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FISHERIES RESEARCH

The differential effects of changing management regimes on yields from two fisheries exploiting the same resources

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Abstract

A yield per recruit model has been used to compare the effects of mesh size increment on the yields and revenues of the fisheries of Cameroon under two different cases. Case 1 assumes the commercial fishery to move from the exploitation of three age-groups to two age-groups with no interactions with the artisanal fishery, whereas Case 2 takes into account these interactions. The difference in the percentage increase of yield per recruit between case 1 and case 2 is 61% at current fishing (46% and 18% yield per recruit increment in cases 1 and 2 respectively). The usually accepted long-term yield per recruit increment with increase of age at first capture (with a single non-interacting fisheries) is, in this case, cancelled out. However, the revenues increase by 72% and 63% in cases 1 and 2 respectively. Therefore the economic approach, compared with purely biological analyses, is more convincing. In general, as fisheries always interact, a single-fishery management approach should not be the rule as it is at present; management strategies should consider interactions between different fisheries and be based on their economic performances and not, as said earlier, on purely biological considerations. This is because a biological approach to fisheries management will, at best, be modified by economic factors, or, at worst, be ignored totally in favour of economic policies.

Keywords: Interactions; Biological; Economic; Yield per recruit; Cameroon; Sciaenidae; Commercial fishery; Artisanal fishery; Management

1. Introduction

The commercial and artisanal fisheries in Cameroon both exploit the stock of croakers (Sciaenidae). While the commercial fishery catches juvenile and adult fish (age-groups 1, 2 and 3), the artisanal fishery exploits only the adults (age-groups 2 and 3). Increasing the current stretched mesh size in use in the commercial fishery from 41 mm to 67 mm, without taking into account any interaction with the artisanal fishery, gives rise to an increasing yield per recruit in the commercial fishery of 46% at current fishing effort level.

This study aims to re-evaluate the effects of this mesh size increase, taking into account the interactions between the two fisheries, and the economic implications of this policy.

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2. Brief description of the fisheries

Of the total fish production in Cameroon 80% comes from the artisanal fishery. The fishery itself is directed towards the capture of small pelagics mainly clupeids which are most important, and demersal resources especially croakers. There are two types of vessel currently in use: the wooden dugout canoe generally 4–7 m long, and the planked canoe 7–10 m in length. These vessels are driven either by paddles, sails, or by outboard motors usually of 8–15 horse power. The numerous fishing gears in use fall into five categories: gillnets, falling nets, seine nets, traps and lines. For the capture of croakers, the fishing gear is gillnet with 5–7 cm stretched mesh size.

The commercial fishery is directed towards demersal species, 75% of which are croakers (Sciaenidae). The vessels are side trawlers ranging between 20 and 25 m in length, and 50 and 250 gross registered tonnes. The stretched mesh size net is 30–40 mm cod end (further details on this fishery can be found in Djama, 1988).

3. The model

To illustrate the effect on the yield per recruit of increment of age at first capture, a dynamic pool model seems to be appropriate. The first reason is that croakers investigated herein constitute an assemblage (Longhurst, 1965; Djama and Pitcher, 1989) and assessment using single-species models can be reasonably justified (Larkin, 1982). The second reason for the choice is that particular attention is given to the effects of altering the two parameters that can be directly controlled by man: i.e. the amount of fishing as measured by the fishing mortality F, and the way the fishing is distributed on different sizes of fish as measured by the age at first capture. We then assume (as usual) that the stock of croakers is in steady-state: i.e. the stock remains constant from one year to the next due to constant parameters of recruitment, growth and mortality. It is also assumed that there is a 'knife-edge' recruitment process happening within the age structure captured in the fisheries. Under these assumptions, the composition of the stock may then simply be calculated by consider-

ing a cohort during its life-span (Beverton and Hc 1957). The number of fish at time t, can then expressed as:

$$N_t = N_{t_r} e^{-(F+M)(t-t_r)} \qquad ($$

where N_{tr} and N_t are the number of fish at time recruitment and time t, respectively. F and M a fishing and natural mortality rates. The number fish dying of fishing (C) during a short time interv (t_0, t_1) is:

$$C_{(t_0,t_1)} = \int_{t_0}^{t_1} F_t N_t \, dt \qquad ($$

Eq. (2), which represents catch in number, w fail to illustrate the importance of catching fish of particular age-group. To include the effect of age the catch equation, the weight of the fish is intr duced in the model, as most fish increase in weig with size. Eq. (2) then becomes:

$$Y_{t_1} = \int_{t_0}^{t_1} F_t N_t W_t \, dt \qquad (3$$

In order to solve Eq. (3), we considered W_t, derived from Brody's equation (Brody, 1927, 1945

$$W_t = W_\infty (1 - e^{-kt}) \qquad (4$$

k here is not the von Bertalanffy growth coefficien Eq. (4) describes the adult phase of growth in weigh which is derived from a general S-shaped growt curve obtained from the plot of weight against ag (Brody, 1927, 1945). Replacing N_t and W_t by the values (Eqs. (1) and (4) respectively), Eq. (3) be comes:

$$Y_{t_1} = \int_{t_0}^{t_1} F_t N_{t_r} W_\infty e^{-(F+M)t} (1 - e^{-kt}) \, dt \qquad (5$$

Putting all the constants of Eq. (5) outside th integral we obtain:

$$Y_{t_1} = F_t N_{t_r} W_\infty \int_{t_0}^{t_1} e^{-(F+M)t} (1 - e^{-kt}) \, dt \qquad (6$$

It is important at this point to recall that th commercial fishery catches age-groups 1, 2 and : (relative years), and the artisanal fishery only age groups 2 and 3. The solution to Eq. (6) for age-grou 1, in the commercial fishery will then be:

$$Y_{t_{1c}} = F_c N_{t_r} W_\infty \left(\frac{e^{-(F_c+M)t_0} - e^{-(F_c+M)t_1}}{F_c + M} \right.$$
$$\left. + \frac{e^{-(F_c+M+K)t_1} - e^{-(F_c+M+k)t_0}}{F_c + M + k} \right) \qquad (7)$$

F_c represents fishing mortality from the commercial fishery alone. The yield per recruit equation for age-group 2 from the commercial fishery will be:

$$Y_{t_2c} = F_2 N_1 W_\infty \left(\frac{e^{-(F'+M)t_1} - e^{-(F'+M)t_2}}{F'+M} \right.$$
$$\left. + \frac{e^{-(F'+M+K)t_2} - e^{-(F'+M+k)t_1}}{F'+M+k} \right) \quad (8)$$

where, $F' = F_c + F_a$, F_a being the artisanal fishing mortality. We are also recalling that $N_1 = N_{t_r} e^{-(F_c+M)(t_1-t_r)}$.

Following the reasoning above, the yield per recruit equation for age-group 3 from the commercial fishery will be:

$$Y_{t_3c} = F_3 N_2 W_\infty \left(\frac{e^{-(F'+M)t_2} - e^{-(F'+M)t_3}}{F'+M} \right.$$
$$\left. + \frac{e^{-(F'+M+K)t_3} - e^{-(F'+M+k)t_2}}{F'+M+k} \right) \quad (9)$$

The total yield per recruit from the exploitation of three age-groups in the commercial fishery will then be:

$$Y_c = \sum_{t=1}^{t=3} F_c N_{t-1} W_\infty \frac{e^{-(F'+M)(t-1)} - e^{-(F'+M)t}}{F'+M}$$
$$+ \frac{e^{-(F'+M+k)t} - e^{-(F'+M+k)(t-1)}}{F'+M+k} \quad (10)$$

This equation has been used to compute the various yield per recruit from the commercial fishery.

4. Economic model

It should be noted that fish are mostly sold in the artisanal fishery on an individual basis and not by weight. In that case, implications of the change in the management regime would be very different from those considering only catch by weight. In order to assess the economic effect of exploiting a specific age-group, we then convert the weight W_∞ to price $P_{r\infty}$, and Eq. (10) becomes:

$$PV_c = \sum_{t=1}^{t=3} F_c N_{t-1} P_{r\infty} \frac{e^{-(F'+M)(t-1)} - e^{-(F'+M)t}}{F'+M}$$
$$+ \frac{e^{-(F'+M+k)t} - e^{-(F'+M+k)(t-1)}}{F'+M+k} \quad (11)$$

Table 1
Parameters values used in the computation of various yields from the artisanal and commercial fisheries (data from Djama, 1992)

Parameter	Value	Definition
F_c	1.08	Commercial fishing mortality
F_a	0.42	Artisanal fishing mortality
M	0.50	Natural mortality rate
k	0.20	Brody's growth coefficient
W_∞	3260	Average infinite weight
$P_{r\infty}$	US$ 0.7, 1.6,2	Prices of age-groups 1, 2 and 3
N_{tr} *	1000	Initial number of recruits

P_∞ is proportional to the age-group and was taken as 0.7, 1.6 and 2 US$ for age-groups 1, 2 and 3 respectively. N_{tr} *: the initial number of recruits is unrealistic, but, if changed, does not affect the results.

where PV_c is the revenue (or present value) accrued in exploiting three age-groups (1, 2 and 3) in the commercial fishery. It will be necessary to assume for simplicity that fish price is proportional to size, remains constant, and that the discount rate is zero. To that end, fish prices of age-groups 1, 2 and 3 were assumed to be US$ 0.7, 1.6 and 2 respectively.

In the following, two cases are considered. Case 1, assumes the industrial fishery to move from the exploitation of age-groups 1, 2 and 3, to only age-groups 2 and 3, without taking into account the fishing mortality of the artisanal fishery. In other words, case 1 illustrates a situation whereby fisheries are studied or managed in isolation.

Case 2 is the repetition of case 1, with the fishing mortality of the artisanal fishery taken into account. This case illustrates the ideal situation whereby interactions between various fisheries are taken into account in studies and/or management of fisheries.

Table 2
Exploitation scenario of case 1, which moves from exploitation of three age-groups to only two age-groups without considering the effects of the artisanal fishery

	% increase	
	Commercial	Artisanal
Case 1	84	10
Case 2	26	398

5. Results and discussion

Table 1 shows the parameters (taken from Djama, 1992) used in the computation of yield per recruit curves. The increase of yield per recruit in case 1 is 46% at current fishing level in the commercial fishery (Table 2), whereas the revenue increases by 72%. Case 2, which includes the fishing mortality of the artisanal fishery, indicates an increase in yield per recruit of 18% at current fishing levels and of revenue by 63% (Table 3).

Basically, these results are not surprising, as from the model itself one could expect a relative reduction of the yield per recruit in the commercial fishery

Table 3
Exploitation scenario of case 2, which moves from exploitation of three age-groups to only two age-groups, this time taking into account the fishing mortality of the artisanal fishery

Exploitation of three age-groups					Exploitation of two age-groups			Percentage increase	
Effort	Age 1	Age 2	Age 3	Total	Age 2	Age 3	Total	Yield	Revenue
0.1	20749	2539	259	23546	33143	1425	34568	32	66
0.2	38990	4066	406	43462	60028	2518	62546	31	66
0.3	54985	4885	478	60348	81749	3354	85103	29	66
0.4	68968	5211	501	74681	99209	3992	103200	28	65
0.5	81151	5201	493	86845	113154	4474	117627	26	65
0.6	91723	4968	466	97156	124200	4835	129035	25	65
0.7	100855	4593	428	105877	132857	5102	137959	23	65
0.8	108702	4136	386	113225	139546	5295	144841	22	64
0.9	115403	3640	343	119385	144615	5430	150045	20	64
1	121080	3133	301	124514	148351	5520	153871	19	64
1.1 ***	125847	2637	261	128746	150993	5573	156566	18 ***	63 ***
1.2	129804	2164	226	132194	152738	5599	158337	17	63
1.3	133041	1725	193	134959	153748	5602	159351	15	63
1.4	135640	1322	165	137127	154160	5588	159748	14	62
1.5	137672	960	140	138772	154083	5561	159644	13	62
1.6	139204	639	118	139961	153611	5522	159133	12	62
1.7	140293	356	100	140749	152820	5476	158296	11	61
1.8	140992	111	84	141188	151773	5423	157196	10	61
1.9	141349	−98	70	141321	150523	5366	155888	9	61
2	141405	−275	59	141189	149112	5305	154416	9	60
2.1	141199	−423	49	140825	147576	5241	152817	8	60
2.2	140762	−544	41	140260	145946	5175	151121	7	60
2.3	140127	−641	34	139520	144244	5109	149353	7	60
2.4	139319	−717	28	138630	142492	5041	147533	6	59
2.5	138362	−774	24	137611	140705	4974	145679	6	59
2.6	137278	−815	20	136482	138898	4906	143804	5	59
2.7	136086	−843	16	135260	137080	4839	141919	5	59
2.8	134803	−858	13	133958	135261	4772	140033	4	59
2.9	133444	−863	11	132591	133449	4706	138155	4	59
3	132021	−860	9	131170	131649	4641	136290	4	59
3.1	130548	−850	8	129705	129867	4576	134443	4	58
3.2	129033	−834	6	128206	128105	4513	132617	3	58
3.3	127488	−813	5	126680	126366	4451	130817	3	58
3.5	124334	−762	4	123576	122969	4330	127299	3	58
3.6	122739	−733	3	122009	121314	4271	125585	3	58
3.7	121140	−702	2	120440	119688	4213	123901	3	58
3.8	119541	−670	2	118872	118094	4156	122250	3	58
3.9	117946	−638	2	117310	116530	4101	120631	3	58
4	116360	−606	1	115756	114997	4047	119044	3	58

*** Values representing either the actual fishing mortality or the related percentage increase of yield and revenue.

with the inclusion of the fishing mortality from the artisanal fishery. However, the difference in the percentage increase of the yield per recruit (61%) between cases 1 and 2 is so high that it cancels out the policy of long-term yield per recruit increment with increase of age at first capture. As can be seen, and particularly where yield per recruit is concerned, cases 1 and 2 lead to two conflicting arguments, the first for and the second against the increase of age at first capture in the fisheries (46% increment in case 1 and only 18% in case 2).

Adopting the economic performance as a management strategy of the fishery, things appear more clear. In fact, the revenues of the commercial fishery increase by 72% and 63% in Cases 1 and 2 respectively. This proves that, the fishery is economically healthy in both cases. Therefore, when fisheries are interacting, mesh size increment policy, with a view of economic performance of the sector, is more appropriate than the classic yield per recruit increment strategy. To that end, better management of either the commercial or the artisanal fisheries of Cameroon should include interactions between these.

These results once more confirm the fact that advice based on economic factors are better tools in fisheries management than those based purely on biological analyses. The foregoing has also demonstrated the extent to which one can be biased in studying fisheries in isolation, without taking into account their interactions. This suggests that the single-fishery management approach ought to cease being the rule as it is at present; management strategies should consider interactions between different fisheries, and be based on their economic performance and not on purely biological analyses, because the biological approach to fisheries management will, at best, be modified by economic factors or, at worst, be ignored totally in favour of economic policies.

This example is not a panacea or unique in its kind, but shows, among other possible examples, how one can reach a better understanding of a particular fishery.

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