Catch Efficiencies of Purse and Beach Seines in Ivory Coast Lagoons

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ABSTRACT: Catch efficiencies of two commonly used fishing gears in Ivory Coast lagoons, purse seine and beach seine, were studied. Only fish larger than the 100% mesh retention size (L_{100}) were considered. Escapement was estimated from the retention rates of marked fish released within the closed seines in shallow waters. Simple and reliable upper estimates of the catch efficiency were provided by these retention rates, which ranged from 10% to 79% for the purse seine and from 35% to 53% for the beach seine depending on the species. The purse seine efficiency was estimated by performing 25 sets (one set covering 0.72 ha) inside the closed beach seine (covering 9.4 ha), on both marked and unmarked populations of the bagrid *Chrysichthys* spp. and the cichlid *Tilapia guineensis*. The efficiency was close to 15% for the species considered, but this estimate may be sensitive to experimental bias (marking and "enclosure" effects). Avoidance, calculated for the purse seine from escapement and efficiency, appears to be considerable. Comparison of the catch rates by the two gears showed interspecies selectivity ("species selectivity") and intraspecies selectivity ("size-selectivity", regardless of mesh size). An understanding of both types of selectivity appears to be essential for an interpretation of the catch rates.

Artisanal fisheries are well developed in Ivory Coast lagoons, yielding from 10,000 to 20,000 tons of commercially valuable fish per year. Various stock assessment programs have been initiated at the Abidjan C.R.O. (Centre de Recherches Océanographiques) for fisheries management purposes during the last few years, but more direct methods of estimating fish abundance from catch rates are needed. The catch rates, which can be considered as relative abundance indices, can be converted into absolute abundance measurements, if the efficiency of fishing gear is known or can be estimated (Beverton and Holt 1956). Unfortunately, this is always a difficult process because efficiency depends upon various factors such as the behavior of fish, the environmental conditions (depth, nature of the bottom, etc.), and the physical characteristics of each particular gear. Previous studies have mostly dealt with towed gears such as trawls and plankton nets (Barkley 1972; Kjelson and Colby 1977; Merdinyan et al. 1979). The efficiency of these gears appeared to be a function of the active avoidance rate by fish, and models can be designed to explain, at least partially, the process (Barkley 1964). Measures of gear efficiency have been based on the "swept-area method" (Beverton and Holt 1956). Mark-recapture experiments have been made in well-defined areas, and the recapture rate has been compared with the ratio between the area swept by the gear and the area where the marked fish have been distributed (Kuipers 1975; Loesch et al. 1976; Watson 1976; Kjelson and Johnson 1978). Unlike trawl nets, surrounding nets and beach seines have rarely been studied in terms of efficiency, except the Danish seine (Hemmings 1973), which can be compared with a beach seine. For the surrounding-type gears, there are two different phases: 1) the shooting of the net, during which active avoidance takes place, and 2) the hauling of the net on board once the circle is closed, during which escapement can occur.

In this report, an experiment, based on an estimation of catchability according to the areas swept by the gears, in conjunction with a mark-recapture procedure, is described. This study was designed to better understanding multi-species catch-rates and to provide estimations of catchability for stock assessment.

MATERIAL AND METHODS

The two main fishing methods used in the Ivory Coast lagoons are the beach seine without a bag for shallow waters (about 1,200 m long) and the purse seine for depths of 2 m or more (ranging from 300 to 500 m long). Both gears reach the bottom and catch pelagic species as

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Manuscript accepted June 1989.
Fishery Bulletin, U.S. 87: 911–921.

well as demersal species (Durand et al. 1978; Charles-Dominique 1983).

In this experiment, the purse seine was 305 m long on the lead-line and 14 m deep; the net was in excellent condition. The beach seine was 1,100 m long and 8 m deep; although the net was carefully checked, a few holes may have been overlooked owing to its very large size. The mesh size for both seines was 14 mm (bar measure).

Catchability (q) is the probability of capturing one fish from the standing stock by one unit of effort ($q = C/N$, where C is the catch in number per unit of effort and N the total standing stock). It may be divided into three elements (Laurec and Le Guen 1981): 1) overall accessibility (p_A), the probability of the presence of one fish in the fishing area A; 2) local accessibility (p_a), the probability of the presence of one fish in the area a that has been swept by the gear in one fishing operation; and 3) efficiency (e), the ratio of the number of fish caught to the number of vulnerable fish that were present in the area swept in one set (see Figure 1). Thus,

$$q = p_A \cdot p_a \cdot e \tag{1}$$

In shallow waters, where the net reaches the bottom, the efficiency can be broken down into a product of three retention rates, corresponding to three successive phases: 1) avoidance (u), beginning with the net-shooting and ending with its closing; 2) escapement through the mesh (v), occurring if the fish size is less than L_{100} (the size at which 100% of fish are retained by the mesh); and 3) other forms of escapement (w), i.e., jumping over the net, burrowing or slipping through holes in the net or under the lead-line.

This catch efficiency can be written as follows:

$$e = u \cdot v \cdot w \text{ (purse seine)} \tag{2}$$

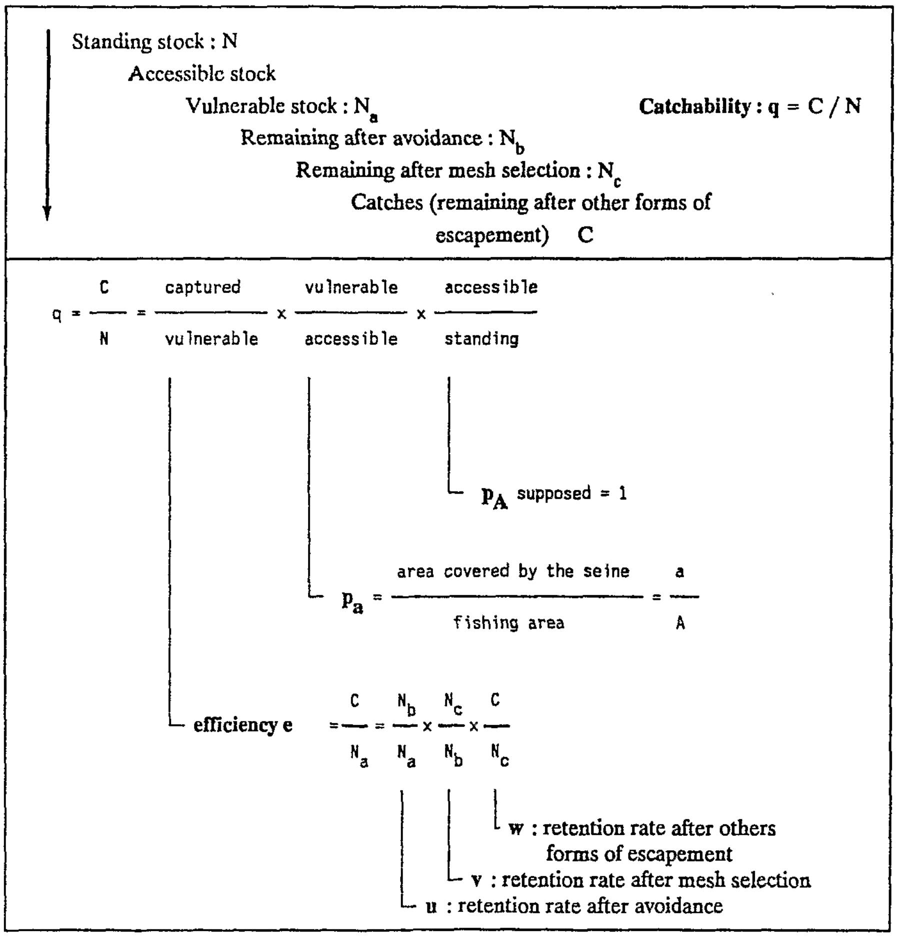

FIGURE 1.—Schematic representation of the catchability parameters for a seine in shallow waters and the catchability equation that comprises these parameters.

$$E = U \cdot V \cdot W \text{ (beach seine)} \qquad (3)$$

where capital letters refer to the beach seine and small letters to the purse seine (Table 1).

TABLE 1.—Summary of the methods used in this paper to estimate the parameters of the catchability, as defined in the text and on figure 1. Small letters refer to the purse seine and capital letters to the beach seine.

Parameters	Purse	Beach sine
Retention rate after escapement through mesh	v = for fishes greater than L_{100}, 100% mesh retention size	V = 1 (idem)
Retention rate after other forms of escapement	w = 15 independent mark-recapture estimates	W = 2 measures (W_1, W_2), 5 replica
Catchability	q = 5 measures using two methods (from captures and from recaptures)	—
Efficiency	$e = q \cdot a/A$ a = area covered by the purse seine (0.72 ha) A = area covered by the beach seine (9.4 ha)	$E = W$
Avoidance	$u = e/w$	supposed negligible

Two independent experiments were designed 1) to estimate the purse seine retention rate and 2) to estimate both the beach seine retention rate and the purse seine efficiency.

To estimate the purse seine retention rate, 15 mark-recapture experiments ($i = 1 \ldots 15$) were conducted in the open lagoon.[1]

Marking was done without anaesthetic by clipping either the superior lobe of the caudal fin, the right or left pelvic fin, or the adipose fin. Fish were stored in 1 m^3 floating cages with up to 100 fish per cage. The minimum size of the marked fish (mm) was greater than the L_{100}.[2]

At each experiment i, m_i fish were marked and released within the "closed" purse seine (i.e., when the two ends of the seine are joined together before pursing). At the end of the fishing operation, the species and sizes of the recaptured fish (r_i) were noted, and the retention rate ($w_i = r_i/m_i$) was calculated for each set. The weighted average (w) and variance ($v(w)$) were then calculated (Table 2).

$$w = \frac{\Sigma r_i}{\Sigma m_i}$$

[1]The experience was conducted in the Aby lagoon, one of the largest lagoons of the Ivory Coast (424 km^2), situated on the southwest of the country.

[2]Fish were larger than 9 cm (*Chrysichthys* spp.) or 10 cm (*Tilapia guineensis*). See footnote 3: Cantrelle et. al. (1983).

TABLE 2.—Estimation of the purse seine retention rate (w) from releasing m fish within the closed purse seine and recapturing them (r). C.V. is the coefficient of variation in percentage.

		Purse seine mark-recapture experiments																
Species		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	w	C.V.
Tilapia guineensis	m	20	3	12	15	2	34	45	1	18	23	9	16	5	28	21	0.544	27
	r	11	2	10	9	1	16	17	1	10	12	8	10	5	12	13		
Chrysichthys auratus	m	1	1		6		6	2	30		14	20	13	2	3	23	0.711	34
	r	0	0		6		3	1	29		9	13	11	2	3	9		
Chrysichthys maurus	m	19	40		26	25	27	41	62	14	67	2	7	32	5	38	0.760	21
	r	13	37		19	13	24	38	30	8	57	2	6	24	5	32		
Chrysichthys nigrodigitatus	m	2			18	8	1	10					2			2	0.581	33
	r	1			11	6	1	3					1			2		
Hemichromis fasciatus	m	1	3	2						9	2	2	1	17	6	4	0.787	32
	r	1	2	2						5	2	2	1	17	4	1		
Tylochromis jentinki	m					6		1	1	3		1	1			4	0.471	73
	r					3		0	0	0		1	1			3		
Gerres spp.	m											6	51	35	41		0.699	25
	r											4	47	19	23			
Callinectes amnicola	m				6	4	13	6	6	9	4	10	8		5		0.099	95
	r				1	1	2	1	1	0	1	0	0		0			

$$v(w) = \frac{\Sigma(r_i^2/m_i)}{\Sigma m_i} - \left[\frac{\Sigma r_i}{\Sigma m_i}\right]^2$$

In the second experiment, the beach seine was set in a shallow area of a lagoon where the average depth was 3 m. Fish were marked with a type-1 mark (M_1 fish) at the beginning of the experiment and released into the closed beach seine. A 30 min delay allowed the fish to disperse in the enclosure. Five successive purse seine sets were made randomly within the beach seine. Each set lasted about 22 minutes (the net was closed after about 3 minutes; the rings were placed on-board after about 9 minutes).

Species and size of captures and recaptures were recorded for each purse seine set; the unmarked fish were marked with a type-2 mark and stored in the floating cages. After the fifth purse seine set, the marked fish in good condition were released (M_2 fish). The retrieval of the beach seine took 6 hours. Species and size of the captures and recaptures (both M_1 and M_2 types) were recorded (Table 3). The experiment was repeated five times.

In this experiment, one should note that the storing period differed for marked fish: the marked-1 fish, captured the day before, were held captive approximately 15 hours, while the marked-2 fish on average were retained only 1 hour in the cages. Based on an aerial observation, the shapes of the seines were almost circular, although the beach seine was in some cases distorted by tidal currents; however, it was assumed that the nets were perfect circles (purse seine area 0.72 ha, beach seine area 9.4 ha).

Two retention rates by the beach seine (W_1 and W_2) were calculated for the whole experiment:

$$W_1 = R_1(M_1 - (r_{11} + r_{12} + r_{13} + r_{14} + r_{15}))$$

and for the second period of the experiment (beginning after the fifth purse seine set):

$$W_2 = R_2/M_2.$$

W_2 and W_2 correspond to fish that have stayed an average of 8½ hours and 6 hours in the enclosure respectively; thus, W_1 was expected to be lower than or equal to W_2. The difference between W_1 and W_2 was tested with a χ^2 test at the 0.05 level (Dagnélie 1975, p. 88). If W_1 and W_2 did not differ significantly, escapement was assumed not to have occurred during the purse seine fishing period. The mean retention rate (W) was calculated:

$$W = (R_1 + R_2)/(M_1 - (r_{11} + r_{12} + r_{13} + r_{14} + r_{15}) + M_2).$$

Assuming that the fish were equally available inside the enclosure, the overall accessibility (p_A) is 1 and the expectancy of the local accessibility (p_a) is equal to the ratio of the areas cov-

TABLE 3.—Experimental scheme used to measure the purse seine efficiency and the beach seine retention rate: a large beach seine reaching the bottom is set and closed over a shallow area, making a circular enclosure. M_1 fishes are marked and released within it at time 0, and a 30 min delay allows them to disperse. Five purse seine sets are then successively made within the enclosure. At every set i, the catches c_i and recaptures r_{1i} are recorded. The standing stock within the enclosure before set i is noted N_i. The unmarked fishes caught with the purse seine are marked with a type-2 mark (m_{2i}) and stored, then are released together after the fifth purse seine set (M_2). The beach seine is then retrieved and catches (C) and recaptures of both type-1 (M_1) and type-2 (M_2) are recorded.

Operations		Beach seine closed	Five purse seine sets (in hours elapsed) 0.5	1	1.5	2	2.5	Beach seine retrieved	Beach seine catches
Standing stock			N_1	N_2	N_3	N_4	N_5	N_6	
Releasing	mark-1	M_1							
Captures			c_1	c_2	c_3	c_4	c_5		C
Recaptures	mark-1		r_{11}	r_{12}	r_{13}	r_{14}	r_{15}		R_1
Marking	mark-2		m_{21}	m_{22}	m_{23}	m_{24}	m_{25}		
Releasing	mark-2							M_2	
Recaptures	mark-2								R_2

ered by the gears, $p_a = a/A$; therefore, according to Equation (1), $e = q \cdot A/a$.

Catchability q was estimated by using two partially independent methods (see notations on Table 1). In the first method (estimation "from captures"), catchability was estimated for each purse seining operation by the equation: $q_i = c_i/N_i$ (i = 1...5), where c_i represents captures at set i and N_i, the standing stock in the enclosure just before set i. When escapement did not occur during the first period ($W_1 = W_2$), the standing stock after last purse seine set (N_6) was estimated by the ratio of the beach seine captures (C) to the retention rate W. The previous values of N_i were then calculated backward ($N_i = N_{i=1} + c_i$, i = 5...1), and the q_i values follow.

In the second method (estimation "from recaptures"), catchability was estimated from the recaptures of marked-1 fish only when escapement did not occur during the first period ($W_1 = W_2$). In this case, $q_i = r_{1i}/M_{1i}$, where M_{1i} is the standing stock of marked-1 fish just before the set i. M_{1i} was calculated by successive subtraction of type-1 recaptures ($M_{1,i1} = M_{1i} = r_{1i}$).

The two methods of measuring q were compared using a distribution-free test (Wilcoxon's signed rank test, see Dagnélie 1975), which applies to paired data samples. The experimental design described above is summarized in Table 3.

Both methods rely on some underlying assumptions: A) no mortality of marked fish occurs; B) marked and unmarked fish have the same probability of escaping from the enclosure; C) the efficiency of the purse seine is equal for marked and unmarked fish; and D) all fish present in the enclosure have an equal probability of being caught. The method from captures relies on assumptions A), C), and D); the method from recaptures relies on A), B), and D).

RESULTS

Tagging and Holding Tolerance

No mortality of marked fish was observed during our experiment. This included the holding period in the floating cages as well as the fishing period (no dead marked fish were recovered in the seines). During the preliminary tests, however, marked fish of less robust species (*Ethmalosa fimbriata* and *Eucinostomus melanopterus*) were found dead in both the cages and the fishing nets.

Retention Rates

Purse seine captures and recaptures observed in the 15 independent mark-recapture experiments are listed in Table 2. The mean retention rates and the coefficient of variation were calculated for seven fish species and for the portunid crab *Callinectes amnicola*. The retention rate ranged from 0.47 to 0.79 for fish and was 0.10 for *C. amnicola*, which escaped in large numbers probably by burying itself. No fish were observed jumping over the purse seine net. Therefore, escapement appeared to be due to fish going under the lead-line.

Retention rates were estimated by size group for the two principal species, *Tilapia guineensis* and *Chrysichthys* spp. (grouping the three species, *C. maurus*, *C. auratus*, and *C. nigrodigitatus*). No difference was found between the size groups using a one-way analysis of variance by ranks (Kruskall-Wallis test, see Table 5).

The beach seine retention rates, W_1 and W_2, were calculated and their equality tested for the two principal species listed above (Table 4). For *Chrysichthys* spp., W_1 was always less than or equal to W_2. The mean retention rate (W) was 0.53. No size effect was found in the analysis of variance by size group (Table 5).

For *T. guineensis*, W_1 was less than or equal to W_2 in only two experiments. The mean retention rate was 0.35. In the three other experiments, the unexpected result of W_1 being greater than W_2 was found. This point will be discussed later. Again, no size effect was noticed (Table 5).

TABLE 4.—Estimation of the beach seine retention rates W_1 and W_2 (number of recaptured over number of released fish). If W_1 and W_2 do not differ significantly in one experiment (χ^2 test for the difference of two proportions, $P = 0.05$), the mean value W is then calculated. Parentheses mean a departure from the limit of application conditions of the test.

Retention rates	Capture dates (Oct. 1984) 8	9	12	13	16	Mean
Chrysichthys spp.						
W_1	7/15	57/78	28/107	78/141	31/106	
W_2	21/36	9/13	16/27	17/27	3/11	
χ^2	0.58	(0.36)	11.5	0.41	(0.13)	
W	0.55	0.73		0.57	0.29	0.53
Tilapia guineensis						
W_1	45/102	24/50	19/26	19/27	14/53	
W_2	38/90	28/92	27/102	13/36	8/27	
χ^2	0.07	4.31	19.5	7.2	0.09	
W	0.43				0.28	0.35

TABLE 5.—Comparison of the retention rates of purse seine (W) and beach seine (W_1 and W_2), calculated by size group: one-way analysis of variance by ranks (Kruskall-Wallis test). Critical value of $\chi^2_{0.95}$ is 7.81. M = mean, C.V. = coefficient of variation.

Purse seine					
Chrysichthys spp.					
Size	10–12 cm	13–15 cm	16–18 cm	>19 cm	χ^2_{obs}
W: M	0.725	0.776	0.686	0.622	2.21
C.V.	17	19	36	38	
Tilapia guineensis					
Size	8–11 cm	12–15 cm	16–19 cm	>20 cm	χ^2_{obs}
W: M	0.506	0.495	0.488	0.483	0.48
C.V.	50	43	68	49	
Beach seine					
Chrysichthys spp.					
Size	10–12 cm	13–15 cm	16–18 cm	>19 cm	χ^2_{obs}
W_1: M	0.563	0.476	0.386	0.377	0.75
C.V.	35	43	41	34	
W_2: M	0.565	0.632	0.600	0.250	0.40
C.V.	25	17	37	58	
Tilapia guineensis					
Size	8–11 cm	12–15 cm	16–19 cm	>20 cm	χ^2_{obs}
W_1: M	0.596	0.432	0.511	0.400	0.48
C.V.	35	23	66	47	
W_2: M	0.356	0.295	0.316	0.375	5.99
C.V.	38	25	67	111	

Catchability and Efficiency of the Purse Seine

The catchability equivalent to a purse seine set was estimated using both methods from captures (Table 6) and recaptures (Table 7). The mean and the standard deviation were then calculated.

For *Chrysichthys* spp., using the method from captures, q_c equaled 2.35% (SD = 5.38), and using the method from recaptures, q_r equaled 0.97% (SD = 2.03). Most of the variability of the q_c values comes from one set (#3, Date 13), where one quarter of the fish were caught. We tested the two q measures obtained for this set (24.2, 6.85) as outliers in their respective series (Dagnélie 1975, p. 34). With this procedure, the value to be tested was initially removed from the data, and a new mean and standard deviation were calculated ($q_c' = 1.20$, SD = 1.63). A Student's t statistic was then calculated (15.3 and 4.4 respectively) and compared with the 5% critical value $t_{0.05} = 3.6$. This allowed us to discard the data from set #3. After removal of the outlier set, the difference between the two estimations of q, tested using the Wilcoxon's signed rank test, was not significant at the 0.05 level. Thus, the 39 measures of q were pooled for the calculation of the mean ($q = 0.93$) and SD = 1.58. The efficiency was then calculated using Equation 1 to be 12% ($e = 0.93 \cdot 9.4/0.72$).

For *T. guineensis*, the two catchability estimation methods yielded the following results: using the method from captures (Table 6), the mean, noted q_c equaled 3.54 (SD = 1.70) and from recaptures (Table 7), the mean, noted q_r, equaled 1.39 (SD = 1.44).

We compared the two samples (Wilcoxon's rank test) and found a highly significant difference ($P = 0.01$). The q_r value was considered to be more reasonable and the reasons will be discussed later. The efficiency follows was then calculated to be 18% ($1.39 \cdot 9.4/0.72$).

Avoidance of the Purse Seine

The avoidance rate (u) was estimated using Equation (2), $e = u \cdot v \cdot w$ (pooled mean from Table 2), knowing e, w, and with v being equal to 1 in our experimental conditions. For *Chrysichthys* spp., $e = 0.12$ and $w = 0.73$, thus, $u = e/w = 0.16$. Thus active avoidance rate appears to be the main factor in the efficiency. For *T. guineensis*, the q_r estimation from recaptures

TABLE 6.—Estimation of the catchability relative to the purse seine by the method "from captures" (c_i = purse seine captures; N_i = standing stock; q_i = catchability %; C = beach seine catches; W = beach seine retention rate).

Dates (Oct. 1984)		Set numbers 1	2	3	4	5	6	C,W
Chrysichthys spp.								
8	c_i	4	1	13	6	15		149
	N_i	310	306	305	292	286	271	0.55
	q_i	1.29	0.33	4.26	2.05	5.24		
9	c_i	0	10	0	0	0		1,031
	N_i	1,367	1,367	1,357	1,357	1,357	1,357	0.76
	q_i	0	0.73	0	0	0		
13	c_i	3	0	32	4	1		56
	N_i	135	132	132	100	96	95	0.59
	q_i	2.22	0	24.2	4.00	1.04		
16	c_i	0	2	1	2	5		202
	N_i	641	641	639	638	636	631	0.32
	q_i	0	0.31	0.16	0.31	0.79		
Tilapia guineensis								
8	c_i	16	17	9	26	28		165
	N_i	480	464	447	438	412	384	0.43
	q_i	3.33	3.66	2.01	5.94	6.80		
16	c_i	3	5	9	5	3		47
	N_i	193	190	185	176	171	168	0.28
	q_i	1.55	2.63	4.86	2.84	1.75		

TABLE 7.—Estimation of the catchability by the purse seine by the method "from recaptures" (m_i = marked fish; r_i = recaptured fish; q_i = catchability, as a percentage).

Dates (Oct. 1984)		Set numbers 1	2	3	4	5
Chrysichthys spp.						
8	r_i	0	0	0	0	1
	m_i	16	16	16	16	16
	q_i	0	0	0	0	6.25
9	r_i	0	0	0	0	0
	m_i	78	78	78	78	78
	q_i	0	0	0	0	0
13	r_i	0	0	10	3	0
	m_i	146	146	146	136	133
	q_i	0	0	6.85	2.21	0.00
16	r_i	0	0	1	1	2
	m_i	100	100	99	98	97
	q_i	0	0	1.01	1.02	2.06
Tilapia guineensis						
8	r_i	1	5	1	1	3
	m_i	133	112	107	106	105
	q_i	0.88	4.46	0.93	0.94	2.89
16	r_i	1	0	0	1	0
	m_i	53	52	52	52	51
	q_i	1.89	0	0	1.92	0

yielded $e_r = 0.18$ and $w = 0.54$ (Table 2), thus, $u_r = 0.33$. According to these results, the purse seine seems comparably efficient for both species (12% and 18%), but the avoidance and the escapement rates are very different.

Species and Size Selectivity

The total catches by the purse seine (25 sets) and by the beach seine (5 sets) are summed in Table 8, along with the ratio of these values. Important difference appear between the ratios for the 16 species listed. They range between 0.003 and 0.17; this will be termed "species selectivity".

The same ratio was also computed by size group for seven species and analyzed using a Kruskall-Wallis one-way analysis of variance (Table 9). A large size effect, termed here "size selectivity", appears for *T. guineensis* and is likely for *Gerres nigri*, but is not significant for the other species.

TABLE 8.—Total catches in number by purse seine (PS) and beach seine (BS) during the whole experiment. The mean ratio of catches per set by both gears is calculated with the coefficient of variation (C.V.) expressed as a percentage.

Species	PS	BS	Ratio	C.V.
Gerres nigri	167	8,591	0.0039	130
Pomadasys jubelini	6	143	0.0084	101
Tylochromis jentinki	22	366	0.0120	32
Chrysichthys auratus	139	2,232	0.0125	127
Chrysichthys maurus	26	384	0.0135	120
Chrysichthys nigrodigitatus	9	96	0.0187	127
Caranx hippos	2	17	0.0235	132
Elops lacerta	135	1,049	0.0257	39
Arius latiscutatus	6	32	0.0375	173
Ethmalosa fimbriata	1,958	8,816	0.0444	37
Trachinotus teraia	11	44	0.0500	148
Sarotherodon melanotheron	27	81	0.0667	156
Callinectes amnicola	96	137	0.1401	261
Citharichthys stampflii	61	75	0.1627	145
Tilapia guineensis	362	437	0.1657	18
Penaeus notialis	1,234	32	7.7125	92
Total	2,973	22,963	0.0259	

DISCUSSION

The validity of the different results depends to a large extent on the robustness to departures from the underlying assumptions: no marking and holding stress, no mortalities, and no enclosure effect (e.g., accessible stock may differ from the standing stock if fish are crowded along the enclosure).

Escapement

For the *Chrysichthys* spp., the estimates of the retention rates are consistent with estimates of catchability and seem valid. On the other hand, for *T. guineensis*, the retention rates lead to unexpected results on three occasions ($W_1 > W_2$, Table 4). Marked-1 fishes escaped less than

TABLE 9.—Comparison of the catches per set by both gears, by size group, using a one-way analysis of variance by ranks (Kruskall-Wallis test). Critical value of $\chi^2_{0.95}$ is 7.81.

Species		Size group 1	2	3	4	χ^2_{obs}
Tilapia guineensis	R	1.127	0.804	0.556	0.154	12.78
	C.V.	35	23	48	32	
Gerres nigri	R	0.012	0.023	0.036	0.102	6.15
	C.V.	105	130	99	54	
Elops lacerta	R	0.144	0.092	0.113	0.244	0.09
	C.V.	18	181	87	32	
Ethmalosa fimbriata	R	0.202	0.454	0.376	1.091	2.38
	C.V.	58	1,289	166	201	
Chrysichthys auratus	R	0.065	0.065	0.030	0.077	3.44
	C.V.	130	164	181	235	
Chrysichthys maurus	R	0.162	0.040	0.029	0	5.82
	C.V.	175	294	84		
Chrysichthys nigrodigitatus	R	0.087	0	0.187	0.080	2.30
	C.V.	57		140	163	

marked-2 ones, even though they spent more time inside the beach seine and thus had more opportunities to escape. To explain this result, consider how the two sets of marked fish might have differed: 1) by sampled sizes, 2) by the type of mark, and 3) by the duration of the holding period. Sampling of sizes does not need to be examined because there was no significant correlation between the size and the retention rate. The type of mark itself did not seem likely to influence the fish behavior. However, the duration of the holding period was much longer for marked-1 fish, increasing the opportunities to escape and thus to overestimate W_1. For *T. guineensis*, the two q estimations (Tables 6, 7) differed to a large degree. This was probably due to the stress on marked-1 fish, leading to an overestimation of W_1, and thus to an overestimation of the catchability (q_c) calculated by the capture method. The W value that would produce a catchability estimate of $q_r = 1.39\%$ has been calculated iteratively and equals 14%. This retention rate is very low but is consistent with the known behavior of this cichlid species, which escapes from beach seines by slipping under the lead line and by jumping over the net (to recover the jumping fish, local fishermen often place small canoes equipped with net curtains along the seine).

In any case, a retention rate estimated with a marking procedure is greater or equal to the actual efficiency and can be used as an upper estimate of the efficiency. For example, efficiency of the purse seine for the crab *C. amnicola* is smaller than the observed 10% retention rate (Table 3).

The comparison of the retention rates for both seines indicates that the purse seine is more efficient in limiting escapement than the beach seine. This can be explained to some extent by the difference in the duration of the sets (22 minutes versus 6 hours). The rigging of the gears may also have an influence; the purse seine lead-line hugs the bottom, owing to the drag and weight of the rings, more efficiently than the beach seine; noise and vibrations in the ropes also generally keep the fish away from the net (Hemmings 1967). Therefore, pursing is more efficient than the manual closing of the beach seine. The better efficiency of the purse seine should, however, not be generalized because the efficiency of a particular gear may be influenced by subtle differences of rigging (MacMullen 1981). We did observe during another experiment[3] some important differences in the efficiencies of two apparently similar purse seines, probably resulting from a slight difference in lead-line weights.

Species and Size Selectivity

Other robust results came from a comparison of the catch rates of the two gears in terms of species relative abundance (species selectivity) and size distribution (size selectivity).

Species selectivity is due to differences between the efficiencies, which depend upon complex interactions between the gears and the behavior of the species. In this experiment, an additional "enclosure effect" can happen if all fish are not equally available. For instance, by crowding along the net, the fish become inaccessible to the purse seine (p_A, the overall accessibility is then less than 1).

The ratio of catch rates by the two gears, calculated in Table 8, can be compared to the theoretical value that would be obtained if both gears were equally efficient, and if the avoidance rate for beach seine was negligible. This can be assumed as a first approximation since the net is very large (1,100 m) and fairly silent (no engine was used in the boat).

From the formulas given above (see methods: estimation from captures):

$$c_i = \frac{q \cdot C}{W} \cdot \frac{1}{(1 = q)^{6-i}} \qquad \text{and } r = \frac{q}{W} \cdot \alpha,$$

$$\text{with } \alpha = \frac{1}{(1 - q)} + \frac{1}{(1 - q)^2} + \ldots + \frac{1}{(1 + q)^5}$$

since $q = p_a \cdot e$, then $r = p_a \cdot (e/W) \cdot \alpha$.

The parameter r appears to be roughly proportional to e/W, α being a correction factor accounting for the successive catches in the enclosure. The parameter α, depending on the value of e, which varies between 0 and 1, is in the interval (1–1.276). If the efficiencies of the two gears are equal ($e = E$ or $e = W$, since U is assumed to be equal to 1), r is in the interval $[p_a - 1.276 \cdot p_a]$, that is [0.076–0.097]). In Table 8, r is smaller than 0.076 for most fish species, indicating lower efficiency of the purse seine. On the contrary,

[3]Cantrelle, I., E. Charles-Dominique, Y. N. N'Goran, and J. Quensière. 1983. Etude expérimentale de la sélectivité de deux sennes tournantes et coulissantes (maillage 25 mm et maillage mixte 14–25 mm) en lagune Aby (Côte d'Ivoire). Unpubl. rep., 36 p. Cent. Rech. Océanogr, Abidjan.

the purse seine is more efficient for the burrowing species (*Callinectes* spp., *Citharichthys stampflii, Penaeus notialis*) and for *T. guineensis*.

Size selectivity appears for two species (*T. guineensis* and *G. nigri*) when the ratio of catches is calculated by size group (Table 9). As it has been shown above for the marked species, the size composition of fishes in the enclosure during the experiment does not differ from that of the final catches of the beach seine. Two factors remain explaining this size selectivity: 1) a size selective accessibility within the enclosure and 2) a size selective catchability by the purse seine. The first factor is impossible to assess. The second one may happen with active gear, like the seines. Larger individuals may be better able to avoid capture because of their higher maximum swimming speed (Bainbridge 1958; Blaxter 1967). This type of size selectivity has been shown in sampling plankton larvae with an experimental active gear (Murphy and Clutter 1972), and may here explain the decrease in the ratio of the catch rates with size in *T. guineensis*.

In *G. nigri*, the selectivity is reversed, small sizes being underrepresented in the purse seine catches. This point seems difficult to interpret, and probably complex mechanisms are involved: enclosure effect (size-dependent accessibility) and size dependent catchability owing to complex behavior. Some descriptions of complex behavior of fish during a fishing operation are given in the literature. For trawlers and Danish seines, the flight is triggered by a stimulus, mainly visual, from the moving gear at a certain distance (MacMullen 1981). Different species react differently; some demersal species jump perpendicularly, while others jump in random directions (Hemmings 1967). Anchovies surrounded by a purse seine tend to move into deeper waters (Inoue and Ayodhyoa 1967).

Efficiency

For the results of the efficiency measurement to be valid, all of the assumptions must be met. Consequently, efficiency estimates may not be completely reliable.

Efficiency of the purse seine for fishes larger than L_{100} is very low according to our results (*Chrysichthys* spp., 12% and *T. guineensis*, 18%). Actually, purse seining is an efficient technique when based on spotting and surrounding pelagic fish schools. However, it probably becomes very inefficient for "blind" fishing of demersal species, as was done in this experiment and as is often practiced in Ivory Coast lagoon fisheries. The main cause of this inefficiency is most likely the avoidance during the surrounding phase of the operation.

The efficiency of a large, nonmotorized beach seine, reaching the ground in shallow waters, depends mostly on a low escapement rate after closing the net. Estimation of the escapement rate by mark-recapture can thus provide a simple and reliable upper estimate of efficiency. However, it is important to stress that a general application of such values to the entire fishery is not possible unless the variability of gears and fishing grounds is considered.

ACKNOWLEDGMENTS

Our thanks go particularly to Jean Raffray, Yann Moreau, Aka Ledjou, and Bilé Adouéni for their valuable help during the field experiment; to the fishermen from Anga; to Nasséré Kaba for the initial translation into English; and to A. E. Dizon for his thorough review and his help.

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