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Socio-Economic Perspectives of Transition in Inland Fisheries and Fish Farming in a Least Developed Country

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Abstract: Small-scale inland fisheries are essential for livelihoods and food security in developing countries such as Burkina Faso. However, there is a gap in research on the ongoing transformation of the sector toward sustainability. This article analyzes the transition in inland fisheries and aquaculture in Burkina Faso and its implications in terms of natural resources management, food security, and livelihoods. We used the Multi-Level Perspective (MLP) method as a reference transition framework and sampled using a mixed approach including 63 qualitative interviews, with fisheries experts and stakeholders, as well as quantitative data gathered through a representative survey with 204 fishermen's households. We examined open access, concession, and co-management fisheries systems. Our results show that technical and institutional changes in fisheries over the last decades deeply shaped and transformed fisheries governance. Technological changes improved the sector's productivity and its contribution to households' livelihoods. Fishermen's households consume up to 25% of fishermen's catches. The share of the catches consumed is typically higher when commercial fishing is "not important", but it remains typically low when it is "very important". The income is higher for fishermen who allocate more time to or gain more income from animals breeding. The establishment of state-based management affects the balance between the coexisting traditional and newer "republican" institutions. Concession and co-management niches can contribute to the empowerment of the stakeholders and establishment of more effective management. However, they are still dominated by the traditional and centralized state regimes and governance. The support of the socio-technical landscape is paramount for the scaling-up of the fish farming niche, which has the potential to improve food security and sustain rural livelihoods in the least developed country, Burkina Faso.

Keywords: sustainability transitions; artisanal fisheries; aquaculture; livelihoods; food security; multi-level perspective; Burkina Faso; LDC



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1. Introduction

Since 2014, the global consumption of fish has doubled. Fisheries (wild-caught and farmed) provide a key source of income to over 820 million people [1,2]. According to the Food and Agriculture Organization of the United Nations (FAO), in 2016, the world's inland capture fisheries produced 11.6 million tons, representing 12.8% of total marine and inland catches [3]. The primary sector of capture fisheries and aquaculture engaged

59.6 million people; out of them, 19.3 million were involved in aquaculture and 40.3 million were involved in capture fisheries. In 2016, Africa's inland capture fisheries produced nearly 2.9 million tons, accounting for 25% of the global inland catches and ranking the continent second worldwide after Asia [3,4].

Inland fisheries are a rich source of nutrients, such as proteins and calcium, that are crucial to human health [5,6]. Fish constitutes the primary animal protein source and a vital component in ensuring food and nutritional security for many communities, especially in developing countries [6]. However, the assessments often fail to account for or underestimate the socio-economic importance of fisheries, particularly wild inland fisheries' contribution to food security and their role in rural economies in developing countries [6,7]. Inland fisheries have been perceived as "backward, informal and marginal" economic activities and are poorly integrated into national or local decision-making processes [7,8]. However, a rising tide of research in small-scale fisheries in recent decades drove the emergence of new global policy tools devoted to the small-scale sectors and concerted efforts to tally their size and impacts on a global scale [9].

Notwithstanding the above, the security of income derived from fisheries is potentially under threat, with approximately one-third of fish stocks beyond biological sustainability. The development of both industrial and artisanal fisheries production has led to the depletion of resources and a global crisis of the fisheries [10,11], affecting the livelihoods and nutritional situation of fishing communities especially in developing countries [11,12]. Since 1950, landings from inland waters have increased 400%, and many freshwater stocks are at risk of collapse [13,14]. They are threatened by overexploitation but also environmental change [15] and diverse drivers including chronic and widespread water shortage [16], overuse of water resources [4], intensive agriculture [17], and climate change [18–22]. In both developed and developing countries, the rising standards of living, combined with high income elasticities, led the demand for fish products to increase regularly and substantially. Nutritional transition (viz. dietary patterns' shift toward more protein-rich nutrition) [23,24] and rising standards of food consumption, following income increases, can affect the demand for fish directly [25].

Developing a comprehensive understanding of these related trends has been complicated by the long-standing dominance of bio-economic approaches in fishery science. Most conventional fishery management assessments [11,26] offered less consideration to social science and kept people at the periphery [26]. Thus, there is a need to reinvent fisheries management and assessment [26] by integrating economic and social features. In Burkina Faso (BF), fishing has long remained as a cultural activity. To date, the sector is still marginal at the macroeconomic level; its contribution to the gross domestic product (GDP) is less than 1% [27,28]. The national fish production has increased almost continuously since 1998 reaching 20,000 tons from capture fishing and 300 tons from aquaculture in 2016 [29]. However, BF relies on 87,000 tons (80%) from fish import to meet fish demand [29]. According to the General Directorate of Fish Resources (DGRH), in 2019, fish supply includes 27,803, 562, and 123,253 tons respectively from capture fisheries, aquaculture, and importation. Improving fishing efforts to make small-scale fisheries more economically efficient has long been at the heart of fisheries management strategies [11,30]. However, the debate about the nature of technology, how technology influences and is influenced by society, and what this implies for sustainable development is scarce in the literature and policy debates on sustainability [31]. Despite their importance as limiting factors, policies, institutions, and processes also have not always been grasped at their fair value [32]. Thus, there is a gap in analyzing possible transition in BF fisheries.

This paper addresses small-scale inland fisheries: both capture fisheries and aquaculture in particular fish farming. The paper analyzes the implications of transition dynamics in traditional fisheries practices and fish farming in BF through the lens of the Multi-Level Perspective on socio-technical transitions method (MLP) [33,34]. In particular, we described the ongoing changes, challenges, and the process of changes at the techno-economic, actor, and institutional levels. We also re-examined the evidence of changes in fisheries manage-

ment from a social science perspective. Rather than relying upon a mere chronological approach, we built on stakeholders' understanding of the socio-ecological changes and transformations in their fisheries.

2. Materials and Methods

2.1. Study Areas

This study is carried out in BF, a landlocked country situated in West Africa, between the latitudes 09°20' N and 15°03' N and the longitudes 02°20' E and 05°03' W. The population of the country is 20,321,378 [35] with an average annual growth rate of 3.1% [36,37]. The gross domestic product (GDP) is mainly based on the primary sector, including agriculture, livestock, forestry, and fisheries [38]. In 2018, the GDP per capita reached 715.12 USD [39]. In 2017, the country was ranked 183rd out of 189 countries, with a low Human Development Index of 0.423 [40]. Most (77.3%) of the population live in rural areas [41]. Out of a working population of 5,285,860 people, 81.1% live in rural areas. The majority of the working population is employed in the primary sector (80.04%), whilst the secondary and tertiary sectors absorb respectively 16% and 3.6% [41]. With an area of 274,000 km², the country is drained by five main rivers (Nakanbé, Nazinon, Mouhoun, Comoé, and Niger), which are almost all intermittent except the Mouhoun. These rivers belong to three international river catchments (Volta, Comoé and Niger).

Purposeful sampling identified three study areas as information-rich cases [42]—namely Moussodougou, Sourou, and Koubri—to thoroughly deal with transition in fisheries in both rural and suburban areas. Criteria such as geographical situation, the state-based management policies implemented, and the socio-cultural backgrounds were considered.

Moussodougou is a rural municipality located in the Cascades region, in the western part of BF. The Moussodougou Dam or Comoé Dam was built in 1991 in the Comoé basin. It was intended to compensate for the inadequacy of the Toussiana dam to meet the water needs of the Société Nationale-Société Sucrière de la Comoé (SN-SOSUCO) for sugar cane production and many actors (such as the rice farmers in the plain of Karfiguéla, the vegetable farmers, and other owners of orchards) located along the watercourse. The construction of the dam has strengthened these activities and given rise to new activities such as fishing. The Comoé reservoir fishery is managed under the concession regime, meaning that the central government has allocated an exclusive right of access to the fish resources to the local fishermen association.

Sourou is located in the northwestern part of BF, in the Boucle du Mouhoun region. It hosts the Sourou, which is a 150 km long river in the Mouhoun Basin shared between Mali upstream (90 km) and BF downstream (60 km). In BF, two hydraulic modifications of the Sourou resulted in a flooded area of approximately 10,000 ha [43] that serves for the irrigation of 39,000 ha, and it serves as a biotope for hippopotamuses and the migratory avian fauna. With a productive potential of 300 tons of fish per year, Sourou ranks fourth after the Kompienga, Bagré, and Samendéni fisheries [44]. Since 2004, the Sourou reservoir fishery has been managed under the participatory approach termed Aquaculture Perimeter of Economic Interest (PAIE) [45] then Fishery Perimeter of Economic Interest (PHIE) [46]. However, the management of the Sourou Lake is challenged by non-harmonized fishery rules between Mali and BF.

Koubri is a suburban municipality on the outskirts of the capital, Ouagadougou, in the central region. Agriculture is the main economic activity. Animal production includes the rearing of ruminants, poultry, and the capture of fish and shrimps. Koubri is part of the Nariarlé sub-basin, which is an affluent of the Nakanbé, the former White Volta River. It concentrates more than 79% of the water resources of the sub-basin Nariarlé [47]. Koubri is one of the most impounded areas in BF with about 8.8 reservoirs/100 km² [8]. The legal management implemented in the fisheries is the open access regime.

2.2. Reference Transition Frameworks: Multi-Level Perspective (MLP)

We used the Multi-Level Perspective (MLP) to analyze transition in fisheries. The MLP analyses transition as the result of interactions within and between three analytical levels: (i) the socio-technical landscape, (ii) the socio-technical regime, and (iii) the niche [34,48–55].

The socio-technical landscape consists of the macro level, meaning the wider exogenous environment that cannot be influenced by the niche and the regime in the short term [48,50,51]. It includes demographical trends [49,56], political ideologies [49], social and cultural values changes [48,49,57–59], environmental problems, e.g., climate change and resource degradation [49,56,57,59,60], macro-economic patterns such as global financial instability, international rules in economics and trade, and globalization [48,49,57,60], the material aspects of society [57], and vulnerability [48,60].

The socio-technical regime corresponds to the meso level, which is the locus of established practices and associated rules that stabilize existing systems [49]. It encompasses the network of actors, social groups, and institutions (viz. the formal and informal rules) and technologies [49,61]. Regimes are characterized by their degree of stability [49,61] due to lock-in mechanisms [49], their purpose (cf. societal function such as food/nutrition), coherence, non-guidance, and autonomy [61]. As a consequence of all these reinforcing feedbacks, regimes tend to change only incrementally [49,59].

The niche corresponds to the micro level, which is the locus for radical innovation [49]. It consists of the whole system favorable to a radical change and working for the transition to another regime. Niche development goes through three main processes: articulation (and adjustment) of expectations/visions; building of social networks; learning and articulation processes on various dimensions [49]. It originally referred to protective/protected spaces (e.g., research and development laboratories, demonstration projects) where innovation activity takes place [49,55].

The MLP stresses that for a transition to occur, the niche-regime landscape processes should be aligned [48,49]. The slow changes at the macro level of the socio-technical landscape (i) provide gradients for the trajectories, (ii) create pressure that destabilizes the socio-technical regime, and (iii) the resulting destabilization of the regime creates opportunities for niche innovations to take the center stage within the socio-technical system and replace the existing regime [48–50,62–64].

2.3. Data Collection and Analysis: A Mixed Approach

We used multiple lines of evidence, by combining both evidence from literature (published articles and gray literature) and data [4,65,66]. Regarding the data, we sampled using a mixed method in which qualitative and quantitative data are combined to enrich the methodology and expand the scope of and deepen the insights of the study [67–69]. Mixed methods overcome the antagonistic cleavages between qualitative and quantitative approaches, emphasizing the advantages of both and filling their specific gaps [68]. Researchers increasingly resort to mixed methods as relevant and more complex methods suitable to understand complex realities [69].

2.3.1. Qualitative Approach

The qualitative approach encompasses both individual and group interviews performed with fisheries experts and stakeholders. The data were collected in three periods, from January to March 2018, July to September 2018, and in March 2019. The content of the interviews includes (i) the fundamental changes in fisheries, (ii) the drivers of changes, (iii) the consequences of changes in terms of governance of natural resources, (iv) the constraints of fish farming niche development, (v) the implications of traditional fisheries and fish farming sector development in terms of food security and local livelihoods, and (vi) perspectives.

Individual interviews: Purposeful sampling was applied to select the informants. Snowball or chain sampling was also used [70,71]. Instead of predefining the number of interviews, we considered saturation, which is a signal given when the researchers gain no

or less new information from additional interviews [72–74]. Furthermore, triangulation helped diversify the sources of information in order to collect contrasting and heterogeneous points of view of the different actors who usually have different rapports to the topic of interest [73].

We performed 52 individual interviews including 17 in Koubri, 11 in Moussodougou, 18 in Sourou, and 6 in Ouagadougou. The interviews were carried out with the governmental services at central, regional, provincial, and local levels. Thus, in the Ministry of Animal and Fish Resources (MRAH), we interviewed four officials at the central level including the General Director of Fish Resources, two regional directors, one provincial director, and three veterinary nurses working at the local level in the Technical Livestock Support Area (ZATE). In the Ministry of the Environment, Green Economy and Climate Change (MEEVCC), we performed two interviews in the provincial directorates and four with foresters at the local level in the local services. In the ministry in charge of agriculture, we interviewed one state agent in the Technical Agriculture Support Area (ZATA) and the director of the Sourou Valley Development Authority (AMVS). Additionally, among public institutions, we interviewed one administrator and one mayor. Two researchers, one from a university and another working in a Non-Governmental Organization (NGO), were also interviewed. Other stakeholders interviewed at the local level included eleven fishermen, seven fish processors, five traditional chiefs, two fish weighing agents, two farmers, one responsible for the catholic community, and two consumers.

Group interviews: They include (i) interviews in naturalistic settings (when other people, members of family, friends, or groupmates join the interviews) and (ii) focus groups, which is an interview with ad hoc groups [73]. The ad hoc groups were composed of the stakeholders themselves. We conducted 11 group interviews including two in Koubri, three in Moussodougou, five in Sourou, and one in Ouagadougou. We performed five group interviews with fishermen, two with female fish processors, two with traditional chiefs, one with fishmongers, and one with fish farmers.

Qualitative data processing and analysis: Both individual and group interviews were recorded and then transcribed in full to ease the exploitation of the collected information. We coded and analyzed the transcription through the qualitative data analysis software QDA Miner Lite (version 4). The coded statements were imported into Excel for further processing.

2.3.2. Quantitative Approach

Structured interviews: A household survey was performed from August to September 2018 with fishermen. We used a structured questionnaire focusing on the following themes: (i) traditional fisheries practices, (ii) sustainable management of fisheries, (iii) governance and rules in fisheries management, (iv) fish farming development, (v) contribution of fishing to livelihoods, food, and nutrition security, and (vi) changes in the marketing and processing of fish (Supplementary Material 1).

Selection of participants: Firstly, we established the list of the fishermen of each study area in collaboration with the fishermen's associations. The update of the lists lasted from 20 to 31 July 2018. An overview of the number of 442 fishermen is given in Table 1. Secondly, the sampling size ($n = 206$) was determined by the following formula:

$$n = ((z^2 \times P(1 - P)) \div e^2) \div (1 + ((z^2 \times P(1 - P)) \div (e^2N))). \quad (1)$$

where N = population size (442, see Table 1); z = z-score (1.96); e = margin of error (5%); and P = standard deviation (0.5) [75]. Finally, a systematic sampling, also known as linear systematic sampling technique, was used to select the participants to the survey [76,77].

Table 1. The sample size by study area ($K = N/n$).

Study Areas	Number of Fishermen	Sample Size	% per Study Area	$K = N/n$
Sourou	317	148	72	2
Moussodougou	47	22	11	2
Koubri	78	36	18	2
Total	442	206	100	2

K = skip or sampling interval, N = population size, n = sampling size. Source: Own data, household survey carried out in 2018.

Socio-demographic characteristics: We considered in total 204 valid questionnaires from the survey with fishermen. The majority is from Sourou (71.6%) followed by 10.8% from Moussodougou and 17.6% from Koubri. Among the respondents, few are literate (20.6%). The highest education level is secondary school. The age of the fishermen ranges from 16 to 74. The distribution in three age classes (viz. 15–29, 30–44, and 45+) shows that a large proportion of the fishermen are aged 30–44 (53.4%) followed by 45+ (33.8%) and 15–29 (12.7%). The fishermen above 45 years are mostly from Koubri (55.6%), whilst those who are in the 15–29 age class are typically from Sourou. Muslims are dominant (75%) compared to the other religions; 20.6% of the respondents are Catholics, 3.9% are Protestants, and 0.5% practice a traditional religion.

Data processing and analysis: We used Sphinx (version 5) to design the questionnaire and to create an input mask for the data entry. Then, the data were imported into Excel for cleaning and validation. We finally used IBM SPSS (version 21) for further data processing and all statistical analyses.

The ratings of the importance or agreement on a scale of 0 to 10 (0 being “not important” and 10 “very important”) by fishermen were in some cases transformed into categorical variables with three- or four-point scales. For instance, fishermen’s initial rating of the importance of commercial fishing were transformed into categorical: 0 to 5 = not important, 6 to 8 = important, and 9 to 10 = very important. Moreover, both dichotomization and trichotomization were implemented. Dichotomization is a way to artificially turn either continuous or ordinal variables into dichotomous variables, which is a 2-class division of a variable in such a way that the two categories have the same (or at least similar) frequencies. As far as trichotomization is concerned, a 3-class division of a variable is made in such a way that the three categories are equivalent in size. The median splits have been used in the dichotomization. That consisted of putting all cases that are below the median into a “low” group and all cases that are above the median into a “high” group. Values exactly at the median can be put into either group, and they are usually assigned in a way that will make the groups most equivalent in size [78]. A median split of ordinal variables may produce unequal groups when the original variable has a limited number of possible values. Therefore, it is sometimes necessary to correct the class boundaries based on scientific arguments. The use of the median as a cut-off when dichotomizing a continuous variable naturally creates equal groups [78]. The median splits were used to categorize the percentage of the catches consumed by the fishermen’s household into dichotomous variables; ≤ 20 (low) and 21+ (high).

A cross-tabulation or contingency table was used, since it is an appropriate descriptive statistic to summarize the association between categorical and nominal variables [79]. Both count and percentage were displayed. However, percentages are the best descriptor for nominal and categorical variables, especially when the numbers in the categories are unevenly distributed [79].

A nonparametric independent sample test was also used because the data did not respect the criteria of normality, and some variables are not continuous. This is partly due to the sampling method. As a nonparametric equivalent of the one-factor repeated measures ANOVA, the Friedman test [79] was used to test whether there is a difference between the rankings of the respondents. Additionally, the Independent Median Test (k samples) was also applied.

3. Results

3.1. Socio-Technical Landscape Developments

Based on the interviews, this section describes different landscape elements such as cultural and religious changes, demographical trends, environmental problems, international rules, macro-economic patterns, macro-political and global standards, material aspects, and vulnerability.

Cultural and religious changes: Among the main drivers of change, the interviews highlighted the expansion of revealed religions (Islam and Christianity) that led to religious diversity and modernity at the expense of traditional practices, such as sacrifices. This trend contributed to fish depletion. Additionally, modernity contributes to shifts in the equipment used.

Demographical trends: According to the interviewees, the population in the whole country is growing. Additionally, the movement of population, including migrants (viz. Bozos, who are professional fishermen from Mali), creates high population densities near the hydro-agricultural installations. Therefore, the number of fishermen and hence the pressure on resources significantly increased. Consequently, that gave rise to changes of fishing gears, the establishment of commercial fishing, as well as the regulation of the sector.

Environmental problems: The interviewees emphasized resource degradation. Firstly, reservoir siltation results in the drying of water bodies. The consequent degradation of the habitat prevents fish from spawning and leads to fish stock depletion. Secondly, the use of pesticide in agricultural activities exacerbated fish mortalities. Although successive droughts initially led to the construction of dams and the development of fisheries and aquaculture that allowed the diversification of livelihoods, over the long run, climatic conditions (e.g., wind, cold, and the declining rainfall) have narrowed those livelihoods by, e.g., causing fish depletion.

International rules: Water and fisheries management in BF are influenced by international and sub-regional rules. For instance, the West African Economic and Monetary Union (WAEMU) adopted in 2014 a text to promote concerted and harmonized trans-boundary fisheries governance. That is crucial in the case of the Sourou reservoir fishery, which is a resource shared with Mali.

Macro-economic patterns: The interviews highlighted the commodification of fisheries among the main drivers of changes. As the profitability of fisheries increases, both the number of fishermen and the pressure on the fish resources increase. Additionally, the past and ongoing changes are associated with globalization. Fish imports are rising to meet the increasing demand for fish products, while the national production is decreasing. This increasing import trend is perceived as a constraint for the development of capture fisheries and fish farming by capping fish prices at levels too low to stimulate investments in local fish production.

Macro-political and global standards: Firstly, the interviews mentioned the colonial period as the beginning of fisheries improvement in BF, especially the speculative dimension, based on the experiences of European countries. Secondly, the emergence of the state and then democracy—in other words, the republican system of governance—weakened the traditional power to manage natural resources, including fisheries management. Thirdly, national policies emphasized fishing as an income source to fight poverty and achieve food security, and they drove the multiplication of reservoirs and the promotion of economic, private investment. Fourth, the development of scientific research increased the knowledge base of data and analysis in support of the decision-making process in fisheries management and development. Finally, the concepts of sustainable and rational management led to the establishment of state-based management.

Material aspects: For many interviewees, dams construction changed the status of watercourses; they cease to belong to the chief of land and the village and became artificial and public infrastructures. Additionally, dam construction increases water availability and provides opportunities for the emergence of other activities viz. fishing. Therefore, many

riparian residents became fishermen. Furthermore, the demand and consumption of fish increased. Likewise, the hydro-agricultural infrastructure, the development of irrigated agricultural zones provided job opportunities in agricultural production. Therefore, they attracted migrants, boosting population density and increasing the pressure on fish resources. Finally, the interviewees described a global context of technological changes that influence fishing sector (e.g., weighing of fish landings, new fishing gears).

Vulnerability: Changes in fisheries are also driven by poverty and unemployment, as suggested by the interviewees. The majority of youth lack steady employment in rural areas; hence, they seasonally engage in fishing. This increases not only the number of fishermen but also illegal fishing practices, e.g., capture of fry, mass catches of fish, poisoning, and fishing without fishing license.

3.2. Dynamics within the Fisheries Socio-Technical Regimes

In this part, the dominant fisheries practices of both the traditional regime and the modern or state-based regime will be described to better understand fisheries regime and its inherent dynamics. Therefore, we will deal with (i) the techno-economic aspects, (ii) the actors and their roles, and (iii) the institutional and governance settings of each regime.

3.2.1. Traditional Regime

Techno-Economic Aspects

The qualitative interviews show that fishing activities, in particular collective fishing, take place during the periods of low water between December and May. Therein, both men and women participate in fishing and use manually operated tools to catch the fish. Men can use machetes, knives, small nets (woven with bark fibers), harpoons, arrows, straw barriers, and axes. Women usually work with small traps and nets. In addition to reservoirs, some men can fish in rivers that do not run dry. In addition to some of the previously mentioned tools (e.g., harpoons, arrows, straw barriers, nets), boats hand-made with tree trunks, big traps (e.g., cages), fishing rods, and poison were used in high-water conditions. Canoes were only mentioned in Sourou.

Actors and Their Roles

The main actors consist of traditional chiefs (e.g., the chief of village, the chiefs of land). In Koubri, the village chief governs both natural and human resources. He manages conflicts and collaborates with the republican government. Additionally, he organizes the collective fishing and the traditions related to managing and protecting water resources. Traditional authorities highlighted that the *Nyonioncés*, are the principal actors for the sacrifices. Additionally, the *Ruanaba*, which according to history descended from the sky to install at the edge of the water are responsible for water and fishing. The chief of land is in charge of land.

In Moussodougou, the interviewees distinguished (i) the chief of village who is in charge of the village and (ii) the chief of land who is in charge of land and water. There are eight districts in Moussodougou, and each chief of land, in his district, is in charge of water, fishing, and the sacrifices viz. sacred action consisting in giving an offering to a deity, according to a certain rite in order to gain his favor (e.g., parrying misfortunes). He assists the chief of village in decision-making.

As far as Sourou is concerned, the traditional authorities consist of the chief of village, the chief of land, and the chief of water. For most interviewees, these actors play almost the same role viz. governing human and natural resources. They solve conflicts between the members of the village, including family issues and land conflicts, and they make sacrifices to spare the village from misfortunes. They organize the collective fishing and collaborate with civil servants for natural resources management. However, one interviewed chief of land stressed that the chiefs of land are the real chiefs who hold the core power. They are the founders of the village and hence, they are the owners of land and the holders of traditions. They induct the traditional chief.

There were few professional fishermen. In Moussodougou, fishing was perceived as an activity for “lazy people”; hence, only a few persons (children and adults) were fishing occasionally for household consumption. However, some foreign ethnic groups—including Bozo, Somono, and Karaboro—were considered as specialized in fishing and did fish on some water bodies. In Sourou, fishermen provide the offerings for the rituals related to water and fishing. Women and children are indirect actors; they sing and dance during the collective fishing to stimulate the men who are catching the fish.

Institutional and Governance Settings

The interviews show that fisheries and water resources were considered as collective goods. They reported the practice of sacrifices in all study areas to keep societies in step with their *geniuses* (e.g., supernatural beings or spirits endowed with magical powers) and ancestors. Thus, the offerings (chickens, sheep, oxen, which are brought to the spirits of the water) aim at the happiness of the whole village, the protection of the users against water accidents (drowning or aggression by hippopotamuses), and the promotion of the abundance of fish. Additionally, the mediation of traditional authorities is occasionally requested during events such as drownings, dangers, or scourges threatening the village. The inhabitants also make sacrifices to entrust their wishes to the *geniuses*. Once the wish is granted, they must give their offerings. Specific sacrifices for fishing take place on the day of collective fishing to open the fishing season, ensuring the abundance of fish and protection of fishing participants.

Fishing was an occasional activity and included two types. Firstly, individual fishing was conducted by individuals with specific knowledge and equipment in rivers and was subject to the authorization of water authorities. However, fishing techniques that require entering the water (e.g., fish barriers, battue, traps) were prohibited before the sacrifice at the risk of drowning. Secondly, collective fishing was organized by the traditional chiefs at the beginning of the dry season as the rivers dry up. He sets the day of the event and invites the whole village and the surrounding villages. On this occasion, he makes a sacrifice before giving participants permission to fish.

Additionally, in Sourou, the use of water demands probity and honesty on the part of the user. Thus, in the water, it was strictly forbidden to capture fry, to steal fish, or to steal the property of the others. It is also forbidden for those guilty of adultery to go to river or reservoir tributaries, e.g., marigot. In Moussodougou, the rules include the prohibition of spreading a net across the entire width of the river and to pour laundry water into the river. In Koubri, there was a ban on capturing certain fish species, and others were not served to children. In Sourou and Moussodougou, fishermen do not fish from Thursday to Friday. Additionally, rivers have totems viz. red or yellow colors, money, which are light at night. While in Koubri, the chief took a share from the fish caught, in Sourou, the whole capture was brought to the chief and shared with the village, including the notables and some people with disabilities preventing them from fishing. Although fish selling was not developed in Sourou and Moussodougou, in Koubri, the participants in collective fishing were not allowed to sell the harvested fish. Offenders were subject to penalties, including bodily injury, fines, or extreme sentences, which are interpreted as the anger of geniuses (e.g., the death of the offender by drowning, aggression by hippopotamuses, crocodiles, or snakes).

3.2.2. Modern and State-Based Regime Techno-Economic Aspects

The quantitative survey shows that commercial capture fishing is the dominant practice in inland fisheries. The main tools currently used by the fishermen include boats, which are used by almost all the fishermen (92%) followed by gill nets (84%), traps (64%), and longlines (61%) (Table 2). Fishing rods (8%), seines (6%), and poisons (2%) are used by a low percentage of fishermen. Further, the Chi-square statistics support the association of most of these tools with the study area. Firstly, the cast net is typically important in

Koubri (86%) and Sourou (62%), but it is rarely used in Moussodougou (23%); $\chi^2 = 23.35$, $df = 2$, $p < 0.001$, Cramer V = 0.338. Secondly, the use of a boat is typical in Sourou (97%), and Koubri (94%) but low in Moussodougou (50%); $\chi^2 = 56.34$, $df = 2$, $p < 0.001$, Cramer V = 0.526. The use of a gill net is characteristic of Sourou (90%) and Koubri (83%), while this tool is quite absent in Moussodougou (45%); $\chi^2 = 29.25$, $df = 2$, $p < 0.001$, Cramer V = 0.379. The use of a longline is higher in Sourou (73%) but low in Koubri (42%) and Moussodougou (9%); $\chi^2 = 39.76$, $df = 2$, $p < 0.001$, Cramer V = 0.441. Fishing rods are mostly used in Moussodougou (59%) but almost unused in the other study areas; $\chi^2 = 85.38$, $df = 2$, $p < 0.001$, Cramer V = 0.647. The use of traps is very important in Sourou (85%) whilst marginal in Koubri (17%) and Moussodougou (4%); $\chi^2 = 96.77$, $df = 2$, $p < 0.001$, Cramer V = 0.689. The use of poisons is very low (Koubri 8% and Sourou 1%). This technique is not used in Moussodougou; $\chi^2 = 9.28$, $df = 2$, $p < 0.05$, Cramer V = 0.213. The association of the use of seine and the area is not statistically significant $p > 0.05$. The seine is rarely used (Sourou 7% and Koubri 6%) and does not exist in Moussodougou.

Table 2. Fishing tools used by the fishermen in the three study areas (in %).

		Study Area			
		Koubri	Moussodougou	Sourou	Total
Cast net	Yes	86	23	62	62
	No	14	77	38	38
Boat	Yes	94	50	97	92
	No	6	50	3	8
Gill net	Yes	83	45	90	84
	No	17	55	10	16
Longline	Yes	42	9	73	61
	No	58	91	27	39
Seine	Yes	6	0	7	6
	No	94	100	93	94
Traps	Yes	17	5	85	64
	No	83	95	15	36
Poison	Yes	8	0	1	2
	No	92	100	99	98
Fishing rod	Yes	8	59	1	8
	No	92	41	99	92

Source: Own data, household survey carried out in 2018.

Actors and Their Roles

Alongside the traditional regime, during the colonial era, the national administration took over natural resources' management. Forest guards oversaw the control and surveillance of the fishery based on a decree issued on 4 July 1935 [80]. The service for the administration of fisheries and aquaculture was established in September 1976, within the Ministry of Environment and Tourism, to promote fishery activities. For this purpose, from 1979 to 1982, this service created 28 community centers of fishing in the reservoirs of Loumbila, Tapoa, Petit Balé, Nagbangré, Bazèga, and Dakiri. This initiative was funded by the German state-owned development bank Kreditanstalt für Wiederaufbau (KfW) ("Credit Institute for Reconstruction") and Misereor, the German Catholic Bishops' Organization for Development Cooperation, to provide fishermen with nets and canoes [81]. As shown in Figure A1, over time, the department in charge of fisheries has been transferred to several ministries (e.g., Ministry of Rural development, Ministry of Environment, Ministry of Agriculture, Hydraulic and Fish Resources, Ministry of Environment and Sustainable Development, and Ministry of Animal and Fish Resources).

Since 2013, the Ministry of Animal and Fish Resources (MRAH) is in charge of the fishing sector. Thus, the MRAH formulates and implements the national policy and strategy of

capture fisheries and aquaculture development (e.g., supervising, organizing, and training the actors, delivering fishing licenses . . .). The enforcement of the regulation related to wildlife, forest, and fishing falls under the MEEVCC, the former Ministry of Environment and Tourism, which is followed by the Ministry of Environment and Sustainable Development. Hence, the foresters participate in delivering fishing permits, supervising fishermen, organizing plant production, monitoring, and repression, ensuring the maintenance of environmental order.

In this regime, the core fishing practitioners included specific ethnic groups specialized in fishing. They are in some cases foreigners (from Mali, Niger, and Ghana) encouraged to exploit Burkinabé fisheries (e.g., Bozo, Somono, Karaboro) or Burkinabé (Dafin or Marka). Additionally, some farmers were trained by foreigners in fishing techniques. Projects and international institutions funded and technically supported the fishing sector by training the stakeholders and providing them with equipment. Such interventions contributed to increasing the number of fishermen and their associations. We identified fifteen organizations, including ten fishermen's and five women fish processors' organizations in the study areas. Out of the ten fishermen's organizations, three became Simplified Cooperative Societies (SCOOP), while seven are still associations. As far as women's organizations are concerned, three are SCOOP and two are associations. Additionally, these SCOOP and associations are affiliated with the umbrella organizations that are the provincial and regional unions of their respective provinces and regions.

Institutional and Governance Settings

The modern or state-based management is based on laws that enshrine state ownership over natural resources and, therefore, centralized the management of fisheries. The first national regulation of fisheries was introduced in 1981 [81,82] and made all waters state property. It introduced the fishing license as a prerequisite for the practice of commercial fishing, sport/leisure fishing, and scientific or pedagogical fishing, and it defined the different methods for granting it. It enacted measures for the protection of fish stocks, regulated the practice of fishing, and laid down coercive measures in the event of infringement. This decree prohibited the use of any fishing gear with mesh size less than 30 mm and the use of long lines of unbaited hooks.

The Forest Code [83,84], in force since 1997 and revised in 2011, is currently the main legislation in fishing and aquaculture activities. In accordance with the National Forestry Policy, it sets the basic principles for the conservation, commercialization, development, and management of fisheries resources. The code provides that fishermen should comply with the requirements of fishing type: (i) commercial fishing, which is profit-oriented and gives rise to the sale of all or part of the catches, (ii) subsistence or customary fishing in which catches are not sold but consumed by the fisherman and his family, (iii) sport/leisure fishing, which is practiced for non-profit purposes; and (iv) scientific or pedagogical fishing, which relates to study and scientific knowledge of the fish resources. Additionally, it stipulates that all fishing, except for subsistence fishing, requires a fishing permit, which is specific to the regions and the management system.

Other legal instruments and international guidelines—including the Constitution of 2 June 1991, the Environment Code, the Agrarian and Land Reorganization (RAF), the law of orientation of water management, the Code of Conduct for Responsible Fisheries (CCRF) [85]—influence the management of living aquatic resources. Finally, strategies, policies, and plans, which have also evolved over time, have oriented the fishing regulations. From 2003 onwards, the Strategy Paper and Priority Programs for the Development of Fisheries Resources was developed and implemented. Currently, the objectives of the fisheries and aquaculture sector are formulated by the following:

- The National Policy for Fisheries and Aquaculture (PNPA), adopted in December 2013;
- The National Strategy for Sustainable Development of Fisheries and Aquaculture by 2025 (SN-DDPA—2025), also adopted in December 2013;

- The National Economic and Social Development Plan (PNDES), which covers the period from 2016 to 2020.

Centralized Management and the Open Access

The open access regime is the most widespread approach in BF. All fisheries are open access except those managed under the (i) concession, (ii) Fishery Perimeter of Economic Interest (PHIE), and (iii) protected areas regime as defined by the Forest Code that we will later introduce as niches. It is the model type of management system that applies the basic principles (fishing permit and respect of the gear requirement).

The quantitative survey shows that 72% of the fishermen purchase a fishing license, while 28% do not. The result of the Chi-square $\chi^2 = 48.305$ ($p = 0.000$, $p < 0.05$) shows a significant association of being licensed and the study area. In Koubri, the fishermen typically do not have fishing permits (75%), while the fishermen of Sourou typically answered “Yes” about the possession of fishing rights (81.5%). In Moussodougou, the result is not significant, but 86.4% have a fishing permit.

The interviews show that the stakeholders work for (i) raising awareness about good practices in fisheries, (ii) restocking of fisheries, (iii) protecting the river banks through sensitization and monitoring but also reforestation, and (iv) monitoring fisheries. The fishermen suggested to ban water abstraction by private companies and to seasonally close the fishery to improve fish production. During this period, fishermen collaborate with the foresters in monitoring (Table A1).

3.3. Niche Innovations in Fisheries Practices

Historically, the dominant fisheries management arrangements have been centered both on the state and the traditional chiefs. However, in recent years, new trends suggest the establishment of new managements systems. Those that breach mainstream practices are fisheries management niches. As one example among many, we focus on privatization as illustrated by the concession, and the co-management approaches elaborated within the PHIE. Furthermore, technological innovations are emerging to transcend the limitations of the main regimes viz. capture fishing with relatively no management. With regard to this aspect, we will focus on aquaculture practices, especially fish farming.

3.3.1. Institutional Niches

Privatization and Concession

There are two private management systems. Firstly, the protected areas consist of a specific type of management for fisheries exploitation in wildlife protection areas and classified forests. Whilst the protected areas are established by the government, their management is entrusted to private actors such as fishing guides. Some interviewees, especially the head of the Capture Fisheries Directorate within the DGRH, affirmed that this management regime is the most efficient, since the fishing closed period is well enforced and gives the fisheries sufficient opportunity to replenish. This type will not be the subject of this paper, since we did not collect data in areas applying this system.

The second private management system is the concession. The fishing concession is a mechanism by which the state entrusts to a natural or legal person the private and exclusive right to exploit fishery resources, of all or part of, a water body [84,86,87]. It has been implemented on small and medium water bodies (i.e., Bapla, Léra, Moussodougou, and Tandjari). The concession has been a relatively recent process initiated by the project Management of Fishing in the South West (GPSO) in the 1980s as a way to empower the actors as well as promote and secure their investment in resources considered as public goods [32]. A concession had been granted to the fishermen’s association Wramba. To date, the number of fishermen is 47. The fishermen’s association named Wramba (changed from 35 fishermen in 1992 to 24 members), which is the dealer, allowed the Association of Fishing Rod Fishermen (23 members) to fish on the dam for a fee. A management committee of the dam was created to deal with all issues relating to the management. This

committee was chaired by the village chief and ceased to function due to conflicts between the latter and the fishermen as a result of governance problems. The exploitation right costs 3000 franc of the African Financial Community (FCFA)/ha/year. The fishermen elaborated a management plan as required by the contract (Table A1). Furthermore, the fishermen's association elaborated internal rules. Although the conditions to integrate the association are simple (1000 FCFA as a membership fee and 10,000 FCFA as an annual contribution), the dealers strive to restrict the number of people authorized to fish. All fishermen have to weigh their catches at the landing stage where taxes are collected. The waterbodies are restocked, and fishermen fishing in the spawning ground should pay fines. The membership fees and taxes contribute to paying the concession fees and supporting the development of the municipality of Moussodougou. Fishing is prohibited on Friday. Finally, interviewees highlighted the prohibition of agricultural production on the river banks. The fishermen collaborate with the foresters to control the fishery and raise awareness about good practices. Interviewees, including foresters and fishermen, highlighted that the concession helped enforce the regulations to make fisheries more sustainable: *"If we did not have that concession contract, as I speak to you, there would be no more fish in the pond since people would have caught all the fry; without fry, no more fish in the future and that will be the end of the fishery here. It is thanks to the different training we received that we managed to preserve our fish."* (Interview, Fisherman, Moussodougou). However, the interviewees stressed that the implementation of the concession created conflicts between the fishermen's organization and the community, which were due to mistakes in the procedure of the contract. The populations of Moussodougou hardly understand the concession insofar as, in the local conception, a water body is considered as a public good, a common resource whose access and exploitation must be governed by the rules of the village. That misunderstanding results in strategies that bypass regulations, including night fishing, illegal gear use, poaching, etc. Moreover, the interviewees revealed that a forest guard was even assaulted by illegal fishermen during a night control.

Co-Management and Fishery Perimeter of Economic Interest (PHIE)

A PHIE consists of water bodies greater than 5000 hectares in area during low-water periods whose fishery resources have significant economic importance and are threatened by overexploitation [84,86,87]. Ten fisheries—viz. including Bagré, Kompienga, Sourou, Ziga, Bam, Yakouta, Sirba, Toessé, Douna, and Samandeni—have been classified as PHIE. They are subject to co-management arrangements. The PHIE is technically managed by a Technical Unit of the Perimeter (UTP), which is related to the national ministry, MRAH. Its staff members consist of a manager and officers. A Management Committee of 37 members involves all types of stakeholders, including fishing communities (15 people), general administration (4), decentralized technical services (8), local authorities (5), NGOs (1), microfinance institutions (2), the regional agriculture chamber (1), and the Regional Council (1) in the decision-making process. The Management Committee is chaired by the Governor of the Region de la Boucle du Mouhoun. The Bureau of the Management Committee comprises eight members. The PHIE accounts for 600 fishermen, 700 fish processors, and about 400 fishmongers (from Ouagadougou, Bobo-Dioulasso, Tougan, and Ouahigouya). The UTP supports the fishermen and fish processors to set up organizations, including the umbrella organization at the provincial and regional level. Additionally, the regional, provincial, and departmental directorates of the MRAH support fishermen and fish farmers, while the regional, provincial, and departmental directorates of the MEEVCC are in charge of the surveillance and control. The Bagré and Kompienga Fisheries Co-Management pilot project funded by the Government of the United Kingdom under the Sustainable Fisheries Livelihoods Program (SFLP) helped operationalize the co-management in Bagré, Kompienga, Sourou, and Ziga [87]. In particular, the management committees and executive structures were created and officially installed. Additionally, the participatory management plans of these fisheries were elaborated.

The institutional instruments of the management of the PHIE include (i) an Internal Regulations of the Aquaculture Perimeter of Economic Interest (PAIE)/Sourou, adopted by the General Assembly of the Management Committee on 29 July 2009 in Niassan, (ii) Specifications of PAIE/Sourou, adopted by the General Assembly of the Management Committee on 30 July 2009 in Niassan, (iii) a Development and Management Plan (PAG) of the Perimeter adopted by the Management Committee during its ordinary session held in Dédougou on 27 September 2011, and (iv) a Development Fund: Governor's decree adopted in 2012. Fishing requires a fishing permit specific to each PHIE. To certify the fish product's origin, the fishmongers have to pay also 100 FCFA or 500 FCFA respectively when the quantity is less or higher than 20 kg. The collected funds are shared every semester between the actors (10% for fish processors associations, 10% for fishermen's associations, 10% for the umbrella organization, and 70% to the UTP) to support their activities. The interviewees highlighted that the implementation of the PHIE helps raise the fishermen's awareness and empower them to manage fisheries in a sustainable way.

The interviews revealed that the fishery management includes the restocking of waterbodies, the protection of spawning grounds, the control and surveillance of the fisheries by the fishermen in collaboration with the UTP and foresters, sensitization to raise awareness about good practices, and tree plantation to protect the river banks. The management committee can limit the number of permits in case of high pressure on the resources. Finally, to limit conflicts between actors and sustain fisheries resources, the stakeholders have undertaken consultation with the Malian stakeholders to enforce the WAEMU regulation related to the management of transnational resources (Table A1).

3.3.2. Technological Niches: Fish Farming Techno-Economic Development

Fish farming is perceived as a new activity compared to fish catching. The quantitative survey assessed the fishermen's knowledge of approaches implemented to improve fish production in their area. For most respondents, fish farming (43%), spawning protection (42%), and restocking (41%) were applied. Only 24% know about the application of a no-fishing period. The Chi-square test supports a statistically significant association of these approaches and the study areas. Regarding the application of restocking, fishermen typically answered "yes" in Mossodougou (91%) and Koubri (72%), while in Sourou, they typically answered "no" (only 26% answered "yes"); $\chi^2 = 50.62$, $df = 2$, $p < 0.001$, Cramer V = 0.498. In Koubri, the fishermen (50%) typically answered "yes" about a closed fishing period, while this approach is almost unknown in Mossodougou; $\chi^2 = 20.89$, $df = 2$, $p < 0.001$, Cramer V = 0.320. For spawning protection, a Mossodougou fishermen's answer is typically "yes" (77%), whilst a "no" is typical in Sourou (only 35% answered "yes"); $\chi^2 = 15.16$, $df = 2$, $p < 0.001$, Cramer V = 0.273. Finally, concerning fish farming, unlike Moussodougou where fishermen globally answered "no", in Sourou, fishermen typically answered "yes"; $\chi^2 = 18.73$, $df = 2$, $p < 0.001$, Cramer V = 0.303.

The qualitative interviews highlighted further technological initiatives to push fish farming forward. Table 3 describes some characteristics of fish farming infrastructures used in BF.

Firstly, draining and irrigation canals are seen as "opportunistic fish farming". Indeed, to manage investments costs, draining uses open pits resulting from spatial development and irrigation canals exploit existing infrastructure. Both can contribute to restocking. Unlike draining, irrigation canals can depend highly on industrial feed. Secondly, enclosures (or open-net pens) and (floating) cages were experimented with by fishermen in Sourou and Koubri as alternatives to costly infrastructures. They have the potential for restocking the waterbodies depleted by fish escape and hence contribute to fisheries' sustainability. However, interviews highlighted the destruction of the enclosures and cages by hippopotamuses and crocodiles. Moreover, water (level, quality, and waste) management can be very difficult during periods of drought. In these infrastructures, the farmed fish feed only on artificial food. Thirdly, ponds and concrete ponds are costly and difficult to install. They

tend to be adopted by private investors for intensive production rather than by fishermen. The water is supplied from a reservoir, a river, or in some cases, by a water well drilling, and the water level and quality control is possible. Fourth, fish farmers are experimenting rearing fish in tanks made of wood and covered by plastic. Even though the control of water level and quality is possible, it can be costly and highly dependent on artificial food.

Table 3. Assessment of fish farming infrastructures.

Infrastructures	(Concrete) Ponds	Enclosures and Cages	Draining	Irrigation Canal	Tanks
Easiness to install	Difficult	Easy	Very easy (Already installed)	Very easy (Already installed)	Very easy
Investment cost	Very high	Low	Low	Low	Slightly high
Water level control	Possible	Impossible	Nearly possible	Impossible	Possible
Water quality control	Possible	Impossible	Nearly possible	Impossible	Possible
Dependence on industrial fish feed	Low	High	Low	High	High
Risks of destruction by hippopotamuses and crocodiles	Little	Very high	Very low	Moderate	Very low
Restocking directly natural waters	No	No	Possible	Possible	No
Potential association to agricultural activities	Yes	No	Yes	Yes	No
Source of water	To be taken somewhere	Natural waterbody	To be taken somewhere	To be taken somewhere	To be taken somewhere
Wastewater management	Not difficult	Very difficult	Not difficult	Slightly difficult	Not difficult
Risk of fish escape	Not at all	Moderately high	Low	Low	Not at all

Source: Pers. Comm., Ouedraogo 2020.

The integration of fish production into agriculture is also emerging. That includes the association of fish with the production of vegetables, fruits, or rice cultivation. The fish farmers' strategies include also the production of feed for fish. Some farmers invested in equipment to produce local agricultural by-products-based feed. That is used in association with imported feed to reduce the cost of fish feeding.

Regarding the choice of the species, most farmers produce *Oreochromis niloticus* and then *Clarias* sp., which is considered more resistant to diseases and more tolerant of a wider range of water and feed conditions. However, the interviews highlighted that with this species, cannibalism is an issue. The farmers produce also tilapia. Other fish farms focused on local species production with a wide variety of fish species. Thus, fingerlings fish were caught from reservoirs and rivers. Ongoing research at the University Nazi BONI aimed at improving the fingerling quality for growth. The Lasallian Centre for Initiation in Agriculture Sciences (CLIMA) is illustrative of the ongoing innovations. The center is carrying out feeding experiments to improve the profitability and viability of fish farming (e.g., use of a mixture of three feeds to reduce the time period for the growth of tilapia). Sex inversion and castration are also used as a means of promoting growth and getting a better return. The center plans new installations (e.g., a tighter system of production) so as to rationalize water use. It has given the person responsible for the farm the opportunity to complete his doctoral studies on fish farming.

Niche Actors, Their Roles, and Capabilities

The main actors include public institutions, NGOs, private investors, and traditional authorities.

The public institutions: the national government plays the leading role in mobilizing funds and assembling partners to develop fishing and fish farming. As mentioned by the head of the General Directorate of Fish Resources (DGRH), in 2018, the national budget of the government allocated eight billion FCFA to the fisheries sector. This amount was much higher compared to previous years. However, later interviews with other officers of the department noted budget reductions to fund the fight against terrorism. Additionally, the creation of a specific fund for financing the fishing sector is ongoing. Secondly, the actions of the state include the promotion of research viz. the creation of a research institute, commissioning and financing studies to provide best production techniques to fish farmers. Thirdly, the state works on building the capacity of the actors through trainings, study trips abroad (e.g., China and Israel), the supervision and monitoring of fish farming, providing equipment, organizing the actors in cooperatives, and promoting private investors as core actors. Finally, the DGRH has eight fish farms that supply juvenile fishes to restock waters and fuel fish farms spread over the whole country. This program promotes native species while limiting the introduction of alien fish species.

Projects and NGOs help build the capacity of the actors by training and organizing study trips within the country and in foreign countries (e.g., China) and offer equipment to the actors, install and restore infrastructures viz. spawning grounds, hatcheries, and ponds.

Universities, research centers, and institutes in BF (e.g., Joseph KI-ZERBO University (UJKZ), University Nazi BONI (UNB), International Union for Conservation of Nature (IUCN)-Burkina Faso, Institute for Development Research (IDR), Institute of Environment and Agricultural Research (INERA)) collaborate with DGRH and through their expertise implement the ecological watch. Thus, they carried out research on fish, fisheries, fish ecology, and fish farming and advised the decision-makers on the improvement of the fish resources sector development. The researchers contribute also to improving the production techniques made available to actors (fry production and supply, feed, quality water supply).

Private investors: According to the DGRH, there are about 600 fish farmers in BF, including peasants and agro-businessmen (e.g., civil servants, politicians, traditional authorities). Even though most actors depend on the support from the government, projects, and NGOs, some (including CLIMA) are leading the promotion of fish farming through Research, Development, and Innovation (R&D+I). Similar to fishermen, fish farmers are being organized in cooperatives with the support of the governmental institutions and other partners. These cooperatives are meant to be grouped into unions, which, in turn, would join in a federation. They aim at coordinating the actors' efforts, defending their interests, and helping share knowledge and information. Hence, they are developing an action plan to solve the problems of fish farming (e.g., fingerling availability, feed, training). Traditional authorities also showed their will to support fish farming through their traditional role including sacrifice to reconcile the favor of geniuses for fish farming.

Institutional Innovation

Many policy documents attest to the inclination of the government to develop fish farming in BF (Table A2). The narratives depict an efficient fisheries and aquaculture sector that is able to ensure a continuous increase of fisheries potential exploitation, enhance the sector's contribution to poverty reduction, food security, rural sector development, and reduce the dependence on fish products import. These plans rely on private actors, improving the national production capacities, integrating the protection of fisheries resources into dams and water reservoirs construction, the development of fisheries and aquaculture research, and access to credits and the capacity building of fishermen. Furthermore, the strategy of the government includes the institutional strengthening of the department in charge of fishing. To do so, a Directorate of Aquaculture (DA) was created within the

DGRH to implement the national strategy of aquaculture development. The practice of fish farming requires a legal authorization, a secured land ownership, and an environmental impact assessment. Additionally, to compensate for the inability of the state to enhance the infrastructure and to improve the fishing sector, the Decree No. 2007-035/MAHRH, defining general specifications for aquaculture concessions in BF, allows the concession of fish farming infrastructure.

3.4. Assessment of Transition Impact

3.4.1. Vision, Beliefs, and Narratives

Most interviewees believe that fish farming is relevant for increasing fish production and will be a remedy for lagging fish production in BF. It is expected to be an alternative to capture fishing, whose production is stagnant and a way to fill the gap between the increasing demand and the decreasing fish supply. In this sense, it is also perceived as a solution to the increasing anthropogenic pressure, overfishing, and hence should lower demand for fish imports. Some interviewees also suggested that fish farming is an activity yielding profit that can attract many actors. Success in fish farming is associated with the level of commitment, understanding, and ability to withstand the vagaries of the first moments. However, it is considered to be in an embryonic stage and for the moment, it cannot achieve food security. Some respondents highlighted that fish farming and fishing are complementary rather than competitive.

We investigated the main constraints on fish farming development in BF. As shown in Figure 1, knowledge on fish farming (9), fry availability (8.6), feed availability (8.5), access to credit (8.5), and fish species (8.4) are perceived as the most important constraints to fish farming development. They are followed by water availability (8), cost of infrastructure (8), and cost of tools (8), and cost of tools (8).

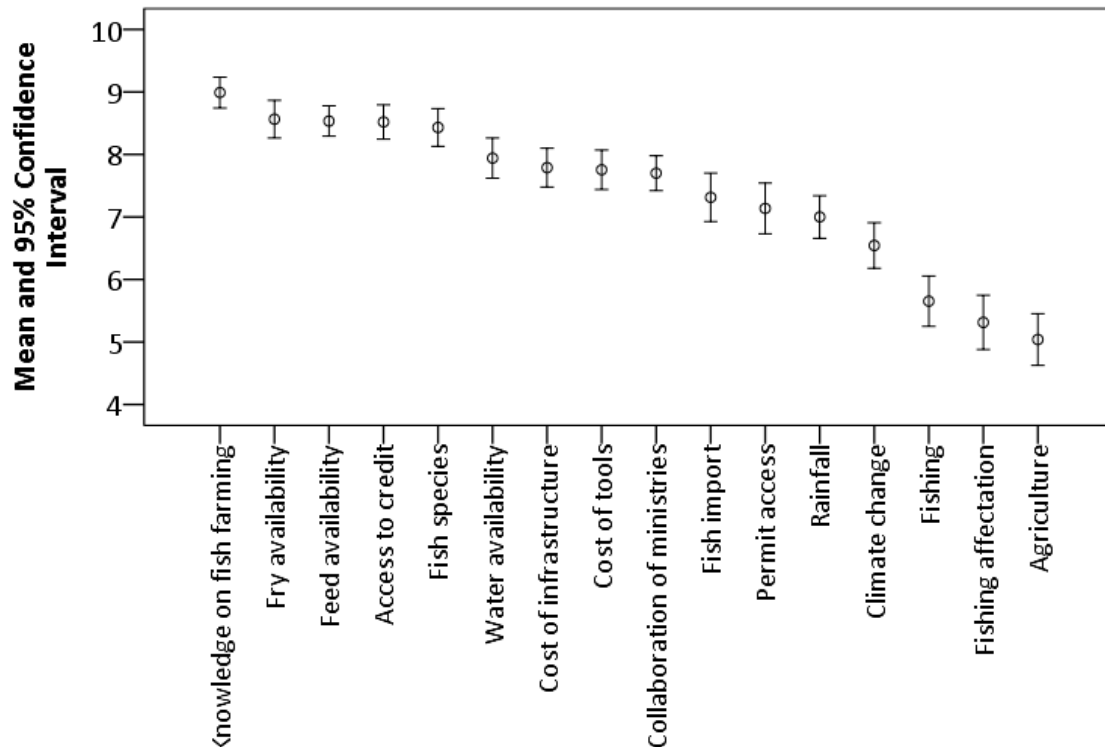


Figure 1. Fishermen’s perception of the importance of the constraints related to fish farming development across the study area. The figure is based on fishermen’s rating of the importance of the constraints on a scale of 0 to 10 (0 being “not important” and 10 “very important”). Source: Own data, household survey carried out in 2018.

3.4.2. Economic and Nutritional Implications of Fisheries

The interviews showed that as a source of cash and immediate food, fisheries contribute to the households' income and nutrition. Fish is a healthy food and one of the main sources of animal-based proteins that households rely upon, especially fishermen's households. According to an interviewed researcher, "it contains more than 60% of protein". As a result of its nutritional richness, fish consumption is recommended to everyone, especially for children, for whom it improves their growth and health. Some interviewees affirmed artisanal fishing as an "organic" form of fish production.

We investigated if the share of catches consumed by fishermen's households is related to the importance of commercial fishing. On average, fishermen's households consume fish 6 days a week and up to 25% of fishermen's catches. The Chi-square statistics show that there is a significant association between the importance of commercial fishing and the share of catches consumed by a fishermen's household; $\chi^2 = 38.98$, $df = 2$, $p = 0.000$, Cramer V = 0.437. The share of the catches consumed is typically higher (21+) when commercial fishing is "not important", and "important", while it is typically low (≤ 20) when commercial fishing is "very important".

Fisheries are cost effective thanks to the increase in the local price of fish. They are the main activities some fishermen rely on and provide immediate revenue. Additionally, the potential of fish resources is increasing. Hence, they contribute to the fight against poverty, improving food security and the national economy. However, as highlighted by the interviewees, the profit of fishing is affected by seasonal variabilities (the profit is lower in December and January, while it is higher from April on). Additionally, fishing is increasingly not enough to secure the stakeholders' livelihoods and food security; hence, they have to find alternatives, such as investing in agriculture or animal husbandry. The income generated from fishing is primarily allocated to investment in other income-generating activities (e.g., crop production, animal breeding) (0.5% absolutely important, 11.8% moderately important, and 56% little important), food supply (0.5% absolutely important, 6.4% moderately important, and 62.7% little important), education (1.5% moderately important and 65.7% little important), and health (2% moderately important and 62.7% little important). Further, fisheries provide jobs to youth and can subsequently contribute to reducing unemployment and limiting migration.

To analyze differences in fishermen's livelihood strategies and income, fishermen global income (measured in FCFA) was trichotomized ($\leq 50,000$; 50,001–100,000; 100,001+). The resulting variables were used to run a nonparametric independent-samples median test with the importance of the time allocated to different activities and the importance of the income gained from these activities. The test statistics showed a significant difference between the different categories of the global income for the time allocated to animal breeding and the time allocated to fish selling as well as for the income gained from animals (breeding gain) and from fish sales (fish selling gain). For the time for breeding, the median was higher in the group having more than 100,001+, $\chi^2 = 15.828$; $df = 2$, $p = 0.000$. Regarding the "time for fish selling", the median was higher in the group $\leq 50,000$; $\chi^2 = 15.480$, $df = 2$, $p = 0.000$ (Table 4). As far as the incomes gained from these activities are concerned, similarly, the highest median was in the category 100,001+ for "breeding gain" ($\chi^2 = 11.645$, $df = 2$, $p = 0.003$) and in the category $\leq 50,000$ for "fish selling gain" ($\chi^2 = 8.657$, $df = 2$, $p = 0.013$) (Table 4). Further analysis using cross-tabulation showed that there is an association between the number of activities and the global income; $\chi^2 = 19.861$, $df = 6$, $p = 0.003$, Cramer V = 0.221. The fishermen who have only one activity are typically in the income group $\leq 50,000$, while those who have three activities are typically in the income group 100,001+. The Chi-square statistics ($\chi^2 = 10.757$; $df = 2$; $p = 0.005$; Cramer V = 0.230) showed that there is a significant association between the possession of animals and the global income. The fishermen who keep animals are typically in the category 100,001+, while those who do not are typically in the category $\leq 50,000$.

Table 4. Independent samples median test of (i) the importance of the time allocated to different activities and (ii) the importance of the income gained from different activities by the fishermen households across the categories of global income of the latter.

Median Test	Global				
	N	Median	χ^2	df	p
Time for agriculture vs. Global income	204	5.000	5.163	2	0.076
Time for breeding vs. Global income	204	0.000	15.828	2	0.000
Time for trade vs. Global income	204	0.000	2.315	2	0.314
Time for fish selling vs. Global income	204	0.000	15.480	2	0.000
Agriculture gain vs. Global income	204	5.000	0.820	2	0.664
Breeding gain vs. Global income	204	0.000	11.645	2	0.003
Trade gain vs. Global income	204	0.000	2.945	2	0.229
Fish selling gain vs. Global income	204	0.000	8.657	2	0.013

Source: Own data, household survey carried out in 2018.

Few interviewees affirmed that state-based management contributed to the sustainability of the resources. Based on the quantitative data, we assessed if fishermen perceived any difference between traditional management and modern management regarding the importance of sustainability and resilience. The mean of the rating shows that traditional management was considered more sustainable and resilient (6.20) than modern management (3.79). Both the results of the Related-Samples Friedman's Two-Way Analysis of Variance by Rank ($\chi^2 = 69.54$; $df = 1$; $p = 0.000$) and the related-samples Kendall's coefficient of concordance (Kendall's $W = 0.341$) showed a significant difference between the importance of sustainability and resilience in traditional and modern managements.

For most interviewees, dam construction provided perennial water resources to the population. Subsequently, fishing became a regular activity and improved fish availability. However, few interviewees mentioned that dam construction created fish barriers that are detrimental to fish migration and fish availability. Meanwhile, some interviewees stressed water drying up from March to June due to climate change but also rivers' banks exploitation for agricultural activities. Furthermore, the use of pesticides associated with land use including intensive agricultural activities contributed to water pollution, the deterioration of water habitat, dam siltation, and fish kills. In Moussodougou, water level variability due to water abstraction for sugar cane production has been stressed as detrimental to the spawning grounds. Climate change and other environmental factors such as rainfall and wind affect water availability and hence fish. Therefore, there is a decrease in fish size and fish availability.

Few interviewees highlighted species diversification illustrated by the introduction of shrimps in Koumbri. However, the take of many interviewees supports a loss of biodiversity, including plants and fish species due to the use of chemicals but also fishing practices. Indeed, the growing number of fishermen and the consequent improvement of the techniques as well as illegal fishing (e.g., use of prohibited gears and harvest of small fish) have exacerbated overfishing.

Based on the quantitative survey, the assessment of fishermen's perception of the importance of factors threatening fish shows that water abstraction (73%), followed by climate change (72.1%), overfishing (71.1%), human settlement (70.1%), deforestation (62.7%), gardening (59.8%), and sand mining (52.9%) have a strong impact on fish (Figure 2).

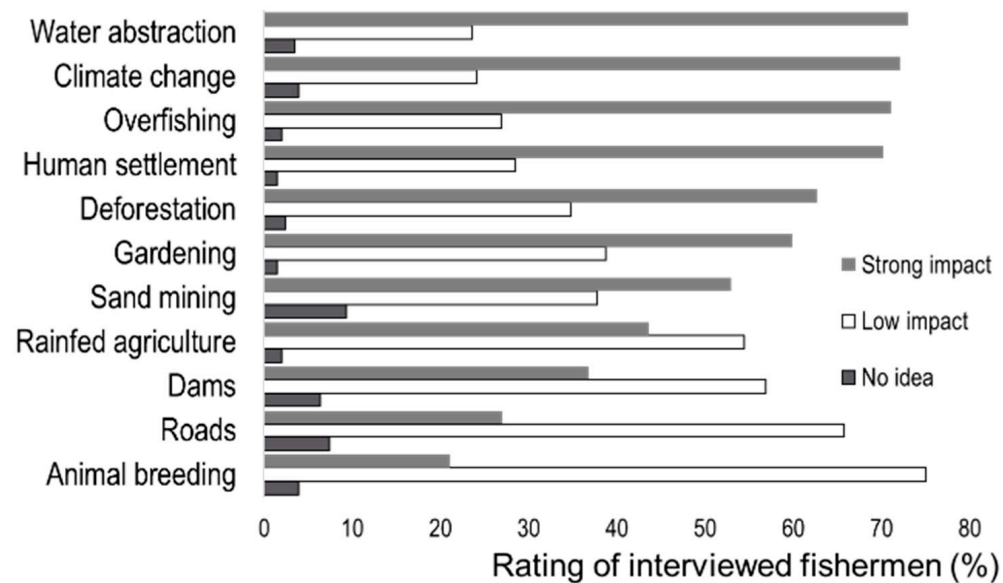


Figure 2. Fishermen perception of the strong, low, and no impact of human activities threatening fish resources. Source: Own data, household survey carried out in 2018.

4. Discussion

Sustainability transitions emerge from a complex set of interactions. This research framed that set as between variables within four categories: technology, policy/power/politics, economics/business/markets, and culture/discourse/public opinion [49]. The MLP framework helped reveal how change happens and fundamentally affects all the dimensions of fisheries management in BF.

The elements of the socio-technical landscape identified in this study include the expansion of new religions, population growth, environmental problems (e.g., drought, climate change), international rules, commodification of fish, macro-political and global standards (e.g., colonial period, emergence of the state and democracy), development of agricultural zones as well as reservoirs, then poverty and unemployment. The regime consists of the traditional fisheries practices as well as the centralized management of fisheries (cf. open access). Meanwhile, the niches refer to new modes of fisheries management and governance, including privatization and co-management, as well as fish farming. The transition in BF fisheries shows a shift from traditional and subsistence fishing to a commercially oriented activity. This process took place in a context that gave all power to the nascent republican state to the detriment of traditional authorities and was based on institutional and technological changes. Therefore, fisheries have become a significant component of the stakeholders' livelihoods and food security.

4.1. Institutional Transition and Sustainable Fisheries Practices

The description of the landscape highlighted the emergence of the state, including the colonial administration and democracy as governance systems alongside the traditional management. Traditional management and modern management are interpreted as two different regimes not totally isolated but meshed to some degree by constant interactions. Cultural change and dam construction contributed to the decline of the influence of traditional management, while modern management became dominant in all public waterbodies. Against a background of relatively ineffective centralized management, privatization and co-management are emerging.

Cultural change (viz. the expansion of new religions) resulted in mass conversion of the population, including sometimes the traditional authorities to new religions. Nowadays, 61% of the population in BF is Muslim, 19% is Roman Catholic, 4% belong to various Protestant groups, and 15% maintain exclusively indigenous beliefs [41]. These conversions undermine the continuity of the traditional regime [88–90] and consequently reinforce the

state-based regime, institutional niches (privatization and co-management), and technological niches (e.g., fish farming).

The transformation of the natural aquatic environment has led to the recession of traditional management [80]. This transformation was driven by different factors, including local people's loss of confidence in traditional authorities as well as new rules introduced by the colonial authorities, which further delegitimized and decreased the power of local and traditional authorities. Subsequently, the emergence of the new management system introduced, on the one hand, the monetization of fishing activities and, on the other hand, the establishment of centralized policies and powers [80]. In the same vein, Nelson [91] stressed that most African states have inherited the colonial system that shaped a centralized political authority over access to land and resources initially controlled by more localized institutions. However, these patterns of natural resources management practices and policy have often resulted in an appropriation of public assets for private gain and patronage due to insufficient human capacity and misaligned incentives [91].

However, traditional management is still in force at local levels in most parts of the country, in fisheries but also in other natural resources management [8,89,92]. Traditional beliefs are very strongly rooted in the daily life practices, especially in rural communities [36], and people usually remain simultaneously connected to their traditional beliefs and to their new religion. Therefore, in general, traditional and state-based regimes are relatively separated. However, sometimes, they are in competition or interact in a way that generates new management systems. Indeed, some aspects of the traditional regime are integrated in the republican governance. For instance, the National Strategy for Sustainable Development of Fisheries and Aquaculture (SN-DDPA) highlights that in the case of a concession, the dealers have rights to exploit resources but only with respect to the habits, traditions, and customs of the local community [87]. Additionally, the forest code authorizes traditional collective fishing. The organization of this activity requires an authorization of the department in charge of fisheries. Depending on the traditions, foresters can be allowed by the traditional authorities to participate in the event or not. At the same time, despite the fishing permit, fishermen cannot fish in some waterbodies without being authorized by the traditional chiefs at the risk of drowning. As presented by Geels [93], relationships at the regime level can include (i) competition between regimes leading to shifts in relative size, (ii) symbiosis between regimes—that is, they positively interact but remain relatively separate, and (iii) integration, in other words, the regimes interact closely to form a new system [93].

The results show that the institutional change did not ensure the sustainability. Instead, most interviewees shared the view that the set of landscape factors (see Section 3.1) as well as state-based management (state-based regime, niche innovations) resulted in fisheries overexploitation due to the weakness of the state to enforce the regulation. This is also interpreted as the consequence of inadequate regulation or an institutional vacuum. However, there is no lack of government regulations [26,92] in both high-income countries and low-income countries. Instead, they all face the subtractability problem (viz. how to institute rules among the users) and the common issue of lack of resources to manage and enforce government regulations [26].

Sustainability transition can also be blocked at the policy level by inadequate regulations. The causes of failure to sustain fisheries production and contribute to actors' livelihoods in low-income countries include firstly the focus of "Orthodox fisheries management" on raising incomes by increasing the efficiency of fishing [10,11,25]. Secondly, state-based management policies have often been conventional top-down fisheries management policies that are informed mainly by equilibrium-based stock assessment methods to remedy the threat of depletion of the resource due to overfishing [11]. Thirdly, conventional management disregards social science and people while emphasizing biology and, to some extent, economics [26]. This relative neglect of social science perspectives may arise in part because of efforts to deal with persistent uncertainties surrounding biological stock assessment [11,94]. However, the lack of adaptability and resilience of resulting

institutions [11] and collapse in confidence in the centralized regulatory systems are also drivers of fisheries crisis [94], and these latter drivers can be profitably analyzed from a social science perspective. In this same vein, institutions analysis reveals that the rules or principles impacting the use of natural resources consist of responses linked to social life and interactions, with power, kinship, and gender, but so far, these have not been sufficiently elaborated in view of their sustainable management [95].

Need for New and Alternative Directions

The results revealed local initiatives to palliate the weakness of the state to enforce fisheries management. For example, small-scale fishers have shown specific capacities to find adaptive responses to the fluctuations of their resources [11,96–98] and to other shocks and uncertainties [11]. The ability and will of local groups to support a given government measures can potentially aggregate as significant bottom-up support for the protection of a national resource [26].

Most fishermen have a fishing permit; however, the possession rate is lower in Koubri. The open access regime applied in this area could have limited the adherence of the actors to the regulation. Fishing is often used to illustrate “the tragedy of the commons”; because of open access, without any individual investment or responsibility (nobody manages a resource belonging to everybody), resources are overused, rendering them spoiled or devoid of future value [99,100]. Consequently, open access leads to poverty and marginalization [11,101]. However, considering the rules enforced and also the local initiatives, the management in Koubri is not really open access. The description of the regimes in fisheries management shows that fisheries have been managed in ecological, rational, and economic logical ways. Furthermore, as argued by Welcomme [7], very few inland fisheries are de facto open access, since most of them are linked to some form of management system at the local/community level [7]. Additionally, the observations of Berkes [26] show that rather than (i) limiting the number of fishers and (ii) fishing licenses as most western industrialized countries do, developing countries use licensing but rarely limit the numbers, since part-time or seasonal fishing is considered as a natural right. Moreover, many developing countries’ governments encourage their citizens to be productive and provide incentives for the fishery sector to grow and produce more [26]. The impact of such policies depends on the scale of the fishery. Low-technology and low-intensity fishing will not necessarily result in overfishing. However, if the fishery is really open access, resources depletion will happen sooner or later and will be rapid, especially when high-technology fishing units are used [26].

Private management, via concession, can help to solve the challenge of excluding illegal fishermen even though it does not stop it. The concession is considered to be an appropriate means to ensure a sustainable management of fishery resources and an efficient approach for the collection of fishing revenues [87]. If a resource is shared by a group of people that have a say in how it is managed, they will take better care of it because they have a stake in it and a responsibility toward the resource. The institutionalization of the ownership (e.g., exclusive fishing) in accordance with traditional local powers and the national legislation rights was considered as the sine qua non condition for a successful implementation of culture-based fisheries, since it can assure a return on investments [100]. The conflict between fishermen and the population reveals the tension between the traditional and the state-based regimes. Indeed, the major bottleneck is that the concession is inconsistent with the national fisheries legislation, which provides fishing rights to anybody having a fishing permit. Additionally, historically, natural resources, especially water resources, are usually collective goods [100]. In the traditions of the Burkinabe people, water is a source of life. Water is free and cannot be denied nor sold to anyone who needs it. Subsequently, access to water, both in private and collective waterbodies, for human drink, the watering of the cattle, construction, and laundry was free [82]. In this context, the attack of forest guards by illegal fishermen denotes not only a lack of civic spirit but also the lack of legitimacy of the state power and its management of resources (e.g.,

privatization) [89]. The concept of traditional management is sometimes globally depicted as communal management, disregarded specificities. Beyond the common good, there was the possibility to own natural resources, especially infrastructures achieved by personal effort in some parts of the country [89,102]. However, the new form of privatization is hardly implemented and accepted due to (i) the ignorance of the regulation, (ii) the great infrastructures development program usually creates frustration for the riverine population due to insufficient compensation, and it (iii) conflicts with migrants and new users. In Moussodougou, the installation of SN-SOSUCO in the 1970s, then the installation of the dam, resulted for many families in the loss of fields and ancestral lands without any compensation [103]. These uncompensated appropriations of resources multiplied conflicts and reinforced the perception of ownership and inequity [103]. Therefore, concessions could be more successfully established with greater involvement of the population in the procedure as well as the empowerment of dealers and foresters.

A co-management regime tends to manage with greater participation by the main stakeholders in the decision-making mechanisms. Such decentralized and bottom-up management empowers local communities for fisheries management. It is a shift from top-down approaches implemented so far by centralized state-based management or by hierarchical traditional regimes. Decentralized management offers the advantages of (i) sharing the management power and responsibility especially by involving the local community in management, (ii) lowering management and enforcement costs, (iii) designing appropriate rules that take advantage of local knowledge, and (iv) strengthening community institutions and establishing more effective fishery management [26]. However, the involvement of state services may bring the hierarchy again in the system, rather than empowering the actors. Co-management has also been an opportunity, as shown by the literature, for traditional chiefs to integrate the new regime and gain in power to control the system [89,103]. Furthermore, structural constraints, including the high rate of illiteracy and the insufficient organization of the actors, may also contribute to their marginalization within the decision-making process in the co-management mechanisms. Therefore, beyond just rules and regulations, capacity and institution building are of high importance to make fishermen capable of making their own rules and solving their own problems.

4.2. Modernization Ideology and Technological Transition in Fisheries

4.2.1. Technological Transition in Capture Fisheries

Fish imports, as an effect of globalization, are perceived as an important limit to the development of fish farming in BF. Although it helps to meet the national demand and hence ensures fish availability and accessibility, it creates market conditions that are not competitive for potential fish farmers. Neither capture fishing nor fish farming have to date been able to reverse this situation. Fish imports may limit a nation's potential to gain sovereign control of fish production. On 18 January 2018, a decree announced the ban on the import, distribution, and marketing of tilapia fish (eggs, larvae, juveniles, broodstock, or dead tilapia fish in frozen or derived form, wild or farmed) from six countries (e.g., Colombia, Ecuador, Egypt, Israel, Thailand, and the Philippines) due to the Tilapia Lake Virus. The virus is not transmissible to humans; however, it can cause 90 to 100% fish mortality if it occurs in breeding. The temporally ban was meant to protect the 200 fish farmers.

Global environmental crises, especially in fisheries, have driven the development of responsible, sustainable management of the resources and the exponential development of aquaculture. The Code of Conduct for Responsible Fisheries (CCRF) [85] adopted by BF and the WAEMU are potential initiatives that can improve modern, state-based management and boost the establishment of sustainable practices in fisheries and also fish farming. Indeed, the CCRF recommends that member states conserve aquatic eco-systems (quality, biodiversity, and availability of fishery resources in sufficient quantities) for present and future generations and establish responsible aquaculture, including culture-based fisheries from the perspective of food security, poverty alleviation, and sustainable development [85].

Our results show a series of socio-technical transitions in BF, especially the introduction of new fishing gears to increase the efficiency of capture fishing. With the decline of traditional collective fishing, most traditional tools have been abandoned. The adoption of modern techniques has been supported also at the institutional level through the ban of most traditional tools and rules to limit the impact on resources and emphasis on the maximum yield perspective of fisheries development [11,100]. From the fishermen's perspective, the adoption of new gears and alterations made to existing gears (mesh size) are adaptations to new ecological conditions (decrease in fish stock) and also to increasing their catches and revenue. Although banned, traditional tools (traps, poison) or newly introduced gears (seine) are still in use. As noted previously [25], small-scale fisheries are not static but technologically dynamic, for they can include new types of craft and adaptations of traditional ones to improve their efficiency. They demonstrated their capacity to respond to technical and market developments and changing fishing regulations [31], and to adapt to changing social, environmental, and economic conditions, despite their conventional associations with traditional practices [9].

The results reveal in capture fisheries how techniques changed as fish stocks declined. Rather than an outcome of technological progress, an innovation is a process with potentially negative, neutral, or positive effects on connected systems [104,105]. The adoption of new gears or modification of existing fishing gears by fishers can positively (or negatively) impact the sustainability of a fish stock and on the surrounding environment [30]. Since gear types are related to catchability and fish mortality [30,106], they determine the ability to reduce the fishing impact of a fishery [30,107]. Additionally, new fishing gear may conflict with the (short-term) economic goals and safety concerns of fishers [30,107] and the perspective of conservation advocated by the management system. Alone and in combination, these factors increase the uncertainty and controversy around technological changes such as the shift to more sustainable fishing gears [30]. Beyond technological design and innovation, the introduction of new gears rather consists of a socio-technical transition [30,33,62]. The elements of a socio technical-system co-evolve, meaning that change within and between groups may lead to other changes [33].

4.2.2. Fish Farming Niche Development

The main constraints of fish farming according to our results include knowledge of fish farming, fry availability, feed availability, the access to credit, and the ecology of various fish species. That corroborates previous studies [108–110]. Fish farming is constrained in BF by a low level of technical expertise or available infrastructure. The fairly recent introduction of fish farming in BF may explain the slow development of the sector [108,109]. Furthermore, critical analyses show that the activity was introduced on a fragile basis (e.g., inadequacy context, poorly defined objectives, poor breeding techniques) [19]. A lack of training for local actors, limited scientific knowledge of fish resources, and ignorance on the part of the agency responsible for the introduction of local knowledge undermine the capacity of the population to master and implement the biotechnical approaches [29,109]. Both the low accessibility and the low quality of fish farming input due to the non-functioning of the entire value chain affect the profitability and the competitiveness of fish farming [19,29]. The actors must resort to exogenous imports raising the costs to maintain their farms. As a result, intensive fish farming for commercial purposes is not considered economically viable in the short term due to capital unavailability [108–110].

Economic constraints are a key stumbling block for the main factors behind fish farming development, e.g., the development and implementation of adequate strategies by the administrative institutions, scientific research, and private actors investment in farm construction and maintenance [29,111]. Indeed, the sector is undermined by the reluctance of financial institutions to finance the agricultural sector, including fisheries, because of important risks, and the lack of governmental subsidies or funds [19,29].

The actions of fish farming niche actors show that the strategies of fish farming development considered enabling factors, including capacity building, financial support to

alleviate financial constraints to investment in fish farming, and the coordination of the actions through the networking. The state still plays a leading role in the establishment of the niches. This is an advantage for the niche to be implemented through impacting policies, laws, and institutions. Scaling up through the government structure ensures a larger impact; however, the niche actors may lose control over the process due to strong government domination and marginalized non-state actors [112].

4.2.3. Relationships and Trade-Offs between Capture Fisheries and Fish Farming Niche

The results reveal that capture fishing and fish farming are complementary, but fish farming is also seen as an alternative to capture fishing. Many approaches, including spawning protection and restocking, are implemented. Fishing closure periods are scarcely implemented and face resistance from the stakeholders even though they could result in high long-term fish yield [8,113]. The application of restocking also resulted in very weak positive results, in some cases, in terms of fish production as well as stakeholders' appreciation [114] because of the lack of consideration of species adaptation to the new ecological environment, the insufficient capacities of the fishermen to carry out this initiative, and their weak involvement [115,116]. Capture fishing and fish farming may have mixed interactions, since sometimes, there is no clear-cut difference between them. Open-access capture fisheries are stocked with larvae or juveniles raised in hatcheries [6,117], creating culture-based "wild" fisheries as are early life-history stages of fish harvested from capture fisheries to be grown out and sold [6,118]. In the enclosure (open-net pens) or cages, there is a free exchange of waste, chemicals, parasites, and diseases between the farm and the surrounding environment [119]. There is also the potential for farmed fish to escape into the wild [119,120]. That can lead to interbreeding and competition with wild fish and can facilitate the spread of pathogens, thereby placing more pressure on already dwindling wild populations [120]. Aquaculture can be a competing sector that impacts wild inland fish production in terms of freshwater use and fish habitat rather than being a growing segment of fisheries [6].

These sectors also compete for financial resources. The state concentrates a lot of effort in aquaculture compared to capture fishing. For instance, out of a financing requirement of 9.5 billion FCFA to implement the SN-DDPA (2004–2008), only 5 billion FCFA (i.e., 53%) were mobilized. Out of this amount, 4.2 billion were for the sole aquaculture program, fisheries co-management received 330 million FCFA, while the programs for capture fisheries have not really been funded [87]. If this discriminating approach does not guarantee the take-off of the niche, it may affect capture fishing. The global crises in fisheries and the stagnation of capture fisheries production as well as the parallel exponential development of aquaculture across the world have given rise to narratives that depict capture fisheries—particularly small-scale ones—as "doomed", subject to "inevitable decline" [5,121], "backward", or disregarded entirely [5,122]. At the same time, aquaculture is frequently portrayed as a "modern" activity in official development discourses [5,122] and the sole way to meet the increasing fish demand [5,123]. The national management of fisheries in many developing countries has been biased by the optimistically widespread view of the "First Development Decade" [25] that modern science and technology could serve as a powerful force in stimulating and sustaining development in the countries of Africa, Asia, and Latin America. Consequently, exclusive priority was given to large-scale fisheries at the expense of small-scale fisheries and their actors who were thought to be "backward" people and irreducible opponents to innovation [25]. Finally, in general, the government assistance to small-scale fishermen came rather late, often following failed experiences with an all-round and ill-conceived industrialization program of the local fisheries [25,124].

4.3. Fisheries, Livelihoods Diversification, and Food Security

The results reveal that fishing shifted from a subsistence and seasonal activity to a commercially oriented activity. Previous literature also showed that the commodification

of fishing started during the colonial period when established fishing became a source of livelihoods for the population [80,82].

Livelihoods diversification is one of the main strategies of rural populations, particularly in low-income countries [11,125]. Our results reveal that the income from fishing is used to fund both natural, resources-based (agriculture and animal breeding) and non-natural, resources-based activities (trade). Of these three activities, fishermen's households allocate more time to animal breeding and those households gaining the most from animal breeding belong to the highest income category. For some fishers' households, fishing is often associated with more than three activities, as illustrated in Lake Volta [126]. Such a strategy responds to high ecological and institutional uncertainties [11,127,128] by increasing the diversity of activities and reducing the risk of livelihood failure [11]. Livelihood diversification was found to create an inequality of income and well-being and, in turn, to deprive poor households from exploiting new economic opportunities even in the future [129]. Instead, households' involvement in "high return sectors", such as trade or salaried jobs, is associated with well-being, since various financial, social, and human capitals do not allow poor households to combat the entry barrier and prevent them from getting access to these remunerative sectors [129].

The fishing sector involves many actors and is expected to involve more people in alleviating poverty and generating employment. Béné et al. [130] argued that small-scale fisheries can act as a "safety net" [5,130] regarding the capacity to provide labor opportunities and incomes to resource-poor households with few other options, thus reducing vulnerability and food insecurity associated with both transitory and structural poverty.

Regarding fish farming, in BF, the contribution of the sector to fish production is still very low (300 tons from about 600 actors), even though the current dynamic and the sector potentially support the possibility to enhance its contribution to livelihoods and food security in the future. Even though it performs worse than small-scale fisheries (due to land access and investment costs) [5,131], aquaculture can promote food security, via income, employment linkages, and consumption [5]. Belton [131] affirmed that even small-scale or "quasi-peasant" forms of aquaculture typically provide high returns in comparison to alternative agricultural activities, with the incomes generated often used to smooth seasonal cash shortages [131]. Furthermore, evidence suggests that employment in support services to "quasi-capitalist" or capitalist forms of aquaculture can also offer significant employment opportunities for the poor in some contexts [5,131]. From the perspective of fisheries development, the SN-DDPA emphasizes the maximal exploitation of the potential. That matches the dominant view in academic and policy arenas regarding the contribution of capture fisheries to development (e.g., economic rent maximization) [130]. However, Béné et al. [130] support a more gradual approach that preserves the welfare function of small-scale fisheries (viz. their capacities to provide labor and cash income to resource-poor households until the appropriate macroeconomic conditions for rent maximization and redistribution are fulfilled) in order to avoid the potentially disastrous consequences in developing countries. More sophisticated or costly sectors may exclude the most vulnerable stakeholders [54].

5. Conclusions

This paper summarizes the biophysical, socio-economic, and political factors important to any transition to sustainability in the fisheries in BF. These have implications for fisheries management, and for developing policies to improve livelihoods and food security. The paper demonstrates the importance of social dimensions of new fisheries practices, including the adoption of new fishing techniques and institutions. It shows that rather than a linear transition from traditional to modern or state-based management, the evolution of fisheries in BF displays multiple socio-technical regimes co-evolving alongside developing niches (e.g., concession, co-management, and fish farming).

Macro-level trends and shocks such as droughts and the consequent vulnerability of a growing population, macro-political changes such as the emergence of the republican

system of governance, and cultural changes strengthened new institutions to the detriment of traditional techniques and management institutions. Centralized management, as illustrated by open access management, is the dominant management in capture fisheries. However, niche interactions resulted in more decentralized managements, such as privatization and co-management. Both approaches contribute to the empowerment of the stakeholders in the management of the resources and may result in more bottom-up approaches and innovations toward more effective fisheries managements. However, they are still too fragile to be able to destabilize the regimes and can only create reconfigurations.

Capture fisheries are more or less stable and autonomous. Technological changes improved the sector's productivity and its contribution to households' livelihoods. Fish farming is still not sufficiently developed, however, although new narratives depict it as an alternative or a complementary production process that can address the crisis of stagnant production in capture fishing. Socio-technical landscape support is paramount in this regard, but the strong involvement of the state may limit innovations and the control of local and community actors over some initiatives. Regarding the constraints, fish farming can hardly replace capture fishing; however, there is a chance that culture-based fisheries can integrate the practice and create new systems of fish production.

We recommend, firstly, the establishment of adequate mechanisms of participation and inclusiveness of communities to strengthen rural livelihoods and food security. The private sector could be supported by the government on all institutional levels to establish sustainable fish farming and harvesting systems while taking adequate measures to include vulnerable stakeholders. That requires specific actions for the different production systems (cf. intensive, extensive, or subsistence). Secondly, non-natural resources-based job opportunities (e.g., trade) could be created as incentives for mobility out of fishing, especially in rural areas to reduce the pressure on aquatic ecosystems.

Lessons learnt from this study should help integrate multidimensionality, especially with respect to the social dimension, in fisheries management and assessment. Further research is needed to understand the multifaceted and multifunctional relationships between fishing and livelihoods and to inform sustainable development strategies in BF. In-depth research to assess the implementation of the decentralization process in natural resources, including fisheries management and the interaction between republican management and the diverse singular local managements is also needed. In this context, collaborations and partnerships are essential to promote the mutual sharing of experiences and good practices among stakeholders in BF as well in other countries in West Africa and Sahel.

Supplementary Materials: The following are available online at <https://www.mdpi.com/2071-1050/13/5/2985/s1>.

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Appendix A

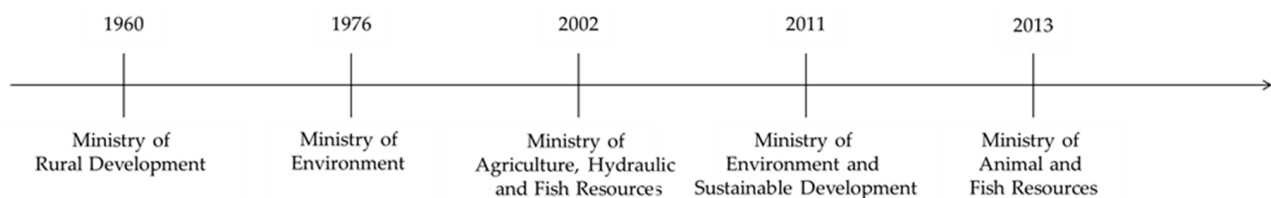


Figure A1. Changes of the ministry in charge of fisheries from 1960 to the present. Source: Figure drawn based on Ministry of Animal and Fish Resources (MRAH) and Management—Intermédiation & Réalisation (MIR) [29].

Table A1. Local initiatives to implement fisheries regulation and sustain fisheries.

Suggested Initiatives	Koubri—Open Access	Moussodougou—Concession	Sourou—PHIE
Prohibition of water abstraction	+		
Fishing closure period	+		
Elaboration of development plan		+	+
Restocking of waterbodies	+	+	+
Spawning ground protection		+	+
Limitation of access to fish resources (issuing permits)		+	+
Raising awareness about good practices	+	+	+
Protection of river banks (revegetation)	+	+	+
Organizing fishers to monitor fisheries	+	+	+
Consolidating the cooperation with the Malian authorities for a better management of Sourou reservoir fishery (WAEMU)			+

The sign “+” shows the existence. Source: Own data, qualitative interviews performed in 2018–2019.

Table A2. Summary of the main policy narratives on sustainable fisheries and aquaculture development in Burkina Faso (BF).

Source	Narratives of Sustainable Development on Fisheries and Aquaculture
Stratégie nationale de développement durable de la pêche et de l’aquaculture à l’horizon 2025 [87] DÉCRET N°2014-790/PRES/PM/MRAH/MEF du 16 septembre 2014 portant adoption de la Politique Nationale de la Pêche et de l’Aquaculture au BF (PNPA) [132]	Vision: Dynamic private actors driving sustainable fisheries and aquaculture management to reach food security and rural sector development

Table A2. Cont.

Source	Narratives of Sustainable Development on Fisheries and Aquaculture
Stratégie nationale de développement durable de la pêche et de l'aquaculture à l'horizon 2025 [87]	Objective: Establishing performant fisheries and aquaculture sector through the continuous increase of the exploitation of fisheries potential to improve the contribution to poverty reduction and food security
DECRET N°2014-790/PRES/PM/MRAH/MEF du 16 septembre 2014 portant adoption de la Politique Nationale de la Pêche et de l'Aquaculture au BF (PNPA) [132]	Objectives: Introducing a dynamic and sustainable management of fisheries and aquaculture; Improving production through entrepreneurship
DECRET N°2014-790/PRES/PM/MRAH/MEF du 16 septembre 2014 portant adoption de la Politique Nationale de la Pêche et de l'Aquaculture au BF (PNPA) [132]	Values and rules of conduct guiding the national fisheries and aquaculture policy: participation of stakeholders, from its development to its assessment; transparency in the implementation of the national fisheries and aquaculture policy, the national strategy and the action plan; sustainability and feasibility of the national fisheries and aquaculture
Deuxième programme national du secteur rural (PNSR II) 2016–2020 [133]	Objectives: Promoting capture fishing and aquaculture to ensure the sustainable management of fishery and aquaculture resources; Increasing fish production from 20,950 tons in 2015 to 30,000 tons in 2020.
Plan national de développement économique et social (PNDES) 2016–2020 [134]	Reversing the trend of dependence on fish import to meet fish demand by (i) improving the national production capacities; (ii) integrating the protection of fisheries resources into dams/reservoirs construction; (iii) strengthening fisheries and aquaculture research and development; (iv) improving access to credits for fisheries and aquaculture's stakeholders; (v) organizing and building the capacity of fishermen.

Source: Policy documents.

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