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Fishing tactics and strategies in coastal demersal trawling fisheries in Senegal

Massal Fall[1], Alassane Samba[1] and Francis Laloë[2,a]

[1] Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), BP 2241, Dakar, Senegal
[2] Centre d'Économie et d'Ethique pour l'Environnement et le Développement (UMR 063 IRD-UVSQ)

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Abstract – Using catch composition data collected on individual fishing trips between 1990 and 2001, we study fishing tactics and strategies of the coastal demersal trawlers operating in Senegal. Types of fishing actions (tactics) are defined through catch composition on fourteen stocks. Types of fishing units (strategies) are defined according to the tactics they can use. These two typologies are built using the K Means method, a non hierarchical classification approach. As results, twelve tactics and six strategies are primarily identified. Using expert knowledge some fishing tactics are gathered and eight tactics and five strategies are finally considered and discussed with a presentation of the articulations between stocks, tactics and strategies.

Key words: Fishing tactics / Fishing strategies / Coastal trawler fleet / Demersal stocks / Typology / East Atlantic Ocean

Résumé – Tactiques et stratégies de pêche déployées par les chalutiers côtiers au Sénégal. Les tactiques et stratégies de pêche déployées par les chalutiers côtiers au Sénégal sont étudiées à partir des compositions spécifiques des captures obtenues lors de marées réalisées entre 1990 et 2001. Les types des marées (tactiques de pêche) sont définis à partir de la composition des captures selon quatorze stocks et les types d'unités de pêche (stratégies) sont définis à partir des listes de tactiques qu'elles peuvent mettre en œuvre. Les deux typologies sont construites à partir de la méthode des K MEANS, méthode de classification non hiérarchique. Douze tactiques et six stratégies de pêche sont d'abord identifiées. À partir de connaissances d'experts, des regroupements ont été faits et huit tactiques et cinq stratégies de pêche sont retenues et présentées avec les articulations entre stocks, tactiques et stratégies.

1 Introduction

Industrial fishery activity began in Senegalese waters (16 °04N–12°20N) in 1950 (Garcia et al. 1979). Indeed, fleet activities really took place around 1954–1955 after the settlement of processing and cold storage infrastructures. The first trawlers were small Mediterranean trawlers with on board refrigeration capacities which targeted Serranid and Sparid in the south of Dakar. Bottom fishing hook-and-line vessels were later introduced during the sixties by a FAO project (Kébé 1991). The discovery of coastal shrimp *Penaeus notialis* stocks in the north and the south of the country (1965–1966) led to the redeployment of some effort towards this species, with a consequent change of rigging and the advent of grey fish. Grey fish refers to species sharing the same biotope as the coastal shrimp and was initially considered as by-catch: e.g. *Cynoglossus* sp., *Galeoides decadactylus*, *Arius* sp., *Pseudotolithus* sp., *Umbrina* sp. Among other major events were the arrival of fish trawlers (since 1971) and freezer trawlers (since 1977), the spectacular explosion of *Octopus vulgaris* populations (since 1986), the advent of numerous export subsidies from 1980 (CRODT 1994), the promulgation of three maritime fishing codes (1976, 1987 and 1998), the signing of several fishing agreements with foreign states (mainly European states since 1974, secondarily Asian ones) and the devaluation of the franc CFA (1994). This later led to noticeable increases in fishing effort and incomes but disadvantaged local noble fish consumption due to more attractive prices abroad. More recently, biological rest periods for particular stocks have been adopted. Initially restricted to octopus and volutes *Cymbium* sp. (1997–2001), rest periods are currently applied to all demersal species since 2003 while concerning industrial fleets exclusively, not small-scale fishing. Rests normally last two months: from May to June for deep fish trawlers, from September to November for deep shrimp trawlers and from October to November for coastal fish cephalopods trawlers.

Many authors have studied the demersal fish communities in the waters of the West African sub-region (see Sidibé 2003). These studies confirm, review or complete the work

[a] Corresponding author: francis.laloe@mpl.ird.fr

Table 1. Main characteristics of the demersal stocks off Senegal.

Ecological Communities	Preferential localizations	Major species	Observations
Sciaenid Community (after Longhurst: Littoral Community)	• Warm coastal waters (0–40 m) Sandy and muddy bottoms • Proximity to mangrove zones (growth and refuge areas for juveniles) • Areas with high flood levels Estuarine areas with a notably important hydrographic network • Extension until the thermocline low level • Preferential area: Guinean Gulf (very favourable conditions, more than 50% of demersal catches; see Sidibé 2003)	• Fish: Sciaenid sensu stricto mainly (with dominance of cassava croakers *Pseudotolithus* sp. in the industrial catches) +Polynemidae + Ariidae + Cynoglossidae + Pomadasyidae + Drepanidae + Clupeidae • Mollusk: Volutidae, cuttlefish, squids • Crustacean: *Penaeus notialis, P. kerathurus* • Echinoderm (sea urchin, starfish) • Jellyfish, gorgonian, etc. (high variability of specific composition, and from one area to another)	Species with high level of tolerance in regard to salinity, and other endogenous factors
Eurybathic Community (Thermocline Community)	Between Littoral Community and Coastal Sparid sub-community	Shrimp (*Penaeus* sp.), sole (*Cynoglossus* sp.), *Trichiurus lepturus*, ray (*Raja miraletus*), shark (*Mustellus mustellus)*, *Brachydeuterus auritus*, etc.	Species hard to classify either among Sciaenid or Sparid community
Sparid Community (Shallow Community)	• **Coastal Sparid**: sandy and muddy bottoms, mainly muddy	Red porgies (*Sparus caeruleostictus*, *Dentex canariensis*), West African Goat fish (*Pseudupeneus prayensis*), white grouper (*Epinephelus aeneus*), Red Pandora (*Pagellus bellottii*), Flying gurnard (*Platypterus volitans*)	• Central part of the continental shelf • Great importance of calcium carbonate ($CaCO_3$) bottom values
	• **Deep Sparid**: sandy and muddy bottoms, mainly sandy. Under the thermocline, between 40 m and 100 m depth	Sparid (*Dentex angolensis, D. congolensis, D. macrophthalmus, Boops boops*), Carangid (*Trachurus* sp.), Triglidae and Uranoscopidae (*Uranoscopus* sp.)	• Around 40 species • 3 discriminated biotopes
	• **Lutjanidae**: hard and rocky bottoms. Sub-community characteristic of the zones of outcrops of the base and benches of fossil sandstone or their proximity (West Africa)	Lutjanidae sensu stricto (*Lutjanus* sp.), O*ctopus vulgaris*, Acanthuridae (*Acanthurus monroviae*) and Chaetodontidae (*Chaetodon hoefleri, Capros aper*)	
Deep Community (Deep Shelf Community)	Shallow waters : 70–200 m depth Bottoms: muddy or sandy muddy	e.g. Jon Dory (*Zeus faber*), bearded brotula (*Brotula barbata*), rockfish (*Scorpaena* sp.), grouper (*Epinephelus caninus*), deep *Dentex*	Around 30 species
Continental Slope Community	Sandy and/or muddy bottoms from 100 to 1000 m, depending on species	e.g. hake (*Merluccius senegalensis, M. polli)*, West African Geryon (*Geryon maritae*), deepwater rose shrimp (*Parapenaeus longirostris*)	

of Longhurst (1969), one of the first to propose an ecological assemblage of species, leading him to distinguish seven (7) communities: Sciaenid, Eurybathic/Thermocline, Sparid with three sub-communities (Coastal Sparid, Deep Sparid and Lutjanidae), Deep shelf and Continental Slope Communities. In the Senegalese context, information is available from several sources including Domain (1980), Chabanne (1987), Jouffre et al. (2004), Domalain et al. (2004). The main characteristics of the identified communities are summarized in Table 1.

Over several decades these communities seem to have been affected more quantitatively (e.g. through the decline of their biomass, indices of abundance, etc.) than qualitatively, since no change nor deep/stable modification in the specific composition of the remaining biomass has been highlighted in recent studies (Jouffre et al. 2004; Domalain et al. 2004). Relevant species appear closely linked to the bathymetry and bottom-dwelling nature while their stability could be interpreted as an adaptation to a relatively strong fishing pressure (Jouffre et al. 2004).

In this paper, we study the fishing tactics and strategies employed by both Senegalese and foreign coastal bottom trawlers operating in Senegal, with respect to works which have dealt with small-scale Senegalese fisheries (Laloë and Samba 1991; Pelletier and Ferraris 2000; Pech et al. 2001). The analysis of data from catch effort surveys made on small scale fisheries highlights the fact that many fishing units may choose among several types of fishing actions with different impacts on the resource (catch composition). In order to take this into account,

it is necessary to explicitly distinguish typologies of fishing actions and typologies of fishing units which are units of a different nature. As the choice of a fishing action results from a decision process, we consider that the type of fishing action is a tactic chosen by a fishing unit through the application of its strategy. A fishing action can be described by a combination of many characteristics (time, place, depth, ground, fishing gear, etc. that can be used as *criteria* to identify the type of a given fishing action, but the *definition* of a type is related to its impact on the resource which means that "*Two fishing actions belong to a same tactic if they have, at each given moment, equal probabilities of catching any given part of the resource*" (Pech et al. 2001). This sentence defines an equivalence relation. The strategy of a fishing unit leads it to choose with some probability each of the available types of action. We may therefore consider another equivalence relation according which "*two fishing units belong to a same strategy if they have, at each given moment, equal probabilities of using a fishing action belonging to a given tactic"*. As a consequence, fishing units of the same strategy have the same set of available tactics from which a boat's decision maker makes his/her choice. Strategies may be elective (if one tactic almost dominates) or composite (if several tactics are applicable). These definitions do not imply that two fishing units of a same strategy always use the same tactic at a given time, or that two fishing units using the same tactic at a given time necessarily belong to the same strategy.

This need of explicit distinction between typologies for fishing actions and fishing units is not new and was identified by several authors (e.g. Laurec et al. 1991; Ulrich et al. 2002; Holley and Marchal 2004; Ulrich and Andersen 2004), but there is no clear consensus on the definitions and on the words. For example the word fisheries can refer to groups of vessels (Holley and Marchal 2004) or to groups of trips (Ulrich and Andersen 2004). It may also be associated with particular species or stock (e.g. herring fishery, cod fishery, etc. The word "métier" is often associated with a characteristic of a fishing action (Laurec et al. 1991) but can also refer to a list of gears for polyvalent fishing units.

In this paper, we propose an identification of tactics and strategies according to the definitions given above and using data of catch composition obtained during fishing trips of Senegalese trawlers between 1991 and 2001. Cluster analyses are common tools for achieving such operations with such data (Biseau and Gondeaux 1988; Pelletier and Ferraris 2000; Holley and Marchal 2004; Ulrich and Andersen 2004).

The Senegalese demersal stocks are generally over exploited (Caverivière and Thiam 1993). They represent strategic resources as a source of devises and as a focal point during fishing agreement negotiations, particularly those between Senegal and European Union. The fleets targeting such resources are old (25 years old on average) and have not been upgraded due to lack of finances. Largely dominated by Senegalese boats (97%), they generally operate over 6 miles from the coast and are composed of shrimp trawlers and fish-cephalopod trawlers. The first ones are blamed for destroying the coastal biotope and stocks due to the small stretched mesh size of their nets (50 mm). The second group uses 70 mm stretched mesh size trawls. They include very small boats ("rougettiers") whose owners wish to be classified as small-scale fleets which are permitted to operate inside the 6 miles coastal zone.

All these points highlight the need for knowledge concerning fishing tactics and strategies in order to provide local authorities with improved fisheries management tools. To do this, it is necessary to extend the works done on small scale fisheries to the other components of the fisheries exploitation system. The diversity of fishing units and target species may result in possible flexibility of the fleet activities that may be very important in terms of exploitation dynamics. A good knowledge of tactics and strategies according to the definitions used here can be very useful for evaluating these dynamics and their possible consequences (Laloë and Samba 1991).

2 Materials and methods

2.1 Data

We have used data collected by observers at the Dakar fishing port and fish processing factories through a sampling system implemented by the Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), in Dakar, Senegal. These data are available from 1990 to 2001 and concern bottom trawlers operating on the continental shelf (0–200 m depth).

Each of the 27 271 available observation units is relative to a fishing trip described by 49 variables. The global dataset is therefore a matrix of 27 271 lines and 49 columns. Among the variables, 9 are discrete: year (1990 to 2001), fortnight (half a month) (1 to 24), boat name (266 trawlers), fishing operation mode (alone or by pair),nationality (Senegal, France, Spain, Italy, Greece, Netherlands, the Gambia or Korea), onboard catch storage methods (fridge, freeze), fishing license (shrimp, fish-cephalopod), and fishing grounds (South, Centre and North of Senegal and Mauritania, Fig. 1). The 40 remaining quantitative variables are the engine power (in horse power), the gross tonnage (in gross registered tonnage), the nominal effort (in hours at sea) and 37 catches by species or groups of species (in kg) of which 14 are really important due to their commercial interest or to their abundance. These 14 species are: bearded brotula *Brotula barbata* (BRO), Carangidae (CAR), coastal shrimp *Penaeus notialis* (PEN), deep shrimp *Parapenaeus longirostris* (PAR), cat fish *Arius* sp. (MAC), red pandora *Pagellus bellottii* (PAG), west African goat fish/red mullet *Pseudupeneus prayensis* (ROU), cuttlefish *Sepia officinalis hierredda* (SEI), tongue sole *Cynoglossus* sp. (CYN), grunts (POM) *Pomadasys* sp. excluding *P. incisus,* lesser African threadfin *Galeoides decadactylus* (TKM), an assemblage of miscellaneous species (DIV), Canary drum *Umbrina* sp. (OMB) and octopus *Octopus vulgaris* (POU).

Data specifically used for fishing tactic and fishing strategy typologies are described hereafter:

- as fishing tactics are types of fishing actions based on catch compositions, we shall consider a classification of the 27 271 fishing trips, each trip being described by the 14 catches per species. Data consist therefore in a table of 27 271 lines and 14 columns corresponding to the

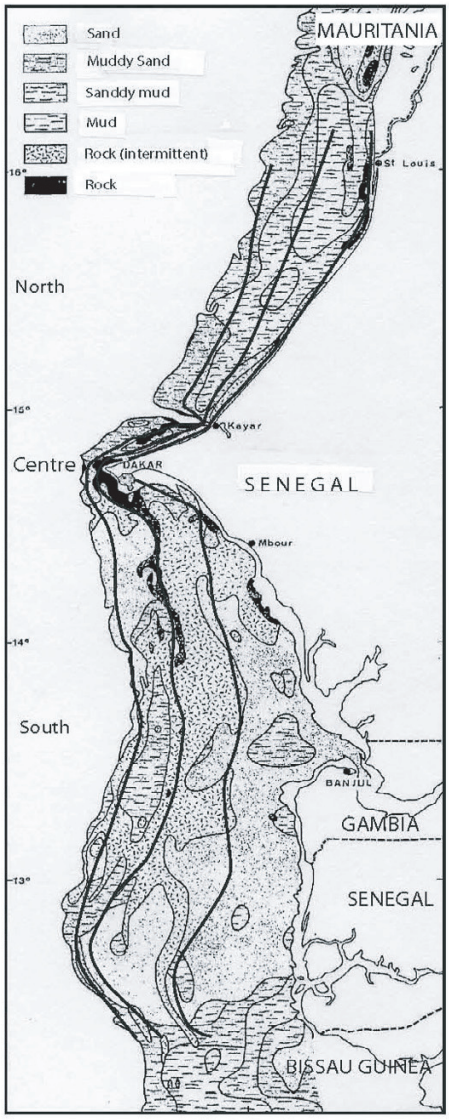

Fig. 1. Map of the Senegalese shelf with isobath 20, 50 and 100 m (redrawn from Domain 1977).

14 stocks that are considered. As we look for catch compositions, each data is transformed into percent of the total catch of the corresponding trip.

- as fishing strategies are types of fishing units based on choice of tactics, we shall consider a classification of the 266 fishing units which are identified by the operating boat. Data consist in a table of 266 lines; each line consisting of the number of trips in each tactic made by the corresponding boat. As we look for tactic choices, data are transformed into percentages of total trips per line.

2.2 Methods

Coastal bottom trawlers in Senegal may choose to target different sets of species. A fishing unit may therefore have an alternative set of choices (see McFadden 1973). Each element of such a set corresponds to a tactic with a given multispecies catch composition. Catch composition can therefore be used as a criterion to identify tactics and each fishing trip belongs to one tactic. We can thus consider the number of trips done by each fishing unit according to each tactic leading to identify its typical "alternative set of choices"; that can be used to identify the strategies.

Both fishing tactic and strategy typologies are built using the K Means method (Mac Queen 1967; Kaufman and Rousseeuw 2005). This method is one of several methods that can be used and we do not pretend here that it is the unique best possible choice. It is widely applied among non-hierarchical clustering techniques and is well adapted to very large set of data. It proceeds with an iterative process by giving an arbitrary initial partition in k clusters and searching for an optimal classification according to a criterion (e.g. minimization of the total within clusters sums of squares):

$$\sum_{c=1}^{k}\sum_{i=1}^{nc}\sum_{l=1}^{p}(Y_{ci}^{l}-\bar{Y}_{c}^{l})^{2}$$

k: number of clusters,
nc: number of units in the cluster c,
c, and p: dimensions of the variable (i.e. number of stocks for the tactic analysis and the number of tactics for the strategy analysis).

At each iteration affectation to clusters changes, either through transfer of one object or a swopping between two of them. The change is accepted if it leads to a progress according to the criterion. We chose to minimize the total within clusters sums of squares because the quality of this criterion does not rely on assumption on multinormality or equality of within class dispersion (Payne et al. 2002). According to the case, each obtained cluster can be considered either as a fishing tactic (cluster of trips) or as a fishing strategy (cluster of fishing units). For a given number of clusters, the final value of the criterion is given. We made analyses with different numbers of clusters among which we chose the most realistic solution considering the evolution of the criterion value. Fishing tactics and strategies can be described through mean values obtained (centroids). All identified tactics and strategies have afterwards been submitted for validation to a ship owner with 40 years of experience.

Pech's diagram

Once fishing tactics and strategies were established, a Pech's diagram (Pech et al. 2001) was built for a synthesis. The diagram allows the visualization of articulations between stocks, strategies and tactics through two-by-two combinations of these typologies (list of the catchable stocks for each tactic and list of available tactics for each strategy. In the case of Senegalese small scale fishery, Pech et al. (2001) provided a more complete diagram with tactics and strata relationships of the sampling design used for catch-effort surveys. This part is not relevant here because we considered an unique population of trips done by bottom trawlers.

Table 2. Labels, number of trips and species compositions (percent) of the 12 globally identified tactics. DIV: miscellaneous species, BRO: *Brotula barbata,* CAR: Carangidae, PEN: *Penaeus notialis,* PAR*: Parapenaeus longirostris,* MAC: *Arius* sp., PAG: *Pagellus bellottii,* ROU: red mullet *Pseudupeneus prayensis,* SEI: *Sepia officinalis hierredda;* CYN*: Cyynoglossus* sp., POM *Pomadasys* sp. excluding *P. incisus,* TKM: *Galeoides decadactylus, OMB: Umbrina* sp, POU: *Octopus vulgaris*.

Tactics	DIV	BRO	CAR	PEN	MAC	PAG	ROU	SEI	CYN	POM	TKM	OMB	PAR	POU
Tactic 1 - Grey Fish 1 3214 trips	5	1	1	5	7	1	1	5	24	6	13	**30**	0	1
Tactic 2 - Red mullet 1 2948 trips	14	0	0	0	0	5	**63**	10	0	0	0	0	0	7
Tactic 3 - Coastal shrimp 1662 trips	11	0	1	**45**	4	2	1	6	12	2	6	7	0	1
Tactic 4- Miscellaneous 12 194 trips	**77**	1	0	4	0	1	3	3	8	1	0	0	0	2
Tactic 5 - Cuttlefish 2148 trips	12	0	1	3	1	2	10	**53**	7	2	2	2	0	6
Tactic 6 - Bearded Brotula 1096 trips	11	**55**	7	1	0	11	0	1	3	0	1	1	0	8
Tactic 7 - Red mullet 2 4406 trips	**46**	0	0	0	0	1	35	11	0	0	0	0	0	6
Tactic 8 - Red Pandora 1880 trips	14	2	3	1	1	**45**	18	6	1	1	1	2	0	5
Tactic 9 - Miscellaneous 2 2057 trips	**50**	1	1	11	1	1	1	9	14	3	2	2	1	4
Tactic 10 - Grey Fish 2 3012 trips	10	1	10	2	18	3	1	5	3	**22**	11	8	3	1
Tactic 11- Octopus1 1014 trips	4	0	0	1	0	0	2	5	1	0	1	0	0	**83**
Tactic 12 - Octopus 2 1640 trips	12	1	2	2	1	4	14	18	4	2	2	1	0	**38**

3 Results

3.1 Fishing tactics

Because of a quite regular relationship between the criterion value and the number of clusters, the K-mean analysis done with different numbers did not provide a clear answer to the question of this number. We chose to first select twelve fishing tactics (Table 2). This choice was mainly done on the basis of the coherence of the results with available knowledge on fish communities (see introduction). The arbitrary initial partition given by the computer program (GENSTAT, see Payne et al. 2002) with 12 clusters of equal size provides a within clusters sum of squares equal to 614×10^5, and the final value is reduced to 193×10^5). Further, on the basis of expert knowledge (see discussion) and of the existence of similarities between some clusters, we finally decided to retain the eight following tactics after aggregations. The name of each tactic indicates the stock which can be considered as the main target (*MT*) of the tactic: MT-Grey fish (tactic 1 + tactic 10), MT-Red mullet (ROU = tactic 2 + tactic 7), MT-Miscellaneous (DIV = tactic 4 + tactic 9), MT-Octopus (POU = tactic 11 + tactic 12), MT-Coastal shrimp (PEN = tactic 3), MT-Cuttlefish (SEI = tactic 5), MT-Bearded Brotula (BRO = tactic 6) and MT-Red Pandora (PAG = tactic 8). The new catch compositions according to such decision are given in Table 3. Grey fishes include here OMB, CYN, TKM, MAC and SOM whose global percentages respectively reach up to 80% for tactic 1 and to 65% for tactic 10.

In addition to comparable species compositions, onboard conservation methods, fishing grounds and fishing periods analyses provide interesting results:

- According to onboard conservation methods, fishing trips of freeze trawlers are dominant in the MT-coastal shrimp tactic. For all the remaining fishing tactics, fishing trips are mainly done by fridge trawlers. This is particularly true in the case of the MT-red mullet tactic for which the proportion of fridge trawler fishing trips reaches up to 95% (Table 4).
- According to fishing grounds, the south of Senegal is the most important fishing area for the following tactics: MT-grey fish (65% of fishing trips), MT-coastal shrimp (68%) and MT-miscellaneous (59%). The centre of Senegal is of great importance for the MT-red mullet (82%), MT-red pandora (54%) and MT-octopus (55%) tactics. The tactics MT-cuttlefish and MT-brotula are lightly dominant respectively in the Central and the Northern part of the Senegalese coast (Table 4).
- We observe (Fig. 2) a high between-years variability of the number of trips per tactic without any clear increasing or decreasing trends over the whole period. The octopus tactic had a special importance in 1999; a year during which 58% of all fishing trips belong to this tactic. There is no evidence of an effect of the devaluation of the franc CFA (1994) on the repartition of tactical choices.
- According to seasonal trend, (Fig. 3) the fishing trips of MT-coastal shrimp, MT-cuttlefish, MT-red pandora and

Table 3. Species compositions (percent) after aggregation of tactics. Species abbreviations, see Table 2.

	Species													
Tactics	**DIV**	**BRO**	**CAR**	**PEN**	**MAC**	**PAG**	**ROU**	**SEI**	**CYN**	**POM**	**TKM**	**OMB**	**PAR**	**POU**
MT-Grey Fish	8	1	6	4	13	2	1	5	14	14	12	19	2	1
MT-Red Mullet	30	0	0	0	0	3	49	11	0	0	0	0	0	7
MT-Miscellaneous	64	1	1	8	1	1	2	6	11	2	1	1	1	3
MT-Octopus	8	1	1	2	1	2	8	12	3	1	2	1	0	61
MT-Coastal Shrimp	11	0	1	45	4	2	1	6	12	2	6	7	0	1
MT-Cuttlefish	12	0	1	3	1	2	10	53	7	2	2	2	0	6
MT- Bearded Brotula	11	55	7	1	0	11	0	1	3	0	1	1	0	8
MT-Red Pandora	14	2	3	1	1	45	18	6	1	1	1	2	0	5

Table 4. Proportions (percent) of fishing trips within tactics according to conservation methods, and according to fishing grounds respectively.

	MT Grey Fish	MT Red Mullet	MT Miscellaneous	MT Octopus	MT Coastal shrimp	MT Cuttlefish	MT Bearded Brotula	MT Red Pandora
Onboard conservation methods								
Freeze trawlers	38	5	43	38	79	36	33	22
Fridge trawlers	62	95	57	62	21	64	67	78
Fishing areas								
South of Senegal	65	14	59	35	68	45	42	27
Centre of Senegal	17	82	27	55	14	48	9	54
North of Senegal	15	2	13	7	17	4	46	15
Mauritania	0	1	0	3	1	1	2	3
Unknown	3	1	1	0	1	1	1	1

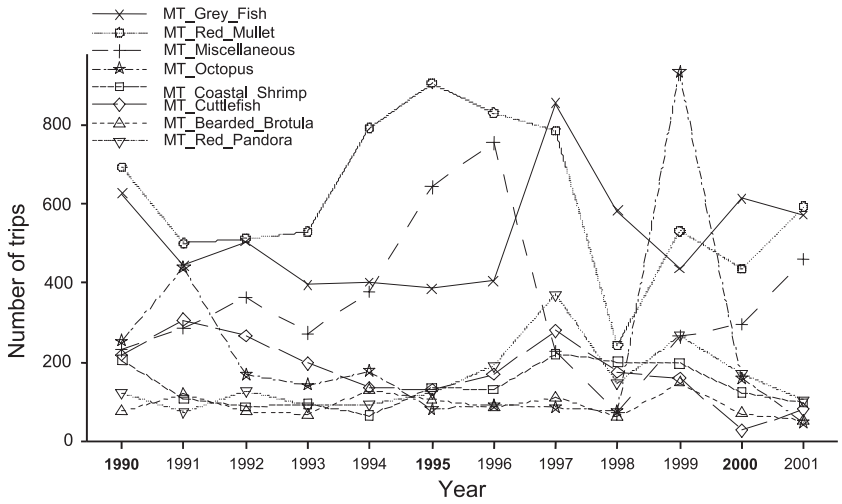

Fig. 2. Evolution of the number of trips within tactics by years.

MT-Bearded Brotula tactics are mainly done during the cold season (from November to May). The MT-octopus and MT-red mullet tactics chiefly occur during the hot season (June to October). No clear seasonality is related to the remaining tactics (grey fish and miscellaneous) which seem to have been quite stable during the studied period 1990–2001.

3.2 Fishing strategies

Six fishing strategies are primarily obtained (Table 5). The arbitrary initial partition with 6 clusters of equal size provides a within clusters sum of squares equal to 532×10^3, and the final value is equal to 305×10^3. The strategy VI gathers 4 boats (less than 2% of the 266 fishing units) that globally act like generalist trawlers (88% of probabilities for tactic 4/miscellaneous 1) with the lowest nominal effort (25 085 hours at sea). We finally decided to exclude the strategy VI from our fishing strategies (see discussion). The descriptions of the five remaining ones in terms of the eight tactic compositions (Table 6) and the boats essential characteristics (Table 7) are summarized here:

– Strategy I within which 68 trawlers have been classified. The most probable fishing tactic are MT-miscellaneous (DIV, 27%), MT-grey fish (25%) and MT-coastal shrimp (24%). The highest nominal effort (3 064 468 hours at sea), percentages of freeze trawlers (87%) and trawlers whose

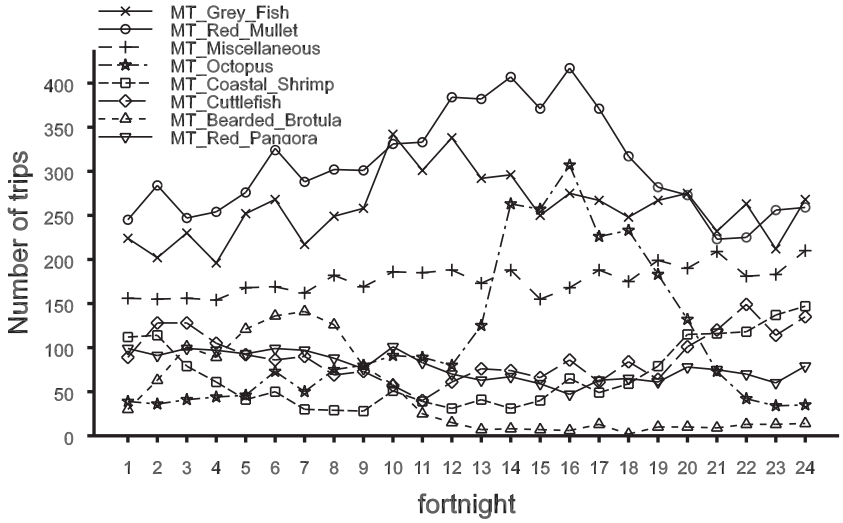

Fig. 3. Evolution of the number of trips within tactics by fortnight (half a month).

Table 5. Strategies tactics compositions (percent) on the basis of 12 tactics.

	Fishing Strategies					
Fishing Tactics	I Shrimp trawlers 68 boats	II Red Mullet trawler) 45 boats	III Deep fish trawler) 35 boats	IV Cephalopod trawlers 72 boats	V Coastal fish trawlers 42 boats	VI Generalist trawlers 4 boats
Tactic 1	16	2	44	5	6	4
Tactic 2	1	23	3	5	2	0
Tactic 3	24	2	4	3	3	0
Tactic 4	7	7	9	5	5	86
Tactic 5	7	8	3	18	8	0
Tactic 6	3	1	10	3	5	0
Tactic 7	2	40	2	4	2	0
Tactic 8	4	4	6	11	5	0
Tactic 9	20	3	4	7	7	2
Tactic 10	9	2	7	7	48	9
Tactic 11	3	2	6	13	7	0
Tactic 12	3	6	3	19	4	0

official license is *coastal shrimp* (78%) are observed in this strategy. Some trawlers with fish-cephalopod licenses may target shrimps. From all those different points of view, the whole fishing units ranged into such strategy can be considered as shrimp trawlers.

– Strategy II gathers 45 trawlers that mainly adopt MT-red mullet tactics (63% of chances). These fishing units include 6 of the 11 foreign boats while grouping the lowest mean gross tonnage (80 GRT), engine power (436 horsepower) and percentage of freeze trawlers (13%). This strategy is basically characterized by the presence of red mullet trawlers.

– Strategy III gathers 35 trawlers. Grey fish tactic (51%), miscellaneous tactic (13%) and bearded brotula tactic (10%) are the most probable choices. This leads to label the fishing units adopting such strategy as deep fish trawlers if one takes into account the noticeable proportion of bearded brotula tactic which belongs to deep stocks.

– Strategy IV gathers the highest number of boats (72 trawlers). It is, somehow, dominated by MT-cephalopod fishing tactics which globalize 50% of all choices (32% for octopus and 18% for cuttlefish). Thus, the fishing units adopting this strategy are typically cephalopod trawlers. These units are mainly freeze trawlers (65%) with fish-cephalopod licenses (81%), showing high mean gross tonnage, engine power and nominal effort

– Strategy V (42 trawlers), like strategy III, is dominated by the grey fish tactic (54%). Indeed, this strategy displays more coastal fishing tactics (e.g. cuttlefish) than strategy III. It is in that strategy V that one finds 12 of the 16 trawlers operating in pairs. Fishing units adopting this strategy are essentially fridge trawlers (71%) with "fish cephalopod" license (93%). They display the highest mean gross tonnage (276 GRT) and the greatest engine power (1066 horsepower). As all these points mainly highlight the coastal aspect of their activities, these boats can be seen as coastal fish trawlers.

4 Discussion

Miscellaneous species

We do believe that the miscellaneous species has somehow influenced the building of both our tactics and strategies

Table 6. Strategies compositions (percent) on the basis of 8 tactics.

Fishing Tactics	Fishing Strategies I Shrimp Trawlers	II Red mullet Trawlers	III Deep Fish Trawlers	IV Cephalopod Trawlers	V Coastal Fish Trawlers
	Number of trawlers				
	68	45	35	72	42
MT-Grey Fish	25	4	51	12	54
MT-Red Mullet	3	63	5	9	4
MT-Miscellaneous	27	10	13	12	12
MT-Octopus	6	8	9	32	11
MT-Coastal Shrimp	24	2	4	3	3
MT-Cuttlefish	7	8	3	18	8
MT-Brotula	3	1	10	3	5
MT-Red Pandora	4	4	6	11	5

Table 7. Main boat characteristics of the five strategies.

Characteristics	Fishing Strategies I	II	III	IV	V	Total
	Number of trawlers					
	68	45	35	72	42	262
Number of pair trawlers	1	0	2	1	12	16
Number of foreign fleet	0	6	1	3	1	11
Freeze trawlers (%)	87%	13%	29%	65%	29%	*
Shrimp trawlers (%)	78%	9%	31%	19%	7%	*
Mean Gross Tonnage (GRT)	159	80	146	261	276	*
Mean Engine Power (HP)	613	436	630	996	1066	*
Effort (hours at sea)	3 064 468	906 785	1 314 259	2 064 837	823 342	8 198 776

GRT = Gross Registered Tonnage, HP = horse power.

typologies. We could not ignore them due to their important role among the 37 initial species (22% of the total catches). Moreover, they figure in the CRODT databases as such. However, they appear in the catch composition of all tactics; in some cases, they are primarily classified as by-catch (e.g. with shrimps) or correspond to a large amount of mixed fish that are not easy to distinguish.

Fishing tactics

Our 12 previous tactics have been summarized in 8 according to species compositions, onboard conservation methods, fishing grounds and fishing period's similarities. In addition, the aggregating decision is supported by the following arguments:

- On the whole, tactics, as described in this paper, are coherent and realistic according to the Senegalese coastal bottom trawl fisheries context. For that purpose, we benefited from the conclusive point of view of the actors, mainly J. Marec, a captain and ship-owner with 40 years of experience. According to J. Marec (pers. comm.) the four couples of tactics (i.e. grey fishes 1 and 2, red mullet 1 and 2, miscellaneous 1 and 2, octopus 1 and 2) have no concrete meaning and so, should be considered through intuitive aggregations respectively as grey fishes, red mullet, miscellaneous and octopus tactics
- An interesting comparison can be made with a previous study (Lhomme 1978). Looking for fishing options in terms of targeted species of the Senegalese coastal bottom trawlers (data from 1969 to 1977), this author found the following types: coastal shrimp, cuttlefish, bearded brotula, red pandora, tongue sole, grey fish, red mullet and seabreams (*Dentex* sp. and *Sparus* sp.). Though our approaches differ, six of his eight targeted species may correspond to our tactics. Therefore, there are two main differences: (1) octopus tactic which appeared in the eighties (Caverivière 1990) (2) the tongue sole – that can be ranged within our grey fish tactic – and the group seabreams are not actually considered as targeted species.

Fishing strategies

The study of fishing units led us to distinguish six types of trawlers (shrimp trawlers/I, red mullet trawlers/II, deep fish trawlers/III, cephalopod trawlers/IV, coastal fish trawlers/V and generalist trawlers/VI) of which we excluded the later one.

Some of these strategies are somehow elective (II, III and V) if one considers that one of their tactics may globalize ≥50% of the probabilities of implementation. This situation expresses a kind of specialization. At first analysis, strategies III and V are quite close together as they respectively display 51% and 54% of grey fish tactics. Further, according to J. Marec (pers. comm.), those two tactics are not distinguished by fishermen. This difference appears to be the fishing depth as reflected by the species compositions. This could be related to the characteristics of trawlers: those of strategy V are more powerful and display higher gross tonnage.

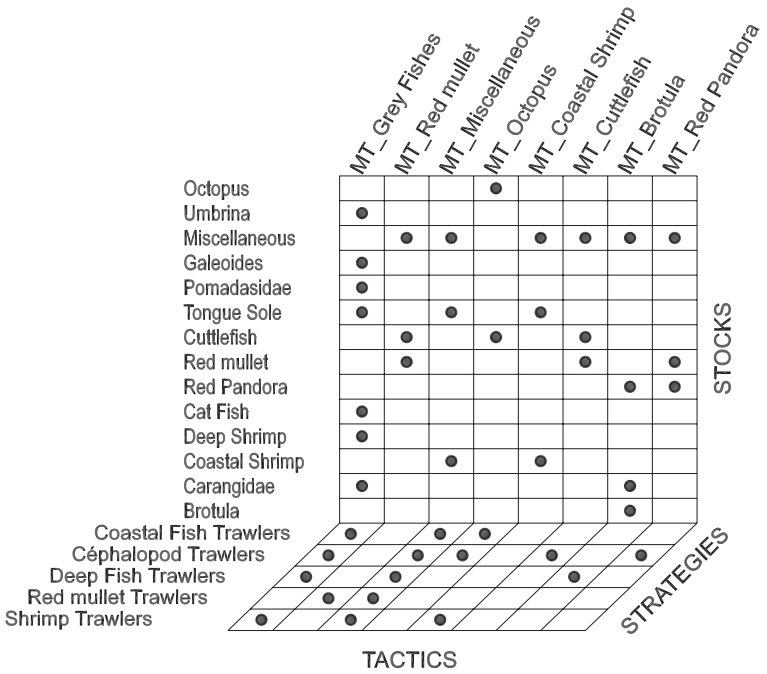

Fig. 4. Diagram of Pech. Relationships between stocks, strategies and tactics.
The names of strategies refer to fishing units that are all trawlers in this study. The names of the tactics refer to the stock or group of stocks which are the main target: MT-stock name.
Stocks-tactics combinations: a bullet indicates that the stock is significantly catchable by the tactic. Tactics-strategies combinations: a bullet indicates that a fishing unit with the corresponding strategy may choose to use the corresponding tactic.

On the other hand, strategies I and IV appear composite. In the case of strategy I, this is partly due to the important proportions of miscellaneous, grey fish and coastal shrimp tactics. We notice that grey fish and miscellaneous species can be by-catch for the shrimp fisheries or be specifically targeted in case of shrimp being scarce. The strategy IV appears to be more composite than strategy. It mainly gathers freeze trawlers but with higher mean gross tonnage (Table 6). Those boats could be considered as the most opportunistic fishing units of the whole fleet.

5 Conclusion

The articulations between typologies from the analysis represent the relationships between stocks, tactics and strategies within the Pech's diagram (Fig. 4). This diagram gives the list of main species caught by each tactic and the list of available tactics (alternative set of choices) for each strategy. Note that only the eight tactics (8) and five (5) strategies are considered.

Two of the boat categories that we have identified are formally taken into account by the Senegalese marine fishing law: shrimp trawlers and red mullet trawlers, the latter being ranged among cephalopod fish trawlers. In terms of coastal demersal fishing licenses, we think distinguishing deep fish trawlers from coastal fish trawlers is unnecessary. These boats are only two varieties of fish trawlers operating on the continental shelf that mainly target grey fish with respect to deep or coastal bathymetry. On the other hand, our study points out a new type of trawler: cephalopod trawlers whose activities in terms of seasonality and fishing grounds are known. We suggest segregating cephalopod licenses from fish licenses in Senegalese waters, like in the neighboring Mauritanian and Moroccan waters, if additional studies concerning jurisdictional and socio-economic aspects are performed.

Our study runs from 1990 to 2001 and points out eight tactics and five strategies. The limitation to such a period of time is due to availability of data. For the first time, these bottom trawler data have been clearly analyzed in terms of determining fishing tactics and strategies. Nevertheless, things have probably changed since 2001 in the same way we noticed differences in Lhomme's effort (1978) compared with our own. Such studies should be performed as frequently as possible for a consequent follow up of changes in the fisheries. There are potential differences between a formal fishing option (license, i.e. shrimp) and the effective fishing behavior (tactics, i.e. from fish to shrimp, including cephalopods) and, consequently, boat categories (a shrimp trawler that catches more fish and cephalopods than shrimp is hard to classify as so). Moreover, such analytical approaches are useful for dynamics studies of the resource and the exploitation as they may optimally categorize the fleet and its impact on resources. At last, this study draws the high tendency of freeze trawlers to dominate industrial fisheries in Senegal. One should focus on this fleet category that is more efficient than the fridge trawlers.

Such classifications of fishing trips and fishing units have been proposed for the Senegalese small scale fishery which harvest the stocks that are exploited by the bottom trawl industrial fisheries. These classifications have been used for an

analysis of the small-scale fishery with an attempt to account for interactions with industrial fisheries (Pech et al. 2001). This was done with the introduction of a synthetic virtual industrial strategy with fishing units having only one synthetic virtual industrial tactic available. This may be sufficient to describe some consequences of fixed changes of the impact of industrial activity (e.g. impact of the industrial trawler numbers on small scale fishing unit activities, see Laloë 2004), but not to describe consequences of changes on the industrial activity and impact (e.g. impact of some fish prices on the tactical choices of industrial vessels). To do this, we also need to provide typologies of fishing tactics and strategies of industrial fisheries. The present study is therefore a piece of research for which the objective is to provide a more complete analysis of the dynamics of the whole exploitation system of Senegalese ecosystems.

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