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The Tuna 'Commodity Frontier': Business Strategies and Environment in the Industrial Tuna Fisheries of the Western Indian Ocean

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An industrial fishery is a geographical area of operation of a complex of capitals whose form of organization is the firm and whose medium of operation is fishing vessels. Tuna fisheries are among the most highly capitalized and valuable fisheries in the world. This paper distinguishes between two relations that function simultaneously at the point of production in capture fisheries to investigate an empirical account of a 'commodity frontier' in tuna (Moore 2010a,b). The first is the vertical relationship between capital and the environmental conditions of production. The second is the horizontal relations between competing fishing firms as they transform nature to produce commodities for the world market. The paper traces the emergence of the European tuna fleet in its search for new commodity frontiers, from the Bay of Biscay (1860s) to the Eastern Tropical Atlantic (1950s) and the Western Indian Ocean (1980s). The primary empirical focus is the Indian Ocean, where, after appropriating an initial, highly productive surplus, the European fleet intensified fishing activities and has partially undermined the natural conditions for the reproduction of its industrial-scale operations. I argue that the complex dynamics of capture fisheries can be better understood through the prism of a commodity frontier.

Keywords: canned tuna, purse-seine fisheries, European Union (EU), Western Indian Ocean, commodity frontier, commodity chain

INTRODUCTION

Tuna fisheries are among the most highly capitalized and valuable fisheries in the world. While tuna sashimi and sushi are emblematic of the Japanese culture of consumption (Bestor 2004), it is less well known that the humble can of tuna is one of the most widely consumed forms of seafood in the United States (US), Spain, Italy, France, the United Kingdom (UK) and Germany. The US- and EU-centred canned tuna commodity chains each supply multi-billion dollar mass markets. Industrial fishing fleets provide the vast majority of raw material for canning. I define an industrial fishery as a geographical area of operation of a complex of capitals whose form of organization is the firm and whose medium of operation is fishing vessels. But the 'business of fishing' is not to be understood as an isolate. Tuna fishing firms are

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often forward integrated in manufacturing and branding canned tuna. The types and industrial organization of firms engaged in the business are far from uniform, despite undertaking a functionally similar activity. Drawing upon Jason Moore's recent work (2010a,b), my main aim is to show the particular strategies deployed by capital to maximize the appropriation of ecological surplus in tuna fisheries. In doing so, I reveal the historical–geographical development of a new tuna 'commodity frontier' and how capital intensifies production to cope when initial frontier conditions decline in relative ecological productivity. It contributes towards developing a more historical understanding of contemporary socio-ecological dynamics and contradictions in tuna fisheries.

For canning-grade tuna fisheries, boats traverse the tropical regions of the world's oceans to hunt tuna. Fishing firms apply organizational and socio-technical innovations and exploit human labour (crew on boats) to extract fish biomass to transform it into commodities for the world market.[1] The tuna commodity chains that connect resource extraction to final consumption are controlled by a wide range of types of firms, including multinational corporations, private investment funds, large family-owned companies and state-owned enterprises. But even the most powerful and sophisticated firm must shape its business strategies *through* the dynamics of the environmental conditions of production. I unpack business strategies to show the historical development of and contemporary dynamics in a tuna fishery through the optic of the competing firms that constitute it and the socio-ecological relations that shape it.

The research is informed by in-depth, semi-structured interviews on global commodity chains in tuna with over 500 people in 21 countries over 6 years (November 2005 to September 2010), as well as referenced secondary sources. The empirical focus of this paper is on the European fishing fleet, which consists entirely of firms headquartered in France and Spain. Since the 1970s, industrial purse-seiners have been the main type of boats used by this fleet.[2] Today, French and Spanish firms own or control a fleet of purse-seiners worth over US$1.5 billion.[3] Although the French and Spanish fleets only comprised 11 per cent of the *number* of purse-seine vessels in the world in 2000, they totalled 18 per cent of world purse-seine vessel *capacity* in gross tonnage. This indicates that French and Spanish boats are larger – and more capitalized – than competitors in other fleets (Committee on Fisheries 2003). The main fishing grounds of the European canning-grade tuna fleet are the Eastern Tropical Atlantic (since the 1950s) and the Western Indian Ocean (since the early 1980s). Today, the latter is the fleet's primary location of production and accounts for around 20–25 per cent of the world's annual tropical tuna catch (Guillotreau et al. 2011).

To separate out the different dynamics at work in the business of tuna fishing and as a method for investigating the continuously expanding tuna 'commodity frontier', I distinguish between two relations that function simultaneously at the point of production in industrial capture fisheries: the vertical relationship between capital and nature, and the horizontal relations between competing fishing firms as they transform nature to produce commodities.[4]

[1] This paper is about the political economy of capital. Despite its importance to capitalist accumulation, the political economy (and exploitation) of labour is excluded from this research project. For an analysis of class relations on boats in a Scottish fishery, see Howard (2012) in this issue.

[2] Purse-seiners deploy a net with a circumference of up to 2 kilometres to encircle tuna. The bottom of the net is then tightened like a purse string to concentrate the fish and haul them on to the deck of the boat (see Figure 1 and discussion below).

[3] I use 'control' in the sense of Stephen Hymer's (1979) important insight that a firm does not need to fully own an investment in order to control it.

[4] This study is part of a wider research project on the EU-centred commodity chain in canned tuna, which connects fishing to manufacturing and retail. The wider project also considers important regulatory mechanisms (e.g. fisheries management and trade regimes), interactions among European firms, the EU and developing coastal

For the first relation, I trace the business strategies of the French and Spanish fleets through their responses to and interactions with the environmental conditions of production (the capital–nature relation). I ask: How are the strategies of the European fleet shaped by (and shape) the natural resources upon which it depends? To rephrase along the lines of Jason Moore (2010a,b): How does capitalist production function through nature in this fishery? The main intertwined dynamics investigated under this relation are: the environmental conditions and geography of production; the historical development of the fishery (its existence is not a 'given'); and the role of organizational and technological change in extending and intensifying tuna fisheries.

The second relation zooms-in from this 'macro' account to examine the role of firms (an organizational form controlling the labour process at the point of production). I deploy this 'meso-level' firm-centric approach to unravel *horizontal* dynamics of competition between fishing firms in the commodity frontier and to differentiate between players in this functional activity of the commodity chain. Corporate strategies around ownership and industrial organization are a constituent component in understanding how the tuna commodity frontier works.

The paper proceeds in five steps. In the first, I offer an overview of Jason Moore's notion of the commodity frontier and other literature that informs the analysis. The second provides context by briefly sketching how environmental and contemporary world-market conditions shape tuna fisheries. The third section focuses on the vertical relation between the EU tuna fleet and environmental conditions of production. I trace the fleet's geographical movement from the Bay of Biscay to the Western Indian Ocean from the late 1860s to the 1980s in its search for new 'commodity frontiers'. In the fourth section, I investigate horizontal relations between the firms constituting the French and Spanish fleets in the late 2000s in the Western Indian Ocean. This account differentiates between the main players in the fishery and the business strategies deployed in this frontier when initial environmental conditions decline in relative productivity. The fifth section returns to vertical capital–nature relations and examines the intensification of production strategies deployed by the French and Spanish fleets in the Western Indian Ocean in the 1990s and 2000s as they try to maintain profitability. I conclude by arguing that this initial work on the political economy of the tuna industry indicates the analytical value of understanding capture fisheries through the prism of a 'commodity frontier'.

THEORETICAL FRAME: THE COMMODITY FRONTIER

There is a vast academic and 'grey' scientific literature on tuna fisheries. But mainstream social science analyses of and debates on tuna fisheries tend to be fairly narrow and focus on three main areas: accounts of and prospects for 'sustainable' fisheries management; applications of and internal debates around how the tools of modern economics can best be deployed to analyse and enhance efficiency in the fisheries; and the role of and potential for tuna-related development in coastal economies.[5] Except for information on the 'nationality' of boats as denoted by the vessel flag and, in some cases, by assumed 'national' ownership, we rarely hear about the organizational form that these boats take as firms. Similarly, researchers rarely acknowledge that tuna fisheries are *capitalist*, and thus essentially constituted and driven by the extraction of surplus value from the transformation of nature by labour to produce commodities for the

states, and the wider competitive dynamics of the global commodity chain (Campling forthcoming). Despite their broad exclusion from the paper, these elements inform the following account implicitly and, occasionally, explicitly.

5 See, for example, Allen et al. (2010), Barclay with Cartwright (2007), Hanich and Tsamenyi (2009) and Petersen (2006).

world market. I seek to fill this void in the literature on tuna fisheries by highlighting the role of *differentiated firms* in fisheries as they seek to find, extract and transform a natural resource, and how competitive dynamics between firms helps to explain the deployment of particular business strategies and their environmental effects.

In contrast to social science analyses of tuna fisheries, political economy variants of the 'commodity studies' literature are primarily grounded in the empirical analysis of firms (Bernstein and Campling 2006a,b), normally based on detailed case studies of particular commodity chains or segments of chains. This tradition of work moves away from uncritical acceptance of abstract notions of the firm and 'the market' as efficiency maximizers that is present in the literature on tuna fisheries, and demonstrates that 'real markets' under capitalism constitute complex sets of social relations (Mackintosh 1990). However, extractive industries have largely been ignored in this commodity studies literature. Further, given that most chain studies are of a particular commodity, it is surprising that few researchers take seriously the historical and relational specificity of the commodity in question and the implications for chain activities and governance. For example, the particular characteristics of any natural resource are constituted through biological/geophysical specificities in concert with the social priorities of any mode of production and commodity sector. In capture fisheries, the extractive resource moves, but within its biologically specific geographical range (e.g. depth and temperature ranges). These features in turn exert 'a powerful influence on the location of competition in the production network, the form that competition takes and on relations of dependency between holders and seekers of resources' (Bridge 2008, 412; see also Gellert 2003; Ciccantell and Smith 2009). I emphasize the relationship between tuna biology/environmental conditions and the business strategies of the French and Spanish fleets.

My approach also connects to a body of work on the agro-food system, especially that concerned with how capitalist agriculture attempts to overcome (and profit from) the tension between the organic and the synthetic (e.g. Kloppenburg 2004; Weis 2007). Given that agri-business is driven by realizing surplus value through production and exchange of commodities, capital engaged directly in the transformation of organic matter faces the risk of it deteriorating before exchange (and eventual final sale) is realized. To mitigate this risk, capital deploys a range of business strategies and technological innovations to (partially) synthesize the organic so as to maximize the potential for accumulation through the simultaneous appropriation of nature and exploitation of labour (e.g. preserved food; see Fine and Leopold 1993). The dual dynamics of 'distance and durability' (Friedmann 1992) take particular forms in tuna fisheries. While the problem of preserving tuna for large-scale commodity production was solved at the point of *manufacture* through canning technology in France from the 1860s;[6] at the point of *extraction*, the business of tuna fishing historically faced constraints on the geographical distance of fishing activities, the durability (or spoilability) of transporting catch, and species-specific environmental limits on catch intensity and vessel profitability. This paper traces how the French and Spanish tuna fleets worked to overcome these constraints, to maximize the extent and intensity of their production strategies.

While these various frameworks help us to identify particular dynamics, relations and processes in the fishery, Jason Moore's 'commodity frontier' framework offers a guiding thread to illuminate the long-range historical dynamics at work, including the vertical relations between capital and nature and the horizontal relations between firms. Moore's historically defined concept is specific to capitalism: it is not based on the simple plunder of resources, but the appropriation of nature for the *production of commodities for exchange* (Marx 1976; Moore

[6] The fish is cooked in the can, killing bacteria and sterilizing the product.

2010a). It is analytically distinct because it reinterprets capitalism as an *ecological regime* that reproduces itself *through* new commodity frontiers, rather than more commonly deployed – and transhistorically applied – notions such as a 'resource' frontier, in which economic activity simply 'impacts' *on* nature.[7] In other words, his perspective 'is not one of a "social" process and its "environmental" consequences, but rather a dialectic of two bundles of human and extra-human nature' (Moore 2012, 2; see also Araghi 2003, 2009; Harribey 2008). The capitalist firms engaged in the movement into new commodity frontiers have enhanced possibilities for accumulation because they are entering zones of minimal (or zero) commodification. The result is an appropriation of a high ecological surplus by capital, at least until the frontier has declined in relative productivity.

I build on Moore's approach to show how forms of business organization and techniques of production in tuna fisheries play out in the geographical movement of fishing fleets into new commodity frontiers as they seek to appropriate high ecological surpluses; and, in turn, how these fleets erode these high surpluses through their corporate and production strategies. In short, new commodity frontiers are the concert of new organization, new technique and new geographies. This process is 'fundamentally globalizing' (Moore 2010b, 191) because of the 'dialectic between the ever-mounting material-throughput demands of an ever-growing mass of capital *and* the ever-mounting biophysical degradation that ensues through the endless accumulation of this capital' (Moore 2010a, 38). In other words, once 'labouring bodies, mineral resources and ecosystems in any single region' (Moore 2010b, 189) are exhausted to the extent that they became relatively less profitable, entirely new frontiers are sought. My account of the geographical movement of the French and Spanish fleets to create new fisheries in new locations between the 1860s and 1980s offers an illustration of this 'globalizing' process.

A 'commodity-*widening* strategy' (Moore 2010b, 219) typifies the early stages of new frontiers in industrial tuna fisheries where the appropriation of a high ecological surplus fuels a boom in a new region, which becomes the 'leading' location of production for a period (a process of 'extensive development'). Over time, the underlying socio-ecological conditions of reproduction stagnate or decline relative to prior levels of appropriation, and with this production costs converge on the sectoral average (i.e. the end of high ecological surplus results in 'mature' frontier conditions). The general response by capital embedded in a 'mature' frontier is to intensify production strategies through enhanced 'capitalization and socio-technical innovation' (Moore 2012, 3) – a 'commodity-*deepening*' strategy. This generates a new frontier based on '*intensive* development'.[8] In this way, capitalism seeks to continuously expand into new commodity frontiers, whether in terms of geographical extent or productive intensity. As a renewable but exhaustible 'free gift' of nature, fisheries can collapse (and have) and the initial frontier conditions of a relatively productive ecological surplus are unlikely to be replicated. But in the context of competitive horizontal relations between fishing firms, the appropriation of tuna can also (temporarily) increase with socio-technical innovation (an intensification of the vertical relation between capital and nature). In the current epoch, no new geographical frontiers are globally available to the tuna industry and several species in the current zones of operation are in (or close to) an overfished state.

7 To elaborate the point: while working from the argument that capitalism is premised on labour productivity and that the appropriation of the rest of nature is a means for advancing labour productivity, Moore's approach also follows Marx to treat labour as labour-*in*-nature rather than labour *and* nature; transcending the arbitrary notion that labour is separate (see Araghi 2009).

8 Moore's framework has some parallel with Fine's work on 'extensive and intensive development', which draws a distinction between 'the extension of existing methods of production on to new lands and the intensive application of capital to land already in use' (1994, 283).

THE ENVIRONMENTAL AND WORLD MARKET CONDITIONS OF TUNA FISHERIES

Environmental Conditions of Production

Tuna are not all the same. The distinct biological characteristics of each species come to bear on capital–nature relations in tuna fisheries and the more specific business strategies of competing fishing firms. I focus on the two main tropical tuna species used for canning in the EU-centred commodity chain – skipjack and yellowfin.[9] Three basic characteristics are central to species' evolutionary strategy and to human strategies for extraction.

First, tuna are top predators that hunt for prey across millions of square miles of ocean. Historically, the 'highly migratory' nature of this species placed a structural limit on human exploitation. Tuna fisheries were generally limited to coastal areas prior to the industrialization of fishing methods and the introduction of on-vessel refrigeration in the early 1900s (Fujinami 1987). In other words, fishers were not able to 'follow the fish'.

Second, tuna have strong schooling behaviour and repetitive migration patterns, which mean that industrial concentration in tuna fishing fleets is necessary to find, catch and move on to the next school of fish. The ever-deepening technological sophistication of fishing methods combined with growing knowledge of tuna biology has made tuna more vulnerable to extraction (Majkowski 1998). Since the 1950s, levels of human appropriation have increased concurrently with the capital intensity and technological sophistication of the fishing methods used, which are, in turn, driven by the compulsion to maintain supply to processors and, eventually, supermarkets (see below).

Finally, variable rapidity of growth to sexual maturity and duration of spawning make different tuna species more or less vulnerable to human appropriation. These factors impose a relative limit on the absolute extent and intensity of levels of fishing effort on a species-by-species basis. For example, yellowfin reach sexual maturity at 2.8 years, spawn for 6 months of the year and live a maximum of 10 years. Skipjack reach sexual maturity at only 1.5 years, spawning all year, and live to a maximum age of 4–5 years (FAO 2001a). As a result of these biological differences, skipjack fisheries are able to withstand greater levels of extraction than yellowfin.

World Market Conditions of Production

World market conditions, like environmental conditions of production, profoundly shape tuna fisheries. Canned tuna is the world's second largest seafood product traded internationally in terms of value and volume (following prawns/shrimp). As an industry, canned tuna is today premised on high volumes and low profit margins. The EU is the largest canned tuna market in the world, in which residents consumed 690,000 tonnes (net processed weight) in 2005 (Valsecchi 2007). Five principal markets dominate this consumption volume: Spain (21% share), Italy (20%), the UK (19%), France (19%) and Germany (9%). The EU import market was valued at €1.7 billion in 2004 (Globefish 2010), on top of which is domestic production for domestic consumption and intra-EU trade in Spain, Italy, France and Portugal. The southern European market (especially Italy and Spain) consumes chiefly canned yellowfin in olive oil,

[9] Juvenile bigeye tuna are also caught in large volumes by purse-seiners targeting skipjack and yellowfin. A fourth species, albacore, is of major importance to the US-centred canned tuna commodity chain. It lives in sub-tropical oceans and is targeted by different fishing methods (mainly industrial longliners) to the other three species mentioned here.

and import-dependent northern Europe (especially the UK and Germany) consumes chiefly lower-cost skipjack canned in brine or vegetable oil. These distinct cultures of consumption influence the production strategies of the French and Spanish fleet. Some fishing operations focus on targeting higher-priced yellowfin and others on catching large quantities of less valuable skipjack to supply specific markets (see below).[10]

Control of the multi-billion dollar EU branded market for canned tuna is highly concentrated. Multinational firms have been competing for share of the EU branded market for decades (Campling forthcoming).[11] Concentration and associated market power in the branded manufacturing and supermarket retail nodes of the EU-centred commodity chain has deepened competitive pressures on fishing fleets supplying tuna raw material. Big supermarkets compete horizontally for market share by attracting consumers with lower prices for 'core category' products. This is especially the case in the UK, France and Spain. At the same time, grocers compete vertically against branded firms by stocking 'private label' (or supermarket own-brand) canned tuna (Campling forthcoming). These competitive market pressures intensify horizontal competition between fishing firms and drive widely recognized global overcapacity in industrial tuna fisheries (Joseph 2003; Reid et al. 2003).

Tuna is also a highly 'political fish' (JICA 2001). Access to tuna fisheries is governed by a complex set of institutional and political relations among states and firms (e.g. Havice and Campling 2010). In the canned tuna chain, EU and US trade arrangements shape the global geography of manufacturing. The international division of labour in canned tuna production is shaped by heavy protection for manufacturers in the global North (e.g. in Spain) and sharp competition between export-orientated manufacturers in the South (Campling et al. 2007; Campling and Havice 2007; Havice and Reed 2012).

In sum, tuna fishing operations are shaped by a combination of environmental conditions and complex social relations outside of the point of production. The next section traces capital–nature relations at the point of production from the 1860s to the 1980s and demonstrates how, driven by growing demand for canned tuna in Europe, French and Spanish tuna fleets used a 'commodity-widening strategy' to extract (temporarily) relatively high ecological surplus.

THE HISTORICAL–GEOGRAPHICAL DEVELOPMENT OF EUROPEAN TUNA FISHERIES, 1860s–1980s

The historical development of the European tuna fleet tells interconnected stories on the themes of overcoming constraints of distance and durability and the search for new commodity frontiers. Contextualized by key developments in other tuna fisheries, I trace how French and Spanish fleets deployed socio-technical and organizational innovations to extend and intensify operations over time and geographical space. Without data on fleet profitability over time, catch per unit effort (CPUE) serves as a useful indicator of vessel productivity. CPUE indicates productivity by measuring how much fish (on average) boats catch per day (e.g. more highly capitalized boats will normally have a comparatively higher CPUE). But it also indicates

[10] On the Bangkok market, imported frozen whole yellowfin was 25 per cent more expensive than frozen skipjack between January 2000 and July 2011 (FFA database).

[11] For example, leading brands in the UK and France (John West and Petit Navire) were owned by Heinz European Seafood before its 2006 sale to a private equity fund controlled by Lehman Brothers. The dominant brand in Italy (Rio Mare) and a leader in France (Saupiquet) are both controlled by Bolton Group – a consumer goods marketing firm based in the Netherlands. And the giant *sogo shosha*, Mitsubishi, owns Princes – a leading canned tuna brand in the UK, the Netherlands and elsewhere.

whether a fishery has, on average, a high (or low) ecological surplus where similar fleets are catching more (or less) on average in one oceanic region compared to another.

Tuna fishing techniques developed in several stages, progressively solving the problematic of distance and durability. Steam-powered fishing vessels began to supersede large fleets of wind-powered boats in the mid-nineteenth century, reducing fishers' dependence on the rhythms of the tides and the vagaries of wind, and speeding-up travelling times to and from fishing grounds (Smith 2000; Cantorna et al. 2007). Diesel-powered 'pole-and-liners' were introduced in 1903 by American and Japanese tuna fishing interests (Rockland 1978; Fujinami 1987). This labour-intensive fishing method relies on a dozen or so crew who each use an individual pole to catch a single tuna. Industrial 'purse-seiners' superseded pole-and-liners after the Second World War. These capital-intensive vessels can circle an entire school of skipjack or yellowfin tuna with their purse-seine nets. The 'modern purse-seiner period' took off from the mid-1960s (Gallick 1984) and this vessel type dominates canning-grade tuna fisheries to this day.

Early European Canning-Grade Tuna Fisheries, 1860s–1930s

The development of canning-grade tuna fisheries can be traced to the demand for raw material by fish canneries in France from the late 1860s and in the USA from the early 1900s, initially as a substitute for sardines and salmon. The canning of fish was a technical solution to the problems of distance and durability in the *manufacturing* node of fish commodity chains because it sterilized and stored perishable product, a clear example of capital controlling and mitigating organic processes so to ensure the consistency of its accumulation and reproduction.

Substitutability between fish species was an important business strategy in the early period of the southern European fish canning industry. For example, in the early twentieth century canneries in Portugal shifted raw material processing between sardines, mackerel and albacore tuna. As these three species were all part of the same food chain, fishing operations had to take advantage of whichever of the three was in relative abundance (Mata 2009). From the early 1900s, a specialized French *tuna* canning industry was supplied by a French fleet of between 700 and 1,000 sailing boats targeting albacore off the Atlantic coast, mainly in the Bay of Biscay (Fonteneau 2004; interview, international fisheries specialist). The spread of production to additional locations – the widening of the commodity frontier southwards along the European Atlantic coast – was a necessary response to the combination of migratory flows of tuna and the growing demands of canned tuna consumption in France and elsewhere. In other words, the confluence of rising market demand and local socio-ecological conditions in fisheries co-determined the southward movement of the commodity frontier.

Having experienced a boom period after the First World War, the Spanish fishing fleet expanded from the Bay of Biscay and the Mediterranean into new commodity frontiers off the Canary Islands and Morocco. But by the 1930s rising operating costs, falling prices, a lack of capital and the Spanish Civil War led to a series of bankruptcies in the sector. This was a period of 'low returns and scant possibilities of capital accumulation' (Cantorna et al. 2007, 364). After the civil war the fascist state identified fisheries as a major source of (import-substituting) animal protein and provided low-cost, long-term credit facilities to develop the sector, although this support did not bear fruit until after the Second World War. The Great Depression and the Second World War had also contributed to the dramatic decline of the French sardine and tuna canning industry (Ferreira-Dias and Guillotreau 2005). Even if the canning sectors in these countries had flourished, fish quality would not have survived the long distances involved in tuna migration flows. Spoilability of catch meant that the tension between the organic and synthetic was yet to be resolved in the fishing node of the chain. The principal initial strategy to overcome spoilability was European tuna fleets offloading to canneries in the geographical locality of the resource (Mata 2009, 46–7) which limited the extent to which fleets could 'follow the fish'.

The Industrialization of Tuna Fleets and a New Commodity Frontier in the 1950s

The industrialization of tuna fishing fleets after the Second World War was a turning point in the development and expansion of commodity chains in canned tuna. Industrial-scale fishing and tuna canning developed symbiotically, driven from the outset of the emergence of the industry by the overarching logic and conditions of generalized commodity production. In the 1950s, industrial tuna fisheries developed rapidly, sparked by military technology developed during the war and closely supported by 'home' states and scientific institutions.[12] Japanese and US pole-and-line fleets sharply increased the geographical extent and extractive intensity of fishing in the Pacific Ocean when wooden hulls were replaced with steel ones and refrigeration and freezer systems were adopted. With these technological changes, global tuna production doubled between 1950 and 1960 (FAO FishStat+ 2007).

The French and Spanish tuna fleets began to rebuild in the postwar era with the introduction of diesel pole-and-liners. But they were now increasingly centred on a new commodity frontier – *tropical* fishing grounds off the coasts of the French colonies of Senegal and (later) Ivory Coast (Le Roy 2008), which meant a shift in target species from sub-tropical albacore to skipjack and yellowfin. In 1953, French cannery owners had funded exploratory fishing by a new fleet of Basque and Breton pole-and-liners in the Eastern Tropical Atlantic, and by 1957 around 90 boats were active in the area (IDDRA 2004, 6–7). This was followed by substantial French and Spanish investment in canning factories in Dakar in the mid-1950s and then in Abidjan in the mid-1970s, a shift in the centring of tuna processing in West Africa that was partly due to the fleet's movement south-east to the Gulf of Guinea (NOAA 1981a,b).

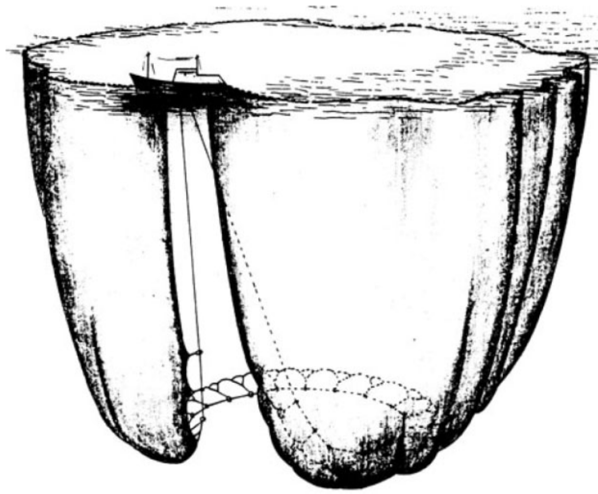
The shift in fishing grounds from the Bay of Biscay to the new frontier in the Eastern Tropical Atlantic was evident in the species composition of catch. Between 1950 and the mid-1960s, the French canning-grade tuna catch was predominantly sub-tropical albacore, but by 1965 tropical yellowfin caught off West Africa was the largest share (FAO FishStat+ 2007). A similar shift occurred in the composition of Spanish catch, but not until the mid-1970s, before which the fleet principally targeted the Atlantic albacore fishery in close vicinity to Spanish tuna canneries.

The 'Modern Purse-Seiner Period' and the European Fleet in the 1960s and 1970s

In the late 1950s, US boat owners began to convert pole-and-liners to house mechanized purse-seine gear. The associated advances in productivity led to the rolling out of new purpose-built tuna purse-seiners through the 1960s. Tropical purse-seiners are among the largest and most expensive fishing boats in the world. The average carrying capacity of the more advanced classes of this boat at this time was five times larger than that of a pole-and-liner (Rockland 1978; Gallick 1984). A skiff tows the net around a school of skipjack and/or

[12] For example, a leading fisheries scientist employed by the US government stated in 1948 that tuna ' "offer the greatest possibilities for the development of valuable commercial fisheries" ' and identified the potential of fisheries science ' "to assist in the development of profitable fisheries" ' (Felando 1987, 103–4 fn 1, see also 95–6). The relationship between fisheries science and the development of capitalist fisheries is an important sub-text, but one that is beyond the scope of this paper.

Figure 1 An illustration of an industrial purse-seiner



Source: FAO (2001b).

yellowfin tuna at the surface (Figure 1). The catch is normally too heavy to haul directly aboard, so it is either scooped aboard using pan nets or pumped on to the vessel using sea water (Jennings et al. 2001). The fish are stored in frozen brine in the hull of the vessel.

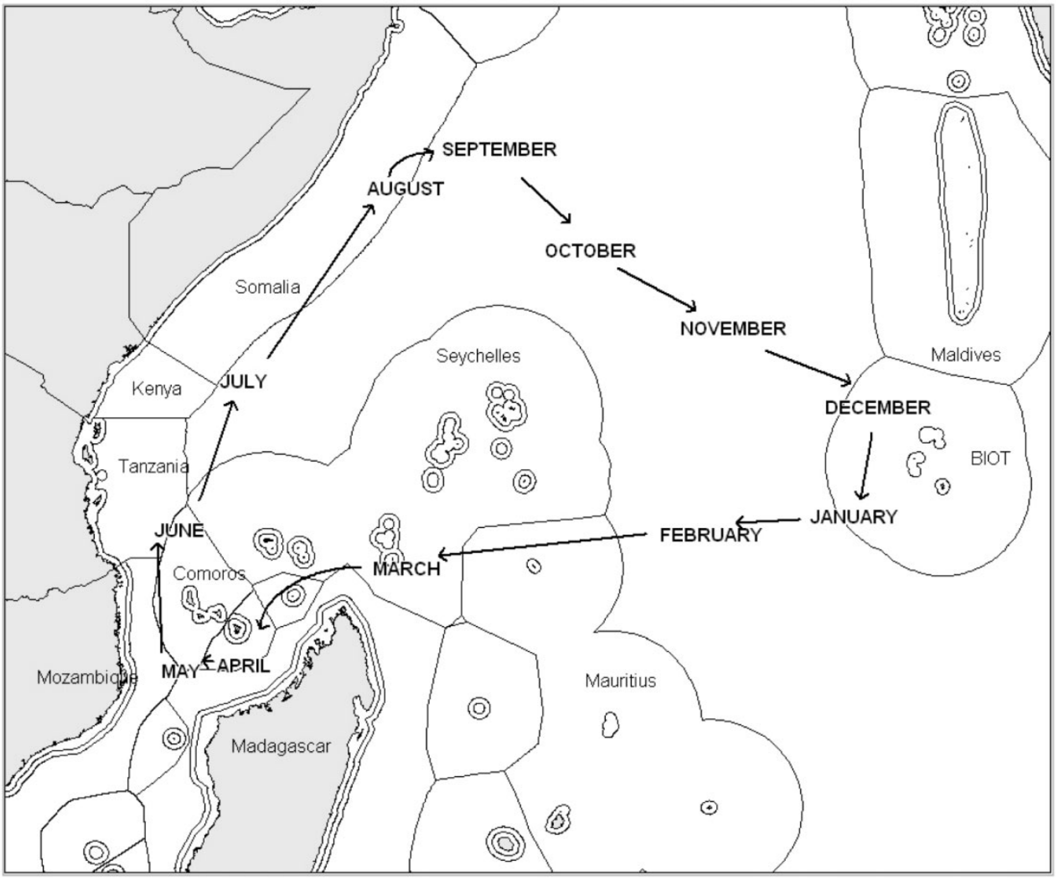
The introduction of purse-seiners from 1964 onwards rapidly enhanced the productivity of European fishing firms based in West Africa (Albacora 2010; Allen 2010). In the 1960s, French and Spanish fishing firms also introduced onboard freezers and advanced navigation systems on purse-seiners (Cantorna et al. 2007). Larger boats travel further and freezers enabled them to stay at sea longer before offloading catch to canneries, eroding many of the constraints of distance and durability in the fishing node of the chain. However, in the early 1970s, only 20 years after the 'discovery' of the Eastern Tropical Atlantic tuna fishery, the purse-seine catch peaked (and then flattened out) at 70,000–80,000 tonnes per year as heavy fishing pressure eroded the initial high ecological surplus (Miyake et al. 2004; and Figure 3 below).[13] If the French and Spanish tuna fleets were to continue to grow, they would need a new commodity frontier.

The Western Indian Ocean in the 1980s – A New Commodity Frontier

By the late 1970s, sustained tuna extraction in the Eastern Tropical Atlantic resulted in a decline in the relative productivity of the fishery. This was indicated by a drop in daily catch per unit effort (CPUE) for high-value yellowfin tuna, which had fluctuated between 5–6 mt in 1972–9, but dropped significantly to an average of 3.3 mt in 1983; in addition, CPUE for skipjack averaged only 2.8 mt per day during 1980–3. By the early 1980s, the Western Indian Ocean (WIO) had been identified by French interests as a new (and the last) tuna commodity frontier.[14] In contrast to the productivity decline in the Atlantic, CPUE in the Western Indian

[13] This fishery continued to be active and would peak again in the early 1990s with the socio-technical intensification of fishing (see the final section).
[14] The other remaining (and larger) canning-grade frontier that was discovered a few years before was the Western and Central Pacific Ocean (Figure 3), a sphere of influence predominantly of East Asian and US commercial and political interests.

Figure 2 A schematic of the Western Indian Ocean tuna migration



Source: IOTC catch and effort database, compiled by John Pearce, MRAG.
Note: The lines in the sea surrounding land mass depict territorial seas (12 nautical miles from shore) and national exclusive economic zones (up to 200 nautical miles from shore): BIOT = British Indian Ocean Territory (UK overseas territory).

Ocean in 1984–5 was 5.8 mt for yellowfin and 5 mt for skipjack (Marcille 1987). Importantly, in the 1980s, the WIO was the only canning-grade tuna fishery in the world where longer-living, higher-value yellowfin were the greatest proportion of catch (Joseph 2000), an initial high ecological surplus typical of a new commodity frontier.

To increase surplus, industrial fishing vessel owners seek to maximize time spent fishing ('fishing days'), and minimize time spent travelling to and from the fishery and to the location of offloading ('steaming days'). If an offloading port is close, boats reduce labour and fuel costs and increase returns to investment through faster return journeys to fishing grounds. Figure 2 illustrates a stylized movement of tuna populations in the Western Indian Ocean based on fishing effort (i.e. it shows roughly where vessels 'follow the fish').[15] This movement explains

[15] The figure is a highly simplified account of population movements. Actual movements are considerably more complex and contingent upon annual changes in environmental and other conditions.

why Port Victoria, Seychelles, at the geographical centre of annual tuna migratory patterns, is one of the most important tuna hubs in the world – the environmental conditions of production mean that offloading in Seychelles minimizes steaming days.[16]

As in the Eastern Tropical Atlantic, French and Spanish fleets *created* the Western Indian Ocean purse fishery and have dominated it ever since. From 1984 to 2007, European-owned boats took a total of 92 per cent of catch in the entire WIO purse-seine fishery (SFA database). The new frontier helped to double the total catch of the French fleet in 9 years (between 1980 and 1988). The geographical distribution of the French fleet was highly concentrated in the WIO during this time. Of the 31 French boats operating in 1988, 21 were based in the WIO (all but one of which were boats between 750 and 1,250 GT) and only ten were in the Atlantic (five of which were under 750 GT in size) (ADB/INFOFISH 1991; Josupeit 1993). The Spanish fleet's total catch doubled in only 7 years (1980–6) although this was not due solely to the new frontier. Seventy-five per cent of the Spanish catch in 1980 was in the Eastern Tropical Atlantic (the remainder was in the Bay of Biscay); by 1988 this was only 52 per cent, with 32 per cent caught in the WIO and the remaining 16 per cent in the Bay of Biscay (ADB/INFOFISH 1991; Josupeit 1993). So while the Spanish fleet had followed the French fleet into the WIO, the majority of its operations continued to be based in the Atlantic in the 1980s. As in the Atlantic, canning factories quickly followed. Two French manufacturers moved into the Indian Ocean through joint ventures in Seychelles (in 1987) and in Madagascar (in 1989), spurred by sustained growth in canned tuna consumption in Europe from the mid-1980s.

In sum, the French and Spanish fleets undertook commodity widening strategies to appropriate (initially) high ecological surpluses in new frontiers in the Atlantic and Indian oceans. The unfolding of this movement included the uptake of new productive technologies and resulted in these two fleets dominating canning-grade tuna fisheries in three oceanic regions. However, as in the Atlantic, the high ecological surplus associated with catching a high proportion of valuable yellowfin species in the WIO was soon eroded. In 1989, for the first time in this fishery, the volume of skipjack catch was greater than that of longer-living yellowfin. In the final section, I introduce the production strategies deployed by the two fleets to maximize profitability through this relative ecological decline. But before doing so, the next section introduces a meso-level perspective of the firms engaged in the WIO. Who owns these firms and how are they organized? Did competitive relations intensify after 1989? In other words, what does a tuna commodity frontier look like at the analytical level of firms engaged in competitive extraction?

CORPORATE STRATEGIES IN A 'MATURE' TUNA COMMODITY FRONTIER

In this section, I step in from the overarching capital–nature relation and sketch the second 'relation' at the point of production: the contemporary organization of firms engaging in fishing and *horizontal* relations between them as they transform nature to produce commodities for the world market. Firms' business strategies are a constituent component in understanding how the tuna commodity frontier works. I demonstrate that in 'mature' commodity frontier conditions in the Western Indian Ocean after 1989 (the end of a high ecological surplus), competitive relations between firms heightened as part of a struggle to take greater control of the fishery. This reveals that corporate strategy is another, but not yet well-explored, component of the commodity frontier. However, these competitive dynamics did not result in a universal 'type' of

[16] Port Victoria received 88 per cent of total transhipment and landing volumes from purse-seiners active in the WIO between 2000 and 2008, which includes a small number of non-EU-owned boats (SFA database).

fishing firm, despite the fact that all firms pursue the same functional objective. Instead, a diversity of organizational forms of the firm is apparent. In the following, I identify four corporate strategies that firms deploy to squeeze more surplus out of the fishery in 'mature' frontier conditions: the use of 'flags of convenience', industry associations, a deepening of corporate concentration, and forms of industrial organization from specialization in fishing to full vertical integration into canned tuna manufacturing. When I return to the capital–nature relation in the final section of this paper, I argue that competitive horizontal dynamics contributed to these firms' move towards greater investment in productive technologies, with a resulting intensification of extraction that is transforming the environmental conditions for capital accumulation in the Western Indian Ocean tuna frontier.

In 2008, there were around 88 boats in the European fleet (Table 1). With an estimated cost of roughly US$20 million per vessel (including gear), total capitalization of this fleet is roughly US$1.76 billion.[17] Elements of the fleet use non-EU flags, or flags of convenience (FOC), where the vessels of 'national' firms are not registered under the flags of their 'home' country. This is a business strategy to reduce firms' exposure to regulation.[18] As a result of a decline in international tuna prices in the early 1990s, the then general manager of Saupiquet – a vertically integrated tuna fishing–manufacturing firm – noted that 'to reduce costs drastically' some European boat owners transferred 'to non EEC flags with less European crews' (Antonietti 1993, 62). By 2008, the French tuna fleet no longer used FOC (except for the French overseas territory of Mayotte), but Spanish boat owners continued to use them widely (Table 1). This flagging strategy allows Spanish firms to avoid a cap imposed by the EU on the total size of its distant-water fleet, and to avoid several other EU regulations. As one EU official put it, 'flags of convenience are much better because of less regulations'. The European fleet is not alone in the use of flags of convenience and the issue serves to highlight the complexity and problems involved in analysing 'national' catch data and assessing the operations of fishing firms with vessels registered under multiple flags.

Ownership Structure

Accounting for horizontal differences between firms, and their forward linkages with processing, is critical to commodity frontier dynamics in 'the business of fishing'. I argue that 'mature' frontier conditions spurred an intensification of competition between firms, including struggles to take control of new fishing fleets. Table 1 presents vessel ownership at the level of the firm for the European canning-grade purse-seine fleet, data that I use to illustrate levels of effective control over fishing activities and to indicate wider relationships to manufacturing in the EU-centred commodity chain in canned tuna.[19] In mid-2008, the most important ownership difference was that the French fleet was highly concentrated through only four players – two corporations, one consortium and a more complex entity called Cobrecaf; while ownership of the Spanish fleet was slightly more fragmented – across seven main family-owned and managed firms.

[17] This high level of investment effectively excludes domestic capital in most of the regions of Africa where the European fleet operates.
[18] On the politics and political economy of flags of convenience in maritime industries, see DeSombre (2006), EJF (2009) and Lillie (2006).
[19] All data are for 2008, except for 'areas of operation', which are based upon fleet status in 2010. The main change in area of operational between these two years is that 54 EU-owned boats were licensed to fish in the WIO in 2008, but in 2010 the number of active vessels had dropped to 47. This shift was due to declining catch rates, especially of yellowfin (see the next section), and the impact of Somali piracy on fishing vessel operations, which dissuaded fishing, especially from the late 2000s (for overviews of the latter, see Campling 2008; Havice and Campling 2009). Several of these vessels switched back to the Eastern Tropical Atlantic.

Table 1. The EU-owned distant-water tuna purse-seine fleet in 2008 (areas of operation – 2010)

Controlling firm (national HQ)	*Type of firm*	*Vessel flags*	*EU industry association*	*Boats by area of operation*					*Gross tonnage (GT)*	
				Atlantic	*Indian*	*Pacific*	*Not known*	*Total*	*% of total EU fleet*[a]	*Average per vessel*
Albacora Group (Spain)	Fishing firm forward integrated into branded manufacturing	Spain (6); Seychelles (3); Ecuador (3); Panama (3); Netherlands Antilles (1)	Opagac	3	6	6	1	16	25	2,919
Cobrecaf (France)	Specialized fishing firm	France (7); Mayotte (2); Italy (1)	Orthongel	0	10	0	0	10	11	2,174
Inpesca (Spain)	Specialized fishing firm	Spain (7); Seychelles (1)	Anabac	1	6	0	1	8	10	2,382
Atunsa (Spain)	Specialized fishing firm	Spain (5); Seychelles (1)	Anabac	2	4	0	0	6	8	2,582
Echebastar (Spain)	Specialized fishing firm (minor manufacturing investment)	Spain (3); Seychelles (3)	Anabac	0	6	0	0	6	8	2,474
Calvo Group (Spain)	Branded manufacturer backward integrated into fishing	El Salvador (4); Cap Verde (2)	Opagac	2	0	4	0	6	7	2,137
Pevasa (Spain)	Specialized fishing firm	Spain (5)	Anabac	0	5	0	0	5	6	2,244
Kühn-Ballery, France-Afrique, CMB (France)	Specialized fishing firm	France (7)	Orthongel	2	4	0	1	7	5	1,447
Garavilla Group (Spain)	Branded manufacturer backward integrated into fishing	Spain (2); Ecuador (2)	Opagac	0	0	4	0	4	5	2,389
Bolton Group/Saupiquet (France)	Consumer goods marketer with backward integration into manufacturing–fishing	France (5)	Orthongel	2	3	0	0	5	4	1,671
MW Brands (France)	Branded manufacturer backward integrated into fishing	Ghana (5)	–	4	0	0	1	5	2	1,050
Others[b] (Spain and France)	Mainly specialized fishing firms	Spain (6); France (2); Guatemala (2)	Misc.	5	3	0	0	8	6	1,778
Total		EU flag (56); Other (32)		23	47	14	4	88	100	2,310

Sources: Estimates based on multiple interviews and personal communications in 2006, 2009 and 2010; company websites; the FIS website; the FFA, IATTC, ICCAT, IOTC, SFA and WCPFC vessel registries and databases; CIMB Securities (2010); Océanic Developpement 2008.
Notes: averages are not always precise because data for three boats is for Gross Registered Tonnage (GRT) rather than GT, and tonnage data for one vessel is missing.
[a]Total tonnage for the 88 boats is around 189,400 mt.
[b]'Others' includes the following firms and their number of boats: Jealsa (two – one of which sank in 2009); Nicra-7 (two boats); Petusa (two); Compania Europea de Tunidos (one); Pebertu (one), reportedly in receivership in 2010; and Sapmer (one), which has since bought at least two new boats.

Concentration of ownership and production in the French distant-water tuna purse-seine fleet has deepened over the past two decades. In the late 1980s, *ownership* of the French fleet of 30 vessels was concentrated in only six firms, of which Cobrecaf was the lead player (ADB/INFOFISH 1991). In 1991, Cobrecaf accounted for an estimated 47 per cent of the French fleet's frozen tuna *production*, Saupiquet 21 per cent and CMB 20 per cent (Le Roy et al. 2008). At this time, Cobrecaf operated solely in the WIO and only Saupiquet kept its entire fleet in the Atlantic, supplying its canneries in West Africa (Josupeit 1993). From the late 1980s to the mid-1990s, Heinz, a branded manufacturer of canned tuna at the time, struggled to gain financial control of Cobrecaf and its fishing fleet so as to ensure supply to Heinz-owned canneries. The outcome of this struggle was that between 1994 and 2006, Cobrecaf was effectively controlled by Heinz European Seafood, which it achieved through a minority share in Cobrecaf (36 per cent) combined with strategic collaboration with another minority shareholder (Guillotreau and Le Roy 2001; Le Roy 2008). When Heinz European Seafood was bought by Lehman Brothers in 2006, the management company – MW Brands – held on to Cobrecaf for another 2 years.

Commercial tussles over the control of Cobrecaf continued in 2008, as did the tendency to corporate concentration in the French fleet. A competing specialized fishing firm – the consortium of Kühn-Ballery, CMB and France-Afrique ('Kühn-Ballery et al.' for short) – had wrestled a leading minority share in Cobrecaf (38 per cent), partly from MW Brands' prior collaborating partner. MW Brands' canning operations had lost effective influence over the fish-selling practices of Cobrecaf and were now unable to use this control 'to guarantee part of their [raw material] needs' (interview, EU industry representative). In October 2008, MW Brands sold its shares in Cobrecaf to the Kühn-Ballery et al. consortium (CREFMPM 2008). This gave the consortium majority ownership of Cobrecaf and represented a major shift in control and industrial organization of France's largest fleet from being intimately tied to a branded manufacturer to being absorbed by a specialized boat-owning consortium.[20] In sum, horizontal relations between firms in the 'mature' conditions of the Western Indian Ocean commodity frontier from the 1990s onwards resulted in a sharpening of competition over the commercial control of tuna fleets. A manifestation of this competition was the intensification of concentration in ownership. But what types of industrial organization do firms adopt to extract tuna?

Industrial Organization

In addition to concentrating ownership, firms deploy a range of organizational structures in 'mature' frontier conditions. Bonanno and Constance (1996) assume that the firms engaged in a tuna commodity chain would deploy similar organizational forms. They use a study of the US-centred tuna commodity chain, where branded manufacturers divested their ownership of purse-seine fleets in the 1980s, to generalize that the 'global' tuna industry underwent a similar 'Post-Fordist' transformation. While this was the case for the US purse-seine fleet between the early 1980s and the mid-2000s,[21] it did not typify the industrial organization of the *global* industry. The European fleet illustrates that industrial organization in the tuna commodity chain is subject to the contingencies of particular firms' commercial strategies as they seek to cope with increasingly competitive conditions.[22] The result is a diversity of forms of firm organiza-

[20] Note that the set of interests identified as Cobrecaf and Kühn-Ballery et al. was formally consolidated in a new firm in January 2011, Compagnie Francaise du Thon Oceanique (Hamilton et al. 2011).
[21] On the recent return to vertical integration of the US fleet, see Havice (2009).
[22] State–capital relations and the contingencies of individual business histories also partly explain why firms adopt different organizational forms, but discussion of these is beyond the scope of this paper (see Campling forthcoming).

tion in the European fleet. Of course, these differences are important in the formation of new frontiers as well, but I focus here on the role of industry associations and levels of vertical integration in 'mature' frontier conditions so as to reveal the contemporary dynamism of this extractive industry.

National 'producer organizations' (industry associations) group the firms that constitute the French and Spanish fleets. Fishing firms use them to apply collective bargaining power in relationships with 'home' and 'host' states to develop and maintain access to foreign commodity frontiers, and to gain access to a wide range of subsidies (Campling forthcoming). For example, vessels flagged by France and Spain gain access to commodity frontiers in the Atlantic, Indian and Pacific oceans through agreements negotiated and largely paid for by the EU (Hamilton et al. 2011). Similarly, a Spanish association, Opagac, has an operational office based in Seychelles, which coordinates the activities of its member firms' vessels when in port. French purse-seine fleet owners are represented by a single producer organization, Orthongel, while Spanish fleet representation is divided into two – Opagac and Anabac (Table 1). The firms in Opagac are vertically integrated into canned tuna manufacturing, while Anabac members are specialized fishing firms.[23] There are widely differing emphases on vertical integration among Opagac membership: Albacora is more specialized in the fishing node, Calvo and Garavilla's main business is branded manufacturing but they also have significant purse-seine fleets, and Jealsa is a very minor player in tuna fishing (Table 1). These producer organizations play a major strategic role in firm–government relations in developing and maintaining the tuna commodity frontier.

A second strategy is for EU-centred canned tuna manufacturing firms to integrate into fishing. But backward integration is far from a universal strategy in the tuna industry. As pointed out by a representative of an EU-centred firm specializing in the marketing of canned tuna: 'Why own boats when there is a global tuna price? Plus the risk taken if the price drops?' We saw an example of this when MW Brands' sold its share of Cobrecaf in late 2008 when it found that it no longer had effective control over Cobrecaf and could not drive price on a 'cost plus formula' (interview, EU industry representative, 2009). To ensure ongoing security of raw material supply on top of its Ghana-flagged vessels (Table 1), as part of the sale, MW Brands established a 5-year supply contract with Cobrecaf vessels – now controlled by Kühn-Ballery et al. – providing MW Brands with first refusal on price negotiations and thus some security of supply.

Why do manufacturing firms backward integrate into fishing when there is an international market in tuna raw material? A major reason is raw material shortages in the context of both global overcapacity in canning plants in the 2000s (Hamby 2009) and the lack of a new geographical commodity frontier. Ensuring tuna supply through the control of purse-seine capacity (either through direct ownership, financial linkages or medium-term supply contracts) is a major strategic consideration in the global commodity chain (see, e.g., Havice and Reed 2012). But for one CEO of a European branded manufacturing firm, vertical integration into fishing is also:

> a question of culture. It depends a lot upon the leader of the company. The business of boats is very specific. You can make money and lose huge amounts of money. You need a big heart for fishing . . . It's a strategy and [its existence is] evidence that you can make money.

[23] Ownership connections mean that some FOC vessels in the European fleet are still partially supported by national producer organizations.

Vertical integration has implications for fish procurement at canneries based in the Western Indian Ocean, which have been experiencing shortages of tuna supply since 2007. The priority of fleets vertically integrated into canning (e.g. Albacora and Saupiquet) is to supply their own factories. For example, while Albacora is known to supply the factory in Seychelles, Albacora also 'sells' WIO-caught tuna to its processing facility in Ecuador.[24] In other words, Opagac vessels' tuna sales are unsurprisingly tied in to supplying their own manufacturing facilities.

The commercial conditions facing specialized fishing firms are very different from those vertically integrating into manufacturing. The owners of specialized fishing firms trade their catch internationally and negotiate prices and sales with buyers while at sea. If the boat is only part of a small fleet, negotiations can be uneven because small firms have limited bargaining power *vis-à-vis* relatively concentrated buyers (e.g. the major manufacturers). To avoid being captive to buyers available in the port at the time of offloading, some Spanish fishing firms own their own freezer cargo vessels ('reefers') that they use to tranship catch to buyers. For example, Atunsa has one reefer based in the WIO that can tranship the catch of one-and-a-half purse-seiners. However, given that Atunsa has a fleet of four seiners active in this region (Table 1), when its own reefer is full and en route to a buyer, it must sell either to locally based manufacturers or trading companies with a reefer in port. Moreover, except for a huge fleet such as Albacora, the volumes traded by individual specialized fishing firms will always be relatively small, keeping negotiating power in the hands of large buyers.

To mitigate uneven market power in their selling relationships, some specialized fishing firms collaborate by establishing trading entities to undertake negotiations with buyers. In the French fleet, all boats except for the Saupiquet vessels sell their catch through the 'Sovetco' trading company. Soveto leases reefers to tranship fish and buys from boat owners at a provisional price, with the final allocation depending upon actual sales (Josupeit 1993; Guillotreau and Le Roy 2001). The sheer scale of the collective sales of the vast majority of the French fleet gives Sovetco enhanced bargaining power in its sales to buyers around the world, and therefore enhances this fleet's competitive position *vis-à-vis* vertically integrated boats. Some Anabac members – Inpesca and Pevasa, also specialized fishing firms – use a similar co-operative trading entity called Peva Eche to improve their selling relationship with buyers.[25] According to one EU government official, Peva Eche's consolidation of catch for international trade gives its members a 'more powerful structure, they're less influenced by the canneries'. Other Anabac members simply trade their catch as individual firms, which weakens their position when tuna supply is plentiful as they can be more easily played off against each other in price negotiations by concentrated buyers.

Competitive relations among fishing firms and types of ownership and industry organization are a significant, but to date, not well-explored, component of how frontiers operate. Competition between firms existed when there were new geographical frontiers to chase, but these relations sharpen when frontiers are 'mature'. Ownership of the French purse-seine fleet has become increasingly concentrated and fishing firms co-operate through complex financial interplay, mutual operational management and marketing arrangements, and the Orthongel producer organization. Like the Anabac members of the Spanish fleet, these French players are now primarily specialized fishing firms, although – except for the example of Peva Eche – Anabac firms are less successful at commercial collaboration. Conversely, Opagac members' fishing operations focus on supplying their own canned tuna factories and compete with the

[24] While Calvo and Garavilla boats are not currently active in the WIO, their activities are also focused on supplying their own factories in Spain and Latin America (Hamilton et al. 2011).
[25] Echebastar used to be a partner in Peva Eche, but pulled out in 2005 due to a commercial dispute.

specialized fishing firms in the wider sales of tuna only when this focus is achieved. Having shown that the increasingly concentrated European fleet is constituted by differentiated firms and that their business strategies are complex and contingent, I now move to examine the production strategies deployed to intensify extraction in 'mature' frontier conditions in the Western Indian Ocean.

PRODUCTION STRATEGIES IN A 'MATURE' TUNA COMMODITY FRONTIER

In this final section, I return to the vertical relationship between capital and nature to examine how capital responds when initial commodity frontier conditions are depleted and new frontiers do not exist, as has been the European fleet's situation since the 1990s. As noted, the volume of skipjack catch by purse-seiners in the Western Indian Ocean in 1989 was, for the first time, greater than that of higher value yellowfin tuna, and marks both a decline from the initial high ecological surplus and a coping strategy of shifting production to catch larger volumes of a less valuable species (Figure 3).[26] The tuna frontiers in the Atlantic and Indian oceans were not abandoned with the end of high ecological surplus. Instead, as the costs of production move to the sectoral average in 'mature' frontiers, capital seeks to enhance profitability through heightened horizontal competition (see above) and 'capitalization and socio-technical innovation' (Moore 2012, 3). Socio-technical innovations are also present in periods of high ecological surplus (such as the emergence of the 'modern purse-seiner period' in the mid-1960s), but it is the degree of intensity in their application that defines the 1990s onwards as a distinct period of intensive development in the WIO fishery – a period when new geographical frontiers are no longer available. This intensification accounts for continued increases in canning-grade tuna catch in this fishery until the mid-2000s (Figure 3). For example, while the number of Spanish purse-seiners operating in the WIO has been approximately the same since the late 1980s, total fleet landings have more than doubled (de Molina et al. 2009). In the following, I sketch production strategies deployed by capital to enhance fishing capacity (bigger boats) and fishing effort (especially 'fish aggregating devices'[27]) that supported a deepening of the commodity frontier and further shifted the principal targeted species from yellowfin to skipjack. I will also show how this intensification of production drove a socio-ecological crisis in the fishery by the late 2000s.[28]

Vessel Capacity

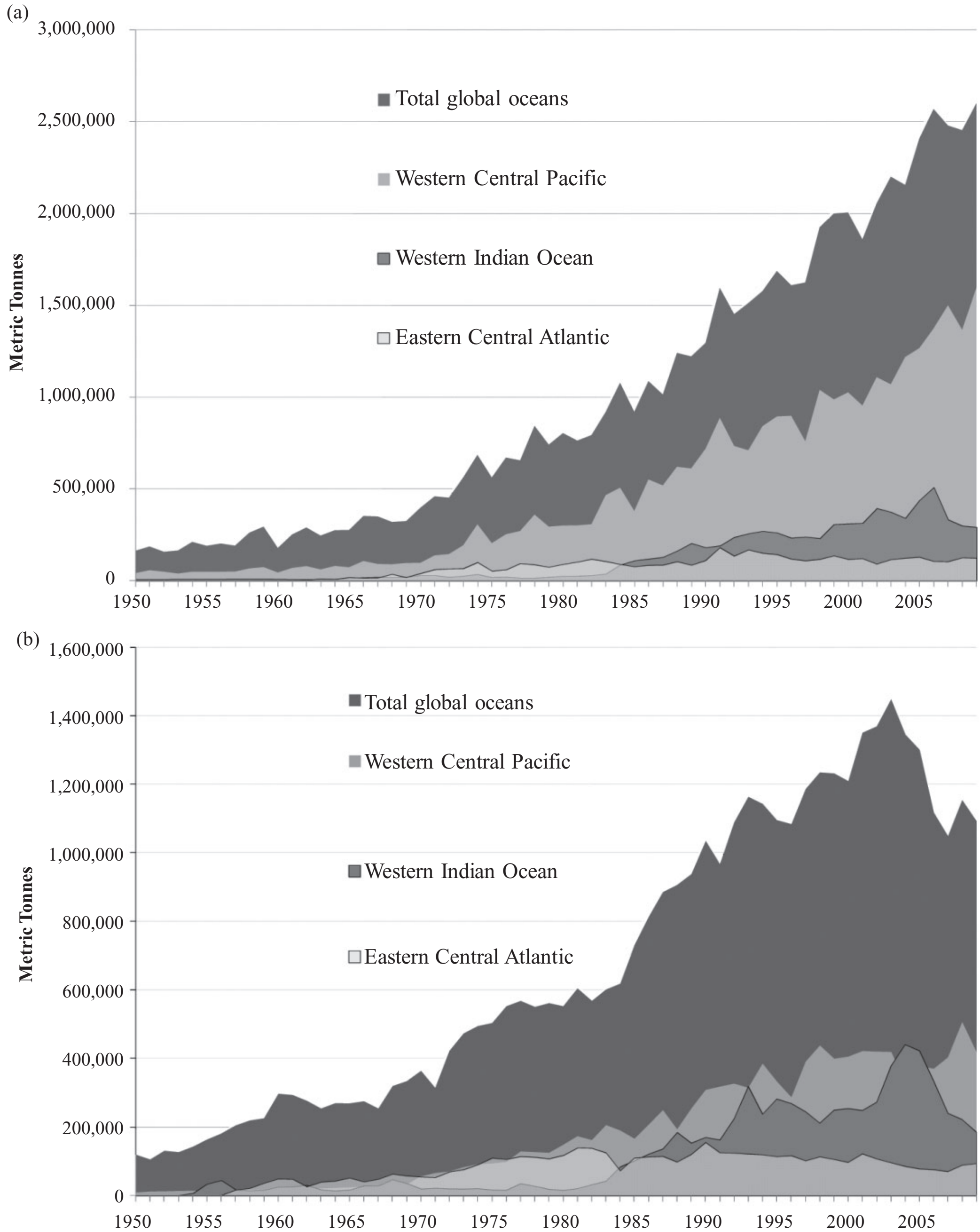
Vessel owners build bigger boats to intensify production. Larger vessels are able to stay at sea for longer periods and over longer distances. With larger fish-holds, they are also able to carry greater absolute volumes of tuna per fishing trip. Larger purse-seine nets enable the capture of a higher proportion of mature yellowfin, because this species swims at a deeper level in the water column. This is important to the economics of the commodity chain: larger tuna command a higher price because of improved labour productivity in processing, while smaller fish yield less edible meat and result in a lower yield of canned product per ton of fish

[26] Yellowfin catch volumes outpaced skipjack again intermittently (i.e. in 1993 and 2003–4), but subsequent catch entered severe decline in 2007. Because the WIO has been a major global source of supply of yellowfin since the emergence of this fishery in the early 1980s, its recent decline played a large proportional role in global catch decline for this species (Figure 3).

[27] Fish aggregating devices (FADs) are man-made floating objects deployed by fishing firms at sea to attract tuna. Tuna aggregate around the FAD as it mimics *natural* floating objects, such as logs, on which smaller fish feed.

[28] Fisheries management terminology such as 'vessel capacity' and 'fishing effort' is ripe for deconstruction (see Bavington 2010), but these terms are used uncritically here due to space constraints.

Figure 3 The global skipjack (a) and yellowfin (b) catch by all gear types and by major oceanic region, 1950–2009



Source: FAO FishStatJ (2011).
Note: The figure includes the WCPO because it is the largest purse-seine fishery in the world and has been the largest source of global growth in skipjack tuna supply from 1985 onwards. 'Total global oceans' combines the catch in these three sub-regions plus all catch elsewhere in the world, in order to provide a sense of the proportional shifts.

(Rockland 1978; King 1987). In addition, as noted earlier, canned yellowfin commands a higher price in the EU-centred commodity chain, especially on Italian and Spanish markets, and is thus routinely sorted from skipjack.

In anticipation of the commercial advantages associated with bigger purse-seiners, French and Spanish firms engaged in a flurry of construction of ever-larger boats in the 1990s and early 2000s. But there are important differences *within* the European fleet. Vessels in the Spanish-owned fleet in the WIO in 2008 were on average over 30 per cent larger than the French equivalent, with an average vessel size of 2,800 GT and 1,900 GT respectively (Table 1). Vessels over 2,000 GT are categorized here as 'super-seiners' and those over 3,500 GT as (rather awkwardly) 'super super-seiners'.[29] The Spanish fleet had nine super super-seiners spread across the main firms (the newest boats in this fleet) and all of the remaining boats were super-seiners. The French fleet had nine super-seiners, which were all owned by Kühn-Ballery et al., and no super super-seiners. One Spanish boat-owner claimed that super super-seiners 'engage in a different type of operation' compared to smaller vessels: 'the net size is similar, but the fuel to catch ratio is lower on bigger boats, and thus better for the environment, [and] of course for owners' businesses'. In other words, with the heightening of horizontal competition in 'mature' frontier conditions and the downstream price pressures in canned tuna retail markets, bigger boats appear to offer fishing firms a competitive advantage. However, while the fuel to catch ratio of 'super super-seiners' may well be more efficient, their operations are also more sensitive to fuel price rises (Miyake et al. 2010; multiple interviews, EU industry and Seychelles government officials, 2006 and 2009). These vessels also have higher initial purchase and depreciation costs. Consequently, value extraction needs to be higher to pay off larger loans and achieve profitability. The business model for managing super super-seiners is thus 'tighter', leading to the deepening of the competitive drive to maximize catch and minimize costs.[30] The ecological implication is that the larger and newer vessels in the European fleet are deepening extractive pressure on the resource (see below).

Effort-Enhancing Measures

Technological and organizational changes extend and intensify tuna extraction and enhance fishing effort (Miyake 2005). Modern industrial purse-seiners utilize cutting-edge technology to locate and hunt fish, including in the European distant-water fleet. While physical vessel capacity might be a constant (e.g. in tonnage or engine power) the efficiency and effectiveness of a vessel's ability to catch fish can change. To enhance effort, vessels use vertical and horizontal sonar and hydro-acoustics, satellite imaging of oceanographic conditions such as temperature (including through cloud cover), satellite imaging of plankton concentrations, bird radar (birds prey on small fish driven to surface by feeding tuna below) and the first-hand spotting of schools using small on-board helicopters (Jennings et al. 2001; Miyake 2005; direct observation of vessels and multiple interviews, 2006 and 2009). Fishing techniques also differ across operations in the WIO. Before the 1990s, the French and Spanish fleets hunted for fish in the WIO in one of two ways. In one technique, crew scan the horizon for birds that are attracted

[29] This is an arbitrary classification. During the 1980s, a vessel classed as a 'super-seiner' was only >1,000 GT (Doulman 1987, 140).

[30] To keep their larger boats at sea for longer periods and to maximize fishing days and minimize steaming days, since the mid-1990s several Spanish-owned fleets use 'supply vessels'. Their principal activity is to deploy, maintain and monitor fish aggregating devices, but they also deliver supplies and transfer injured crew (Roberto et al. 2007; Pianet et al. 2009; Miyake et al. 2010). These activities allow supported purse-seiners to enhance their focus on the extraction of tuna.

to tuna feeding frenzies or by searching for a school from the air using a helicopter (known as catching on 'free schools'). In the other, vessels engage in a 'hunt for logs' (Sibert 1987, 44), because tuna aggregate under natural floating logs or other debris ('log-school'). Until the early 1990s, tuna 'FAD fisheries' were mainly naturally occurring *log*-schools, including in the WIO (Miyake et al. 2010). Subsequently, *man-made* fish-aggregating devices rapidly became an important source of effort enhancement. FADs employed in the purse-seine fishery are normally drifting rafts equipped with transmitting positioning buoys, situated in zones where canning-grade tuna are believed to migrate.[31]

Firms introduced FADs en masse into the Atlantic and Indian oceans in the 1990s to increase CPUE (Hinton 2007). Fishing around logs and artificial FADs has constituted around 50 per cent of the *global* catch of tropical tunas since the 1990s (Fauvel et al. 2009). FADs in the Eastern Tropical Atlantic enabled a new frontier of *intensive* production: the fishery reached a second peak of 140,000 tonnes in the early 1990s (having previously peaked in the early 1970s, as noted above), but it soon flattened off in subsequent years as this socio-technical innovation reached its ecological limits. By the mid-2000s, a FAD in the WIO typically used 'a GPS satellite receiver and a transmitter, a thermometer to measure water temperature, a system to gauge the state of the batteries and a microprocessor to control these systems' (Roberto et al. 2007, 4). Some FADs are also equipped with expensive sounders to detect and estimate volumes of fish to a depth of up to 400 metres (direct observation on docked vessel, Seychelles, January 2009). In the mid-2000s, the French fleet was releasing around 130 FADs per year and the Spanish over 300 (Moreno et al. 2007, cited by Miyake et al. 2010, 44). FAD fishing in the WIO extracts a higher proportion of lower value skipjack, whereas free-school fishing extracts more yellowfin.[32]

The yellowfin catch on FADs tends to be smaller juvenile fish, which are less valuable due to poor recovery rates when butchered. Given that yellowfin caught on a free school tend to be mature, and thus larger-sized, fish, they command a higher price. Since the French fleet is comprised of smaller vessels than the Spanish, and thus has a lower fuel to catch ratio, smaller fish-holds and a reduced maximum number of fishing days, when seasonality permits, *some* French boats compensate by targeting free schools to extract higher-value, larger yellowfin. Conversely, larger and more numerous Spanish boats and other French ones minimize risk by fishing on FADs, extracting a larger absolute volume of fish regardless of species (Campling forthcoming; Guillotreau et al. 2011). In sum, with the launching of ever-bigger boats with tighter cost structures, FADs allow firms to enhance profitability in 'mature' frontier conditions.

Socio-Ecological Contradictions of Production Strategies

The intensification of production strategies by fishing firms to cope with the limits of 'mature' frontiers is undermining the natural conditions for the reproduction of the European fleet's operations at this industrial scale. Today, two main ecological concerns are associated with the purse-seine fishery in the WIO (and elsewhere): the use of FADs and the overfishing of yellowfin. On the first, FADs threaten tuna biomass because they yield high juvenile bigeye and

[31] In the WIO, they are normally bamboo rafts with nets hanging underwater (Fauvel et al. 2009, 2), although various other materials can be used (de San and Pages 1998, 24).

[32] Over the 19-year period 1990–2008, the Spanish fleet caught a total of 2.4 million tons of skipjack and yellowfin tuna and the French 1.6 million. Broken down by fishing technique: the Spanish caught 71 per cent on FADs (with a species composition ratio of roughly 2:1 skipjack to yellowfin) and 29 per cent on free schools (1:2 skipjack to yellowfin); and the French caught 58 per cent on FADs (a ratio of 2.5:1 skipjack to yellowfin) and 42 per cent on free schools (1:3.5 skipjack to yellowfin) (de Molina et al. 2009, 3–4; Pianet et al. 2009, 9).

yellowfin catch (Miyake et al. 2004),[33] eliminating them from the reproduction cycle (Joseph 2000). FADs also increase incidental 'bycatch' of species such as sharks, with wider implications for the health of the oceanic ecosystem (Murua et al. 2009).[34] Finally, it is believed that FADs can artificially shift the migration patterns of tuna populations by diverting fish from areas with rich foraging conditions (e.g. near natural logs) and attracting them to areas with FADs, but less favourable foraging conditions, leading to a deterioration in population health (Marsac et al. 2000; Hallier and Gaertner 2008; Fauvel et al. 2009).

Despite concerns over ecological impacts, firms use FADs because they enhance profitability.[35] However, even this narrow commercial logic contains a contradiction. Increased FAD use since the 1990s has increased fishing effort and led to more canning-grade tuna on the world market, which has depressed prices and, for a period, 'eroded profit margins' for fishing firms (Mills 2001, 27), even while constant capital costs (e.g. fuel) have risen. These dynamics pressure vessels to use ever more FADs to catch ever more fish in order to maintain or expand catch volumes and yield profitability (Guillotreau et al. 2011). The commercial logic of deepening socio-technical innovation to sustain profitability in the 'mature' tuna frontier is heightening competition between fishing firms and eroding the resource upon which those firms depend. As one tuna fisheries specialist put it: 'Purse seiners at the moment need FADs because there are too many boats and the value added is not enough. There is too much capital chasing too few fish.'

The second major ecological concern is the overfishing of yellowfin, driven by the higher price for this species in EU canned tuna markets. The greater proportion of yellowfin catch (compared to skipjack) in WIO catch in the 1980s yielded a high ecological surplus for boat owners. Even when skipjack catch became predominant in the 1990s onwards, yellowfin still played a significant part in catch composition. However, in 2009 the scientific committee of the regional organization responsible for the management of the fishery – the Indian Ocean Tuna Commission (IOTC, an agency of the FAO) – stated that yellowfin 'stock size is close to or has possibly entered an overfished state' (IOTC 2009, 4). Proposed IOTC yellowfin conservation interventions were deterred by divisions around two contesting hypotheses among member states to explain record high yellowfin catches in 2003–6 (Figure 3).[36] This was essentially a debate around 'recruitment vs. catchability' (Anonymous 2009). Proponents of the first hypothesis argued that favourable environmental conditions in 1999–2001 led to increased yellowfin recruitment (i.e. species reproduction). As the species matures at 2.8 years, the high catch rates were simply the result of an abundance of yellowfin. This position supports the argument that management controls are unnecessary. The second hypothesis explains the record levels of exploitation through the increased productivity of tuna fleets (Fonteneau et al. 2008). From this perspective, there was an increase in 'catchability' of yellowfin because of the socio-technical intensification of fishing. This correctly predicted that the 2003–6 boom in catches would result in a reduction in future catch (Figure 3), and the hypothesis indicates the necessity of limitations on fishing activities.

Despite the evidence, little has been done to place effective limits on yellowfin catch (Anonymous 2009, 24; Allen 2010, 24). Instead, states protect the (real or imagined) interests of

[33] Juvenile bigeye tuna are kept on board and sold to canneries at the same price as skipjack and small yellowfin.
[34] 'Bycatch' is in scare quotes as there is arguably no such thing. Everything is caught in a purse-seine net: some is the commercially targeted species, some is of commercial value but not the target species and some is considered by capitalist fisheries as 'waste' (Roberts 2007; Cooper 2009).
[35] Without a reduction in global purse-seine fishing capacity, this will probably not continue in the long term due to the negative ecological effects of their usage.
[36] Catches of yellowfin tuna in the IOTC region averaged 456,000 mt per annum in this period compared to the previous record high of 395,000 tonnes in 1993 (IOTC 2009, 92–4; Allen 2010, 24).

their (existing or potential) 'home' firms and pursue wider policy concerns such as ensuring imports of (anti-inflationary) 'cheap' food. Yet, given the general scientific uncertainties of stock estimates, biomass would have to fall well below estimated sustainable levels before scientists could confidently identify this fall (Anonymous 2009, 24). In other words, fisheries science will only be able to *prove* a problem to reluctant IOTC member states once it has occurred.

In summary, under 'mature' frontier conditions, the French and Spanish fleets have, in different ways, intensified their appropriation of tuna using a range of socio-technical innovations. These generated a socio-ecological crisis in this fishery when yellowfin catches declined sharply in 2007 onwards. Similarly, the attempt to reduce production costs through the extensive use of ever more sophisticated FAD technology by ever-bigger boats (in some cases supported by 'supply vessels'), puts into sharp question the future of the capital–nature relation in the Western Indian Ocean frontier.

CONCLUSION

I have used Jason Moore's work as a guiding thread in the unfolding of this paper: from a historical sketch of the European distant-water tuna fleet as a whole as it searched for and created new fisheries, to differentiation and horizontal relations at the level of the firm in recent years in a 'mature' frontier and, finally, to an overview of the intensification of socio-technical innovation as capital tried to cope with 'mature' frontier conditions over the past two decades. I have shown how new tuna commodity frontiers are the concert of new organization, new technique and new geographies. Over time, ecological surplus declined in relative productivity in both of the tuna fisheries examined here and capital responded by intensifying extraction. For a time, tuna fleets increased productivity per fishing trip, but this was within extractive limits that became apparent with declines in catch in the Eastern Tropical Atlantic in the 1990s and in the Western Indian Ocean from the late 2000s, *despite* ongoing socio-technical and organizational innovations designed to enhance it. In the latter fishery, strategies to intensify production are partially undermining the ability of the European fleet to reproduce itself due to the overfishing of yellowfin, as well as generating threats to other species due to FAD use. In other words, the compulsion of demand in commodity chains in canned tuna and the concomitant deepening of extractive pressure on tuna resources threaten the biological reproduction of the resource upon which this demand is based.

This overarching vertical relationship between capital and nature is undertaken by fishing firms as an organizational form designed to transform nature to produce commodities for the world market. These firms' business strategies are a constituent component in understanding how the tuna commodity frontier works. Even while these firms perform the same function, they do so in a diversity of organizational forms. Different production strategies are employed to pursue different ends depending upon a firm's ownership structure, industrial organization and relation to markets. This approach to analysing fisheries can help to illuminate the complexity of the industry and offer pointers for sustaining the resource. For example, the identification of the main fishing companies and other key players in commodity chains in fish could facilitate more targeted regulation of fisheries (e.g. banning non-compliant firms from entire fisheries), and improve advocacy and resistance (e.g. the use of market intelligence in negotiations with fishing firms, or identifying points of collaboration between fishworkers in different parts of the chain). Either way, the concept of a 'commodity frontier' helps to situate capital–nature relations in historical capitalism, and contributes to deepening our analytical understanding of the political–economy and ecology of capture fisheries.

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