t} \pi(t) \, \mathrm{d}t$$

That is the capital value excluding the point $t = 0$, and the total capital value will then be:

$$\mathbb{C} = hp + \mathbb{C}^{+} \tag{4}$$

If (4) is used as the capital value of objective (2), the first order condition with respect to harvest h at $t = 0$ is:

$$\frac{\partial}{\partial h} \left(hp + \mathbb{C}^{+} \right) = 0 \qquad \Longleftrightarrow \tag{5}$$

$$p = -\frac{\partial \mathbb{C}^{+}}{\partial h} \tag{6}$$

In prose the rule (6) states:

> In optimum, the net value of one fish will be equal to the decline in capital value if that fish were removed.

If the present value of the rent flow $\pi(t)$ is substituted for the capital value, the rule will now look like:

$$p = -\frac{\partial \int_{0^{+}}^{\infty} e^{-\rho t} \pi(t) \, \mathrm{d}t}{\partial h} \tag{7}$$

where 0^+ in the limit indicates the rent flow is discontinued at $t = 0$, and the integral is calculated for $t > 0$, excluding the contribution margin at $t = 0$.

I now assume that the system can be represented by a single state variable—the stock S—that is calibrated in such a way that the S is negatively affected by the immediate extra harvest on a one to one basis. The $\frac{\partial}{\partial h}$ in (7) can then be substituted with $-\frac{\partial}{\partial S}$:

$$p = \frac{\partial \int_{0^+}^{\infty} e^{-\rho t} \pi(t) \, \mathrm{d}t}{\partial S} \tag{8}$$

I next assume that the optimum will be found with a fixed set of controls, and that this fixed set of controls will lead to a steady state situation for the state variable.[2] As there is only one state variable S in the system, the harvest[3] H must be a function of S when the system is in a steady state:

$$\dot{S} = 0 \quad \Longrightarrow \quad f(S) = H \tag{9}$$

As the harvest affects the state variable directly, an infinitesimal extra harvest h will change the stock marginal. In order to maintain the steady state, the controls simultaneously change into those that fit the new stock. The system is then momentarily changed from one steady state into a new steady state. Except at the time of control change, the harvest will then be constant and so will the rent flow. The rent flow in (8) can then, if * is the sign for the optimum, be written as a function of the stock $\pi(t) = \pi^* = \pi(S^*)$; that is, optimal rent is a function of optimal stock. The integral in (8) can then be solved:

$$\begin{aligned} p &= \frac{\partial \int_{0^+}^{\infty} e^{-\rho t} \pi(t) \, \mathrm{d}t}{\partial S} && (10) \\ &= \frac{\partial \int_{0^+}^{\infty} e^{-\rho t} \pi^* \, \mathrm{d}t}{\partial S} && (11) \\ &= \frac{1}{\rho} \frac{\partial \pi(S^*)}{\partial S} && (12) \end{aligned}$$

and rearranged into:

$$\rho = \frac{\pi_s'(S^*)}{p} \tag{13}$$

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[2] Clark and Munro (1975) do not have to make this assumption, but their model has these properties.

[3] The H represents the total and continuous harvest, while h represents the infinitesimal extra harvest at $t = 0$.

As p is the net value of one fish, the right hand side gives the marginal change in rent flow with the investment of one monetary unit as a function of the stock. In prose equation (13) is the rule:

> In optimum, the marginal productivity of the stock equals the discount rate.

As $\pi(S^*) = p(S^*)\, H(S^*) = p(S^*)\, f(S^*)$, equation (13) can be changed into

$$\rho = f_s'(S^*) + \frac{p_s'(S^*)}{p(S^*)} f(S^*) \tag{14}$$

The marginal productivity of the capital is then divided into a marginal change in the harvest, and a relative change in the value of the total harvest as a result of the marginal stock change—Clark and Munro call the latter the "stock effect." With regard to the net value p, Clark and Munro considers only the cost variable and a function of the stock $c = c(S)$. With this additional assumption, the Clark and Munro golden rule of optimum is then:

$$\rho = f_s'(S^*) - \frac{c_s'(S^*)\, f(S^*)}{p(S^*)} \tag{15}$$

The difference in the approaches of Clark and Munro (1975) and Ravn-Jonsen (2009c) can be summarised by the following. First, in the optimising method, Clark and Munro optimise the objective (2) directly, while Ravn-Jonsen uses the first order condition (3). To use the first order condition, it must be assumed that the optimum can be found with fixed controls. With this assumption, solutions with, for example, pulls fishing[4] are disregarded. This does not lead to any difference, as the optimum found by Clark and Munro is a steady state situation. Second, it may be a set of rather cryptic assumptions that have to be made in order to move from the general valid rule (7) to the rule of the optimal stock level (13). All these assumptions are, however, done implicitly when Clark and Munro (1975) assume a stock and that the production in the system is

$$\frac{\partial S}{\partial t} = f(S) - H \tag{16}$$

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[4] If the methods of Clark and Munro (1975) is applied to more complex models, as for example age structured models, the optimum may be found with controls fluctuating over time (see e.g. Botsford, 1981). This is known as pulls fishing.

The stock model assumption (16) seems to be made to facilitate the mathematical method used in Clark and Munro (1975). In contrast, the Ravn-Jonsen (2009*b*,*c*) model builds on assumptions regarding the production in the ecosystem as driven by a predator–prey interaction and a somatic growth as a consequence of the predator's consumption. In addition, the model builds on a thesis for selecting the concepts for the model (Ravn-Jonsen, 2009*a*). This model is, however, not analytically solvable, but the optimum points are found by use of rule (3) based on numerical analysis of the experiments.

3 Method and Results

The golden rule of Clark and Munro is a simple analytical result, and it would be nice if the optimum points found in the model of Ravn-Jonsen could be expressed in similarly simple terms. The model then has to be reduced to just one state variable, the stock. A variable like S can easily be generated, for example, as the biomass of an appropriate part of the spectrum. The biomass will clearly be negatively affected by the harvest on a one-to-one basis, as expected in the assumptions when going from (7) to (13). A difference between the two models is that the model of Ravn-Jonsen is specifically constructed to analyse the consequences of fishery in relation to the trophic level—expressed as the size of the fish in the model. In contrast, the model of Clark and Munro disregards the size of the fish. In order to compare the two models, experiments are therefore performed with the Ravn-Jonsen model in a manner that secures a constant mean size of harvest. The effect of the change of the production in the ecosystem with respect to size and the effect of price as a function of size are thereby minimised. The point of reference for all experiments will be the optimum point for a discount rate $\rho = 0.2$, which has a sustainable yield of $H = 0.003488\,\mathrm{g\,m^{-3}\,year^{-1}}$ and a mean size of harvest $\overline{x} = 8.856507$ corresponding to 7.020 kg.[5] Experiments are therefore preformed on the model with controls to produce a fixed $\overline{x} = 8.856507$ and different sustainable harvest volume H. Rent and population structure are recorded for the model when convergence to a steady state is reached.

The state variable in the Ravn-Jonsen model is the population density with respect to size. In figure 1, the population density is shown. The axis above the diagram indicates the mass m of the fish, while the axis below indicates the principal variable x used in the model, where $\exp(x) = m$. The black line indicates the relative population density for the optimum point given $\rho = 0.2$. That is, the population density relative

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[5] The Ravn-Jonsen model operates with a size dimension x equal to the logarithm of the mass of the fish.

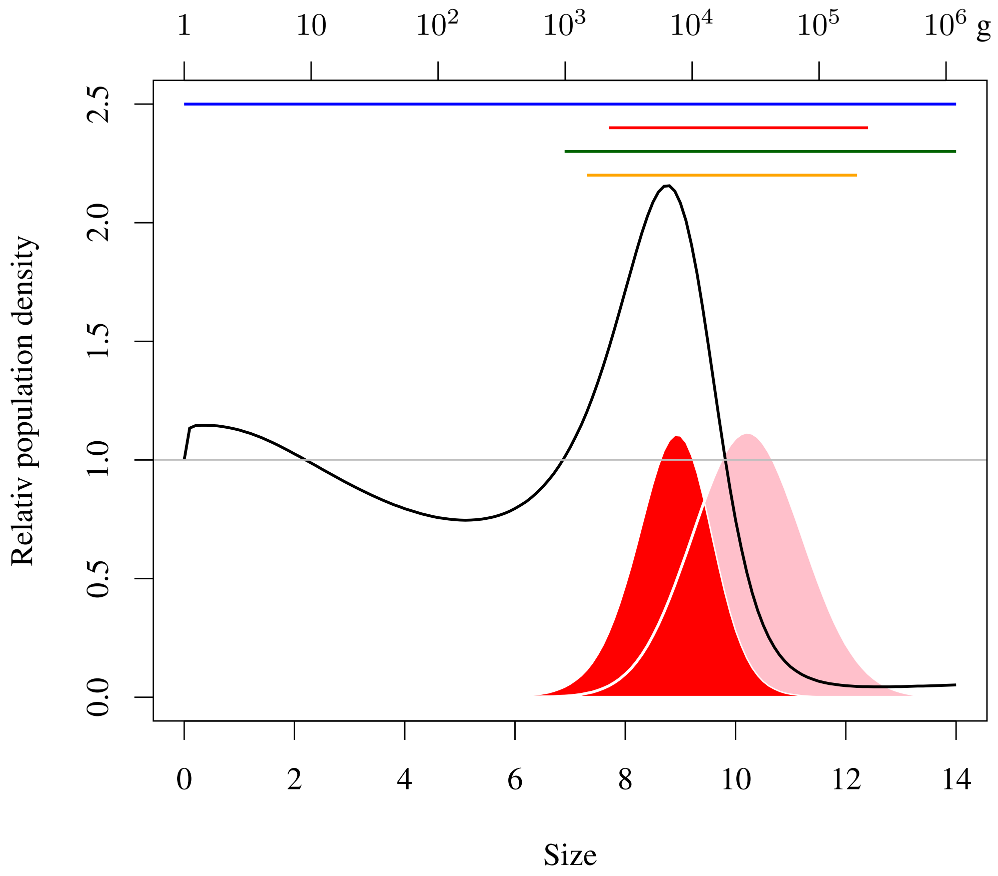

Figure 1: Population density and stock optimum point given $\rho = 0.2$. The black line indicates the relative population density, the pink figure shows the fishing mortality rate caused be the fishery, and the red curve shows the resulting harvest. The lines at the top show the mass interval for the different stock definitions: blue for S_1, red for S_2, green for S_3 and orange for S_4

to the population density in a pristine ecosystem without a fishery. A pink curve shows the mortality rate imposed by the fishery, and the red curve shows the resulting fishing mortality and harvest. In order to compare the models, there must be a stock based on the population density in the experiments. As can be seen from the population density curve, a stock will be affected by how it is defined. Four different stocks definitions are employed:

1. The most simple stock S_1 will be calculated as the biomass of the entire spectrum: $x = 0 \dots 14$ corresponding to $m = 1 \dots 1.2 \cdot 10^6$ g. This is illustrated by the blue line in figure 1.
2. S_1 is to a large extent beyond what is normally considered in stock assessments. Therefore, the second stock S_2 is defined as approximately the section with the intense fishing mortality $x = 7.7 \dots 12.4$ corresponding to $m \approx 2.2 \dots 243$ kg. This is illustrated by the red line in figure 1.
3. The third stock S_3 is defined as the biomass from approximately the smallest landed size and up $x = 6.9 \dots 14$, corresponding to $m \approx 1 \dots 1203$ kg. This is illustrated by the green line in figure 1.
4. A fourth stock S_4 is defined as approximately the landed size interval $x = 7.3 \dots 12.2$ corresponding to $m \approx 1.4 \dots 199$ kg; note that this is only slightly lower than S_2. This is illustrated by the orange line in figure 1.

From the experiment's data, the four different stocks can be compared with the sustainable harvest H. In figure 2, the harvest is plotted against the stocks. While the mapping of S_1 and S_3 into harvest H seems to be rather well defined, the mapping of S_2 into H is problematic, with one particular stock level given a range of harvest levels. S_4 has a rather odd harvest relation, and the mapping of S_4 into H is ambiguous; or in other words, there is no functional relation of S_4 into H.

If the assumptions (16) used in the Clark and Munro model are applied, the growth function can in equilibrium be determined from (9). The curves in figure 2 then represent the growth functions $f_i(S_i)$ given the different stocks $i = 1, 2, 3, 4$.

Clark and Munro make the following assumptions for the growth function:

$$f(S) > 0 \text{ for } 0 < S < K, \qquad f(0) = f(K) = 0, \qquad f'' < 0 \tag{17}$$

where K is interpreted as the maximum equilibrium stock level. The first assumption is satisfied for all four stocks. The second assumption is satisfied with regard to $f(K) = 0$, while with regard to the growth of zero stock, the status is unknown. It

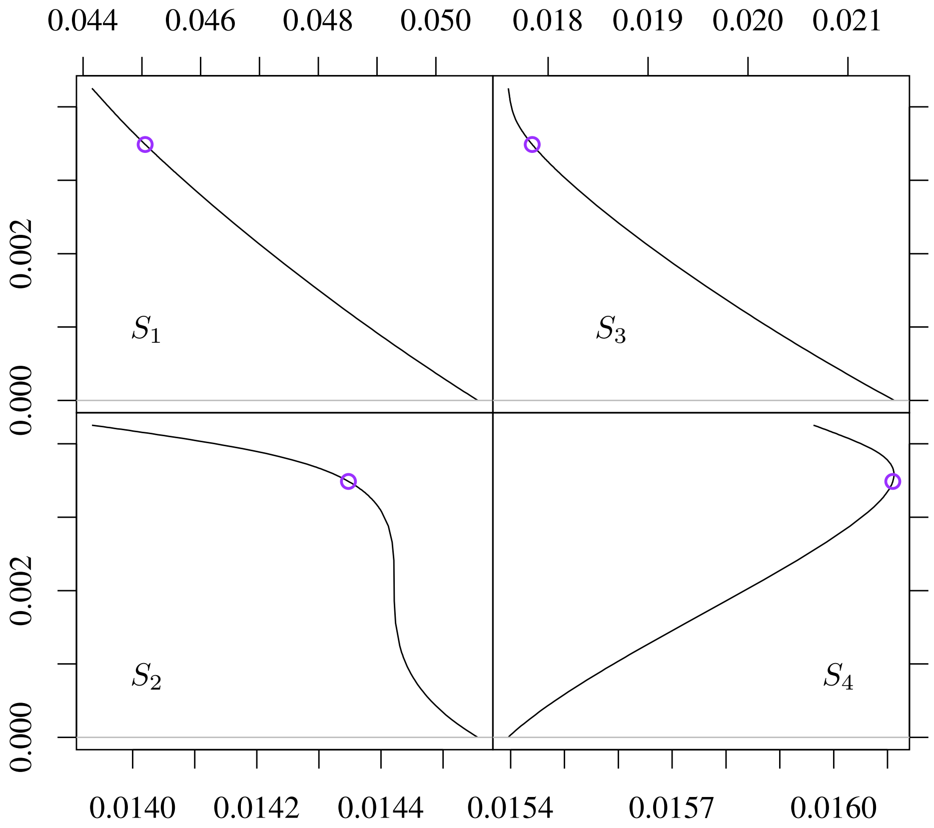

Figure 2: Harvest plotted against the four different stocks. The purple point indicates the optimal point found in the Ravn-Jonsen (2009*c*) model given $\rho = 0.2$

is, however, impossible to fish the last fish in the model of Ravn-Jonsen. The Ravn-Jonsen model does not build on the assumption of the production as a function of the stock. In contrast, the production is caused by a flow up the size spectrum caused by the somatic growth of individual fish. This flow cannot be stopped by the fishery. The last assumption regarding concavity is not met by any of the growth functions in figure 2.

The assumption in (17) is, however, not that important; rather, if version (13) of the golden rule is applied, it is the shape of the rent function that determines if the point found by the first order condition (13) is an optimum. In figure 3, the sustainable rent π is plotted against all four stocks. While the stocks S_1, S_2 and S_3 yield well-behaving functions, at least around the optimum point, the rent cannot be given as a

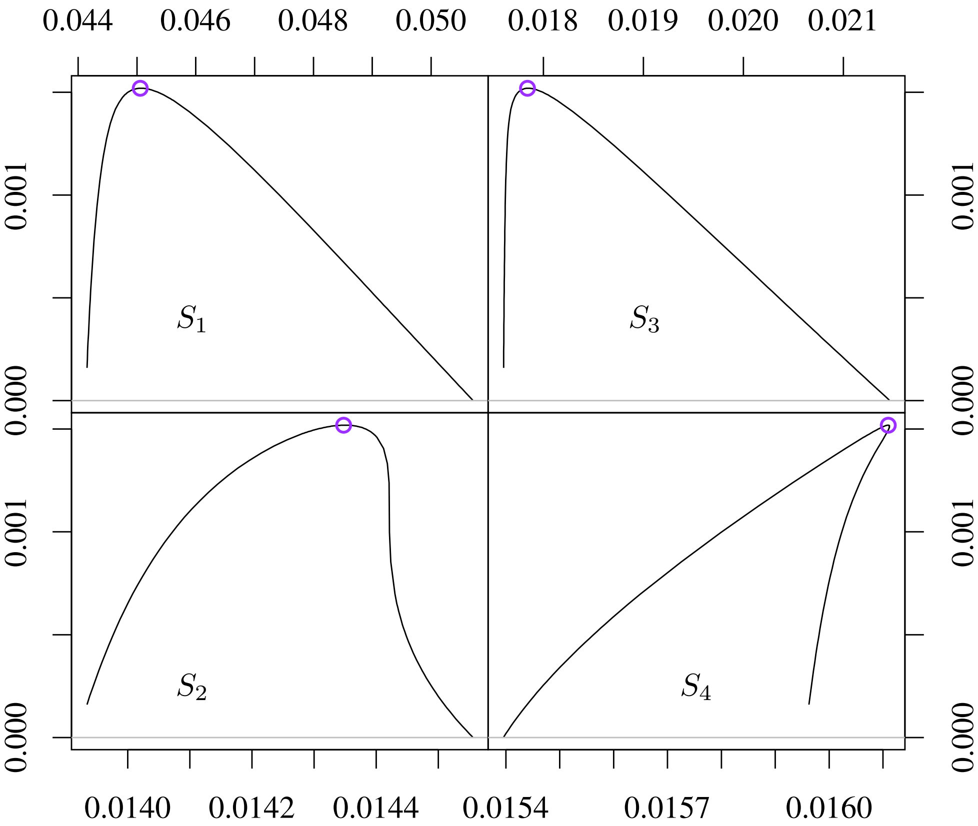

Figure 3: Sustainable rent plotted against the four different stocks. The purple point indicates the optimal point found in the Ravn-Jonsen (2009*c*) model given $\rho = 0.2$

function of S_4, as the mapping $S_4 \curvearrowright \pi$ is not unambiguous.

To value if it is actually possible to determine the right point of optimum from the Clark and Munro view of production, the rule for the optimum as expressed in (13) will be used, rather than splitting the rule up into fragments as the golden rule (15). To find the optimum point, the indicator rate

$$w_i = \frac{\frac{\partial \pi}{\partial S_i}}{p} \tag{18}$$

is calculated. The optimum point can then be found as the point at which $w_i = \rho$.

To compare the different stocks and the model of Ravn-Jonsen, the results have to be compared over a common dimension. Therefore, the indicator rates are plotted

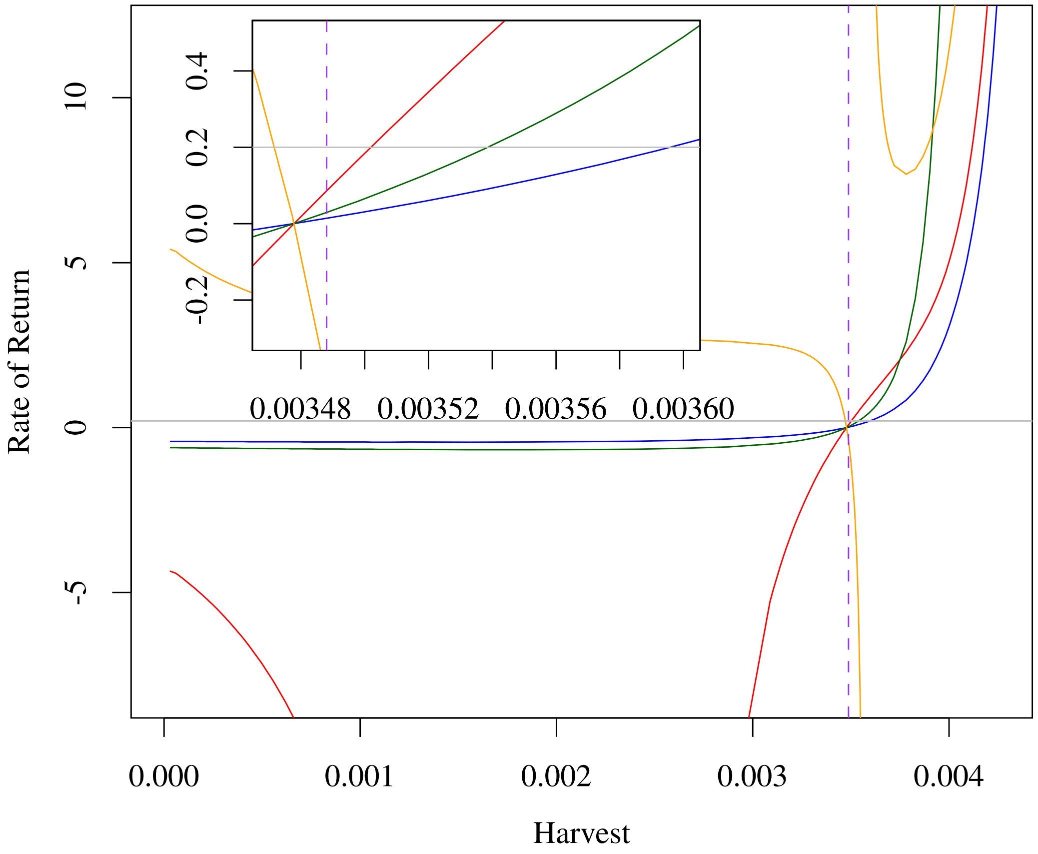

Figure 4: Indicator rate lines for the four stocks. In the large diagram, the rate of return w_i is plotted against the sustainable harvest, and the small diagram zooms in on the area around the optimum. The blue line is w_1, the red line is w_2, the green line is w_3 and the orange line is w_4. The vertical grey line indicates the $w = 0.2$ line and the dashed purple line indicates the optimal harvest found in the Ravn-Jonsen (2009*c*) model given $\rho = 0.2$

against the sustainable harvest in figure 4. The large diagram gives an overview, while the smaller diagram zooms in around the optimum point. The blue, red, green and orange lines indicate the w_i calculated numeric by applying (18). All four w_i lines cross at one point, at which $w = 0$; this point is the maximum rent harvest level, identical to the one found in the analysis of Ravn-Jonsen. The dashed line in the figure indicates the optimum harvest level for $\rho = 0.2$ found in Ravn-Jonsen (2009*c*) by numerically analysing the rent flow as a consequence of a change in controls. The grey line indicates the $w = 0.2$ line, and the optimal harvest level will for each of the different stocks be where the w_i line cross this line. For the orange line belonging to S_4, because of the inexpedient stock properties of S_4, the optimum can not be determined as a optimum harvest level.

4 Discussion

Above the results of the Ravn-Jonsen (2009*b*,*c*) model are compared with results from a stock model approach, as in Clark and Munro (1975). The underlying assumption is that the Ravn-Jonsen will reflect properties of the production in the ecosystem, as it is based on a micro production model, and the model concepts are selected from theory (see Ravn-Jonsen, 2009*a*). On the other hand, the Clark and Munro model is a model in which production is modelled *as if* it were a consequence of a population growth of a stock. This biological model is justified by a reference to Schaefer (1954), who does not refer to any theory with regards to the idea of the population growth of a stock (Schaefer, 1954, equation (1)).

The analysis points to different problems related to the model in which production in the ecosystem is seen *as if* it were the consequence of the growth of a stock:

1. The growth functions and derived points of optimum depend on the definition of stocks. The most stringent definition is the biomass of the biota in the ecosystem above a size well below the minimum landed size. However, as this stock definition changes relatively little around the points of interest, it will be a bad indicator.

2. The growth functions do not have the functional shape expected by Clark and Munro, as stated in (17). In particular, they do not resemble the Verhulst (1838) logistic growth function, recommended by Clark and Munro and preferred by many in the fishery economics literature.

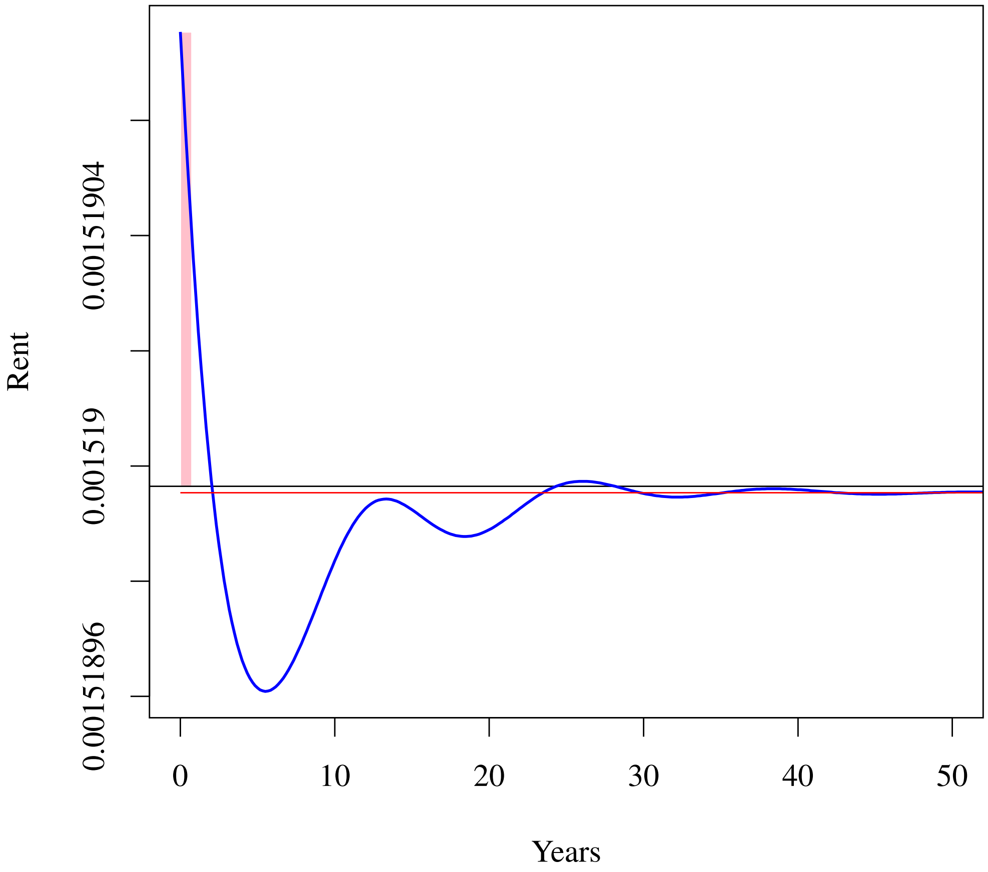

Figure 5: Rent flow diagram. The blue line indicates the rent flow in the Ravn-Jonsen model as a consequence of a small change in controls in order to increase the sustainable harvest. The red line and pink box indicate the rent flow, as expected by the assumptions of Clark and Munro. The rent in the pink box falls at $t = 0$, but as the other lines indicate a continuous rent flow, it is indicated as a box with the area corresponding to the rent. The point of departure is the optimum point for $\rho = 0.2$, and the black line indicates the rent flow if no change was made.

3. The optimum points found with a model in which the production is *as if* it were the consequence of the growth of a stock give the wrong points, as seen in figure 4

To understand why the concept of stock gives the wrong results, I direct the reader to look at the rent flow in figure 5. The blue line in the diagram indicates the rent flow in the Ravn-Jonsen model with a small change in controls that will eventually lead to a increase in the harvest but constant mean size. The point of departure is the optimum point for a discount rate $\rho = 0.2$. The black horizontal line indicates the rent flow if no change was made, that is, the alternative rent flow. The two rent flows in the figure, the blue and black lines, have the same capital value given a discount rate of 0.2009, not exactly the expected $\rho = 0.2$. However, as the optimum point in Ravn-Jonsen (2009*c*) was found numerically and by interpolation, the deviation is acceptable.

The stock model of Clark and Munro (1975) estimates the rent flow as an instant contribution margin estimated as the difference in stock times the price $\pi(0) = -\Delta S\, p$. To illustrate this, a pink polygon where the area equal to $-\Delta S_1\, p$ is drawn in figure 5. Instantly with the additional rent, the rent flow is expected to change into the sustainable yield rent of the new stock. This is in the figure indicated by the red line. The width of the pink box will vary depending on the stock definition. For S_1, the width is 0.745 years, as shown in the figure; for S_2, the width is 0.120 years; and for S_3, the width is 0.353 years. S_4 increases when the harvest increases; therefore, $-\Delta S_4\, p$ is negative. The corresponding rates of returns are $w_1 = 0.019$, $w_2 = 0.118$ and $w_3 = 0.040$, while an analysis with the definition of S_4 will see no intertemporal choice as both short and long term rents are smaller than the rent flow with no changes.

The difference between the rent flow represented by the blue line in figure 5 and the rent flow represented by the red line and pink box can be summarised by:

1. The short term gain estimated by the stock approach, represented by the pink box, is wrong. It is too small for all stock definitions; the appropriate size corresponds to a pink box with a width of about one year.
2. The stock approach overlooks the long-lasting drop in rent after the initial gain, but before the oscillation is damped and the rent approaches the new sustainable yield rent.

These two points are a reflection of the assumptions made in order to reduce the general rule (7) to the optimal stock rule (13). The stock concept introduced under these assumptions clearly neglects the dynamics of the system. As the capital theory builds on a concept where both the amount and time of the rent flow are crucial, a stock concept that neglects the dynamics of the system must be dropped, at least with regards to the evaluation of the economic consequences of management actions in the ecosystem.

As seen in figure 1, there is an increase in population density below the target size, known as a trophic cascade. As there will be a short-term gain from lowering the target, this trophic cascade creates an intertemporal choice. This intertemporal balancing problem is neglected by the stock view, as size is disregarded in this view. The stock view then, in addition to neglecting the dynamics of the ecosystem, neglects the economic consequences of change in the ecosystem other than those that can be measured by the stock.

The idea of production as a consequence of the growth of a stock is an illusion. The primary reason is because the production is caused by the flow of energy from the primary producers capturing the energy of the sun through the trophic system. Therefore, and as discussed above, the idea of production *as if* it were a growth function of the stock has to be abandoned when discussing production in the ecosystem.

As mentioned in the introduction, Clark and Munro did not state what kinds of populations their model should represent. It may be rather speculative to suggest that the model is regarding an ecosystem, and if the model is interpreted as the population of a single species, the present analysis is not directly related to their model. The capital theory applied in the analysis assumes, however, that all changes in rent flow as consequences of management actions are included in the first order condition (3). By conducting a single species analysis, it is then implicitly assumed that the state of this population has neither a direct nor indirect influence on other commercial species. As the production of a population in nature is caused by predation and related somatic growth, it seems to be a rather speculative assumption. If, however, this assumption is satisfied, for example, because the species in question is the only commercial species in the ecosystem, the next question is which assumption is implicitly included in order to assume that the species population growth can be modelled *as if* the production were a consequence of a stock determined population growth. As the production of the species is caused by interaction with other species and not by the stock in isolation, there is behind the stock-determined growth concept an underlying assumption of each species having a well-defined proportion of the total community. The proportions of the species in the community can be changed by external forces, for example, by fishing, but if the fishery is stopped, the community will eventually return to the original proportions. For a stock model to be true the composition of the community must be caused by such a self-regulation mechanism. This view of Nature, in which the destiny of a community is a predefined property of the community, is essentially the holistic community view that Clements (1916) applied to plant communities. This view utterly failed to explain the great dust catastrophe in the prairies of North America in the 1930s. Events in which the holistic community view fails are also known in fishery. One example is the collapse of the New England ground fish fishery in the 1990s: the New England ground fish community has not returned to its previous proportions after the fishery stopped. The population stock growth model is essentially an application of holism and essentialism to the fish community.

The consequences of fishery economics focus on models with production *as if* it were the growth of stock is that the management primarily focuses on stocks. If the production of the ecosystem is not determined by the stocks, this focus on stocks will lead to a poorer management than if a more realistic view of the ecosystem were applied. For example, a model built on the idea of production as stock growth, will exhibits a high degree of unpredictability because of the lack of causality between production and stock.

Conclusion

The production of the marine ecosystem cannot be reduced to a model *as if* the production were a consequence of the growth of a stock. There is no way of defining a stock that will produce the correct rent flow as a consequence of the stock. The concept of a stock growth is an illusion and so is the concept of an optimal stock level. If fishery economics has to contribute to ecosystem management, it is essential to liberate it from a traditional simplified view on population and communities, and apply concepts related to the ecosystem, which is founded on philosophical reasoning and avoids the simplification in developing models without a proper foundation of the concepts.

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