“An overview of empirical analysis of behavior of fishermen facing new regulations”

AUTHORS	Sturla Furunes Kvamsdal
ARTICLE INFO	Sturla Furunes Kvamsdal (2012). An overview of empirical analysis of behavior of fishermen facing new regulations. *Environmental Economics*, *3*(2)
RELEASED ON	Tuesday, 10 July 2012
JOURNAL	"Environmental Economics"
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

Sturla Furunes Kvamsdal (Norway)

An overview of empirical analysis of behavior of fishermen facing new regulations

Abstract

This paper reviews the empirical literature on fishermen's behavior under changing regulations. The review is not exhaustive; instead, the work focuses on the historical development of empirics in fisheries economics and the parallel development of fisheries regulations. While historic parallels are difficult to observe for later developments, recent empirical analysis of fishermen's behavior illustrates the breadth and interdisciplinary nature of current empirical fisheries economic research. It merges biology, economics, and social science with statistical, mathematical, and rhetorical methods. The author hopes to capture some of the interdisciplinary interplay in the review.

JEL Classification: fisheries economics, empirical analysis, review, fisheries problem.
Keywords: B23, Q22.

Introduction

"*The biological resources of the sea fascinated man's attention for a long time. The mystery of what lies beneath the surface has stimulated his imagination and nurtured hope that in this vast area there are resources capable of feeding a growing and a still hungry population for centuries to come. But, at the same time, realization of this hope is impeded by the opacity, instability, and sheer magnitude of the medium itself – by man's inability to see and hold. Fishing – one of man's earliest callings – is still haphazard and subject to the vagaries of weather, ocean currents, and mysterious migrations*" (Christy and Scott, 1965, p. V).

So begins Christy and Scott's 'The Common Wealth in Ocean Fisheries,' one of the first textbooks on fisheries economics. It covers an impressive breadth of knowledge from theoretical economics, via international law, to practical policy considerations and already in this early textbook, the interdisciplinary nature of fisheries economics comes into view. While Scott (2011) dates the earliest developments toward an economic analysis of fisheries to the mid-1800s, more than hundred years was to pass before what we can call empirical investigations of fisheries and fishermen's behavior began.

In a broad sense, the topic of this overview covers much of the empirical research in fisheries economics. What happens in a fishery upon a change in regulations? When regulations change in fisheries, the changes depend on an array of factors, from environmental and biological factors to economic and social factors. The fishermen's response to changes in regulations is, therefore, intimately connected to an array of factors, and changes in regulations should be interdependent with the fishermen's response. Upon reflection, the topic is clearly connected to the fundamental and empirical question: What happens in fisheries upon changes? Thus, everything is connected. To better understand the development of empirical fisheries economics, we need to look at the general development of fisheries economics, particularly at its earliest beginnings. I will depart from what has become known, among other things, as the fisheries problem, as well as its discovery and role in fisheries economics. From there, I will discuss the evidence of rent dissipation and inefficiency in fisheries, before moving on to rights-based management and related evidence. I also discuss spatial behavior.

The topic also hints towards behavioral economics, which is one of the more recent developments in economics. Behavioral economics emerged from the interplay between economics and psychology, and relies heavily on experiments. It has recently broadened its methodological scope to use the most common methods in modern economics. With regard to fishermen, experimental economics is quite limited, although some fishermen experiments have been carried out. These experiments are mostly concerned with risk preferences, perhaps as a reaction to or reflection of the seemingly popular idea of risk-loving fishermen. I find experimental research relevant in helping to achieve progress in our understanding of fishermen's behavior and its interaction with institutions and regulatory changes (Ostrom, 2006), and I will discuss some of the experimental work in fisheries economics.

Fisheries economics is highly interdisciplinary (Branch et al., 2006). Its core is the interaction between biological and economic systems. Empirical analysis brings in statistical and mathematical methods. And all science involves rhetoric. Working on problems of interdisciplinary nature brings additional challenges which perhaps in part explains why progress in fisheries economics was slow in the beginning (Scott, 2011). The slow theoretical progress meant that it

The discussion and presentation have benefitted from comments and suggestions from Rögnvaldur Hannesson, Theodore Groves, Quinn Weninger, Nils-Arne Ekerhovd, and Lars Ivar Oppedal Berge. A special thank for advice and inspiration goes to Dale Squires.

would take years from the first fundamental insights were established to when economists started to rigorously compare theory predictions and empirical evidence. While the field now has seen both theoretical progress and the introduction of a wide array of empirical methods, a long list of issues remains to be solved, particularly those involving problems that transgress disciplinary boundaries (see Squires, 2009, for a full account).

Although I have taken a broad approach to the topic, there is a time for everything, and I cannot address all aspects of the topic at hand. The main focus is on fishermen's responses to regulations in change, but in places I have found it necessary to discuss responses more generally. Further, I've chosen to put more emphasis on the earliest contributions, what I see as pillars upon which most of the literature rests upon.

2. The fisheries problem

The fundamental problem in fisheries was already recognized in 1911 by the Danish economist Jens Warming (see Warming, 1911). He wrote in Danish, however, and his ideas remained unknown for many years; his seminal 1911 paper was first translated into English in the 1980s (Andersen, 1983).

It was not until 1954, with Gordon's 'The Economic Theory of a Common-Property Resource: The Fishery' (Gordon, 1954), that the economic analysis of fisheries really began (Squires, 2009, p. 638; Scott, 2011, p. 78). Gordon established a model of rent dissipation under open access which made it clear that the fundamental reason for overfishing and overcapacity in fisheries is the lack of property rights (Gordon, 1954, pp. 130-131). The idea is simple; as long as there is a positive rent in a fishery with open access, new fishermen will enter until the rent is dissipated. Put into the economist's language, excess effort enters until average rather than marginal product equals opportunity costs (Wilen, 2000, p. 308). The allocation of inputs would be inefficient; each fisherman has an incentive to catch as much fish as possible and as fast as possible, before anybody else catches it.

Gordon (1954) also pointed out that as a management objective, the maximum physical yield promoted by biologists overlooks the fundamental issue in common properties (p. 136). Economists are still working to convince biologists and marine scientists of the true nature of the fisheries problem: unwanted incentives from incomplete property rights (see Wilen, 2006, for a recent attempt.) Notwithstanding, Squires (2009) finds that Gordon's insight about incentives "*... has been the central contribution of fisheries economics to fisheries management, and its concepts and ideas have widely diffused to other social sciences, fisheries science, conservation biology and ecology, industry, governments, and international organizations, and are even starting to make inroads into the thinking of conservationists*" (p. 638).

The progress, represented by Gordon (1954), was of such a fundamental nature that Scott (2011, p. 78) recently identified it as a Kuhnian revolution. Even among specialists (Scott, 2011, p. 80), a perhaps more well-known description of the commons problem is Hardin's (1968) article in science: The Tragedy of the Commons. He writes:

"*Therein is the tragedy. Each man is locked into a system that compels him to increase his [input] without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons*" (Hardin, 1968, p. 1244).

It has been suggested that Hardin's enormous influence and his depiction of the situation as a tragedy has been unfortunate (Ostrom, 1990, p. 8; Wilen, 2006, p. 543); in a tragedy, helpless individuals are led to destruction in an inexorable process. Such a view underpins modern management systems (Wilen, 2006, p. 543).

While half a decade has passed since Gordon's (1954) fundamental insight into the fisheries problem, the majority of fisheries are still overfished (Hilborn et al., 2003, p. 371), and 63 percent of the worldwide fish stocks require rebuilding (Worm et al., 2009, p. 578). By extrapolating current trends into the future, Worm et al. (2006) projected that all of the world's fisheries could collapse by the year 2048. I can only conclude that the understanding of fisheries economics in general and fishermen's behavior in particular is not yet complete, and much of the existing knowledge has yet to make an impact on policy (Squires, 2009; Hanna, 2011).

3. Rent dissipation, inefficiency and overcapitalization

In their path-breaking analysis of the Pacific Halibut fishery, Crutchfield and Zellner (1962) were perhaps among the first to investigate and document rent dissipation and overcapacity in fisheries in an economic setting. They noted, for example, that from 1929 to 1951, the size of the fleet increased by 78 percent, while the total catch only increased by 27 percent from 1932 to 1951 (p. 44), a clear sign of overcapacity. The overcapacity led to shorter fishing seasons, which went from more than 200 days in the early 1930's to close to 20 days in the 1950's (see Table 4, p. 43).

Not only did Crutchfield and Zellner (1962) establish a quality standard for applied work in environmental economics (Zilberman, 2003, p. 177) with their historical account of the fishery and its regulation, their comprehensive analysis of the industry and related markets and their policy recommendations, they also developed methods and new theory as they went along. A particularly interesting instance is their first Appendix, which was the first to solve the dynamic fisheries problem, that is, not only solving for the optimal steady state, but also for the optimal path leading to the steady state (which depends on the discount rate, biological growth, and dynamic costs), using calculus of variations (Crutchfield and Zellner, 1962, pp. 112-117; for a discussion, see Wilen, 2000, p. 311, footnote 8).

Another early empirical analysis in fisheries economics was that of the Norwegian winter herring fishery conducted by Pontecorvo and Vartdal (1967) (Pontecorvo visited Vartdal at the Norwegian School of Economics at the time). They found 'disturbing results.' Assuming no productivity gains for the period from 1950-1966, they found that one-sixth of the fleet was redundant (p. 81). The technical innovations had been many, however, as echo sounders, sonar, nylon nets, power blocks, and larger and faster boats all contributed to increasing the fishing power of the fleet (footnote 3, pp. 73-74). By assuming a 50 percent increase in productivity, more than 40 percent of capital and labor inputs in the fishery were found to be in excess. Pontecorvo and Vartdal were stricken by 'the gross nature of the misallocation' revealed (p. 81). Nevertheless, it is important to bear in mind that the fleet which operated on winter herring also participated in other fisheries, and that the apparent excess capacity may have turned out to be less 'gross' in a more comprehensive analysis. In that regard, while suggesting limited entry to the fishery, Pontecorvo and Vartdal noted that it would only shift capacity elsewhere in the short run and that a more general evaluation was needed (p. 85). This was an interesting comment which resonates with recent concerns about the shifting of capacity from the Northern to the Southern Hemisphere (see Alder and Sumaila, 2004; Figure 3, p. 166).

In 1969, Crutchfield and Pontecorvo published an analysis of the Pacific salmon fisheries (see Crutchfield and Pontecorvo, 1969). It was subtitled 'A Study of Irrational Conservation,' which clearly signaled their opinion of the current and historical regulation of the Pacific salmon fisheries as well as the nature of their findings. The salmon fisheries in Northwest America are an extremely complicated situation to analyze, even by today's standards. The Alaska fisheries, for example, are dispersed across 2,000 miles of rugged coastline, from the Alexander archipelago in the east to the Bering Sea in the west. Five different species are present, sometimes all in the same river, while at the time (late 1960's that is) salmon was also found in approximately 2,000 streams across Alaska (Crutchfield and Pontecorvo, 1969, p. 60). Furthermore, some salmon runs last for only a couple of weeks per year, though possibly at different times in different rivers, and different species spawn at different times of the year. In contrast, at the beginning of the 20th century, one man and one assistant were responsible for the enforcement of fishery regulations for all of Alaska (Crutchfield and Pontecorvo, 1969, p. 95).

In their analysis, Crutchfield and Pontecorvo found clear evidence of overfishing and overcapitalization in the Alaska fisheries (Figures 9 & 10, pp. 58-59). For example, at the time they wrote their book in 1969, twice as many fishermen, using more equipment, fished only 40% as many salmon as were caught in the mid-1930's (Crutchfield and Pontecorvo, 1969, p. 60). As the fishery was believed to be in a bionomic (rent dissipated) equilibrium in the mid-1930's, a rise in the real price of salmon explained the increased effort (Figure 8, p. 57). They also calculated (guesstimated) the dissipated rents and efficiency of the fishery, and concluded that if the efficiency of the gear had improved by 50% over 20 years, the relative amount of unnecessary gear was at 83% in the latter half of the 1950's (Table 5, p. 115).

Crutchfield and Pontecorvo also analyzed the salmon fisheries in the Puget Sound. There, too, they found evidence of excessive capacity (Figure 12, p. 127). From 1946, the fishery was regulated by an international commission (U.S./Canada). The main regulative measure was seasonal openings (and a host of gear specifications), and the target was a biological escapement level (an escapement level is simply the share of stock left unfished). In addition, the distribution of catch between Canadian and U.S. fishermen should ideally be 50/50, which is a clause that severely complicated the regulations. Moreover, one needed a license to fish, but these were seemingly unlimited. While issued licenses were increasing, the average catches of pink salmon declined (Figure 18, p. 156). Crutchfield and Pontecorvo concluded:

"*As long as the present situation continues, there can be no real hope of economic health in the fishery. Any increase in relative prices of salmon is promptly swallowed up by increased entry, rising costs, and more stringent pressure on the physical resource and those charged with its management. It simply leads to a new equilibrium, no more satisfactory than the previous one, with a net loss to the economy as a whole as more factors of production are trapped in the fishery*" (Crutchfield and Pontecorvo, 1969, p. 196).

Just as Crutchfield and Pontecorvo's analysis appeared in print, Canada introduced a new regulation scheme in their salmon fisheries (a fleet control program) to cope with their problems of overcapacity (see Pearse and Wilen, 1979, p. 765). The regulation scheme went through several steps in order to control capacity (Wilen, 1988, pp. 314-315):

- limited numbers of vessels (1969);
- limited total tonnage of the fleet, with a ton-for-ton replacement rule (1970);
- limited length of smaller vessels with no registered tonnage;
- limited gear types (1977);
- limited combined licenses, prohibiting more than one license per boat.

Despite the spiraling regulations, the effort continued to increase. As pointed out by Pearse and Wilen (1979, p. 765), the regulations did not address the fundamental problem that needed be addressed: the excessive use of inputs.

The phenomenon observed by Pearse and Wilen in the Canadian salmon fisheries was already predicted by economic theory (Scott, 1962; see Pearse and Wilen, 1979, footnote 10, p. 765), and has later become known as capital stuffing; if some dimension of effort is restricted, fishermen will expand their effort along some other dimension whenever they find it to be worthwhile. The related theoretical shortcomings were pinpointed by Wilen (1979). The capital stuffing observed by Pearse and Wilen (1979) is a case of regulatory induced innovation and regulatory induced changes in investment (Wilen, 1988, p. 319). Townsend (1985) claimed that some capital stuffing may indeed be economically desirable, but in order to evaluate the total net effect, a case-by-case empirical investigation would be necessary.

Pearse and Wilen (1979) set out to analyze and evaluate the impact of the fleet control program. Their measure of success was 'whether the scheme [had] driven a wedge between costs and revenues and allowed some of the potential economic rents to be realized' (pp. 765-766). They found that labor input in the fishery had declined by 16 percent for the period 1968-1975 (p. 767), and that revenues had increased by 4.4 percent per annum from 1957 to 1977. Additionally, capital input increased annually by 5.7 percent prior to 1969 and 3.7 percent after (p. 768). Pearse and Wilen concluded that the fleet control program, or 'rationalization scheme' as it was also called, had been partially successful in checking the expansion of capital engaged in the fishery (p. 768). However, capital input had continued to increase from already redundant levels in 1969, as reported by Crutchfield and Pontecorvo (1969).

The first step in the fleet control program was to limit the number of vessels. Entry restrictions in fisheries have spun an entire literature; see survey by Townsend (1990). He noted that limited entry does not change the destructive incentives for fishermen (p. 372), and concluded that benefits have more often been generated by reducing short-run externalities than by eliminating long-run stock externalities (pp. 372, 374).

The idea of capital stuffing generalized into input and output substitution. Squires (1987) noted that industry-wide controls on input or output were often inappropriate. He developed the first empirical measure of input substitution and found some evidence in the New England otter trawl fishery that individual input regulations were superior to output regulations. Squires (1987) further asserted that regulations should be adaptive and consistent with production and cost structures. He later formalized input quantity control in the context of rationing theory (Squires, 1994).

In multispecies fisheries, output regulation is not straight-forward. In the British Columbia groundfish trawl fishery, which is one of the few fisheries where the output mix of species is regulated, fishermen were found to adapt to changes in regulations (Branch and Hilborn, 2008).

Closely related to input regulation and substitution are efficiency issues. Hannesson (1983) developed a deterministic production frontier and inspired a string of papers. Kirkley et al. (1995) introduced stochastic frontier analysis and applied it to the Mid-Atlantic sea scallop fishery. They found that input controls could enhance technical efficiency. In the first ex-post analysis, Kompass et al. (2004) found that technical efficiency was constrained by input controls, but increasing in regulated inputs and decreasing in unregulated inputs in the Australian northern prawn fishery.

Branch et al. (2006) carry the generalization of substitutions further and review the literature on fleet dynamics and fishermen's behavior; see also the review by Nøstbakken et al. (2011). Branch et al. (2006) also survey further literature on rent dissipation and overcapitalization.

4. Rights-based management

As Gordon's (1954) legacy started to 'make inroads into the thinking' of others than just economists, and after the extension of national jurisdictions in 1976 that put many fish stocks in exclusive national waters, the stage was set for a new approach to fisheries management. The new approach, known as Individual Tradable Quotas (ITQs), simply transferred use rights of the fish stock to individual fishermen. ITQs are usually put on top of a quantity control such that they represent the right to a share of a total quota (Squires, 2009, p. 645). Christy (1973) presented the first theoretical consideration of individual quotas. Since then, ITQs have come into global use, with some prominent examples being the New Zealand and Icelandic fisheries (see Hannesson, 2004, for an extensive discussion). Subsequent, formal analysis of ITQs in combination with quantity controls have established that efficiency can improve as fishermen no longer have to compete for shares of the total quantity (Boyce, 1992). In contrast, ITQs cannot eliminate over-capitalization stemming from externalities caused by stock-level-dependent (or density-dependent) harvesting costs and congestion externalities; other issues are bycatch and highgrading (Boyce, 1992; see also Casey et al., 1995 and Squires et al., 1995). Going into more detail, Hannesson (2000) shows how the labor remuneration system may lead to overinvestment under ITQs.

The main attractive feature of ITQs is that they align incentives between fishermen and regulators, and among fishermen themselves, to maintain a sustainable fishery. Additionally, ITQs stimulate development and innovation in end-products, self-enforcement, and input and effort are consolidated. They also lead to capitalization possibilities for future profits and wealth creation (Wilen, 2006, pp. 537-538).

The halibut fishery of British Columbia adopted individual quotas in 1991; initially, there were constraints on trade and exchange that were subsequently loosened. The BC halibut experience is particularly interesting from several aspects; it had been exploited for a long time and could with reasonable confidence be assumed to be in a rent dissipated, inefficient equilibrium by 1991, it had been extensively studied under earlier regimes (Crutchfield and Zellner, 1962) and the BC fleet operated side by side with the Alaskan fishery, which remained open access.

The BC experience was broadly evaluated by Casey et al. (1995) through an analysis of the fleet, the processing industry, markets, and several surveys. Among the most notable changes was the change in landing patterns. Part of the new quota program was the extension of the season to approximately eight months; prior to the new program, the season openings were down to six frantic days (see Grafton et al., 2000, Table 1, p. 685) (the situation in the Alaska halibut fishery was even more extreme, where the season length was reduced to two or three 24-hour openings. Individual quotas were adopted in the Alaska fishery in 1995 [Knapp, 1996, p. 44]). Figures 2 and 3 in Casey et al. (1995, pp. 217-218) demonstrate the new landing pattern and compares it to the Alaska open access fishery. Landings were distributed throughout the season with low volumes upon the Alaskan open seasons. Another notable change was the quality of the end-product; prior to 1991, most halibut ended up as frozen product, while after 1991, most was sold as more valuable fresh fish (Casey et al., 1995, p. 219). In other words, the individual quotas in the BC halibut fishery created wealth through incentives to consolidate effort and through higher quality and more valuable end-products.

In a subsequent analysis of economic efficiency in the BC halibut fishery, that exploited the natural experiment provided by the individual quota program, Grafton et al. (2000, p. 705) found that efficiency fell from 1988 to 1991. The poor performance was explained by low catches and bad weather. From 1991 to 1994, efficiency increased, although the evidence was weak for large vessels (see Grafton et al., 2000, footnote 61, p. 706); there were gains from changes in product form as found by Casey et al. (1995). One possible objection to the analysis of Grafton et al. (2000) would be that the program was not exogenous, but rather endogenous in a manner discussed by Homans and Wilen (1997) ('[...] regulations are fundamentally endogenous and dynamic' [p. 2]). Notwithstanding, one would be hard pressed to argue for any expectation of improvement in a fishery with such a long history of rent dissipation.

As theory predicts and experience shows, open access leads to overfishing. In certain instances, extreme degrees of overfishing lead to a collapse of the fish stock. The Pacific halibut fishery, already discussed at great length, crashed spectacularly in the 1920's, while infamously, the Northern Cod stock collapsed in the early 1990's and has still not returned. Recent evidence suggests that ITQ management may reverse the collapse of fisheries (Costello et al., 2008), which further suggests that fishermen behave more in accordance with conservation or stewardship ideals under ITQs (it has been contested that many fisheries have gone directly from open access to ITQ schemes, and that it is simply the inherent total catch restriction which leads to decreased overfishing).

The last piece of evidence on the behavior of fishermen under rights-based management discussed here is very recent. Grainger and Costello (2011) investigate the relationship between the security of an ITQ and its market price. The idea is to exploit differences in ITQ schemes in different countries. In New Zealand, the property right vested in an ITQ is held in perpetuity, whereas in the U.S., ITQs can be revoked by the government at any time. Grainger and Costello (2011) construct the ITQ lease to sales price ratio, called the dividend price ratio, as economic theory suggests that the security of an ITQ is reflected in its sales price, but not in its lease price. Their evidence lines up with theory; lease to sales price ratios are smaller in New

Zealand than in the U.S. The same effect is seen within New Zealand, where ITQs in less secure fisheries on migratory species have higher lease to sales price ratios (Grainger and Costello, 2011).

Another form of rights-based management is territorial use rights in fisheries (TURFs), as suggested by Christy (1982). A TURF involves the exclusive right to fish in a given area or territory. TURFs are perhaps less commonly used than ITQs, but may become just as important as the focus of economists and marine scientists moves towards the spatial behavior of both fish stocks and fishermen.

5. Spatial behavior

Spatial behavior was in fact an important part of the very earliest insights into modern fisheries economics; both Warming (1911) and Gordon (1954) built their arguments on a model of two fishing grounds, and showed how net profit rates would equalize between the grounds. Despite the early notion of space and distance, empirical analysis of spatial behavior did not surface until the 1980's, and explicit, spatial models of fisheries did not appear in economics until the 1990's.

The location choice among fishermen has been widely studied since the 1980's. In an early contribution, Eales and Wilen (1986) found that location choices among shrimp fishermen in northern California were economically motivated; fishermen maximized their expected profits and behaved according to theory. Furthermore, the studied fishermen were responsive rather than sluggish in their behavior, which was contrary to other evidence (Bockstael and Opaluch, 1983).

The mid-Atlantic clam fishery of the east coast of the U.S. uses dredges to harvest surf clams. Prior to 1990, the fishery was regulated through the number of vessels and dredge time. In 1990, the regulations were replaced with an ITQ program (Marcoul and Weninger, 2008, p. 1935). Analyzing search and adaptive learning, Marcoul and Weninger (2008) found that fishermen searched more for high abundance sites in response to tighter controls on dredge time (p. 1939). Interestingly, restrictions on dredge time led to a higher catch per unit effort, though whether it was an increase in abundance or caused by more searching and increased knowledge about the stock is unclear (p. 1943). Moreover, fishermen displayed behavior 'consistent with a model of rational search and learning' (p. 1942).

The conclusions from an analysis of location choice among New England Trawlers seem partly at odds with the evidence cited above:

"*To assume that effort will flow between areas or fisheries to equalize catch or revenue rates is unlikely to provide reliable predictions even when steam time differentials are accounted for [...]. What is very clear is that in a fishery with complex seasonal patterns of fish movement, catchability and value, individuals' historical fishing patterns are major determinants of how effort is distributed in the future*" (Holland and Sutinen, 2000, p. 148).

Holland and Sutinen (2000) did find a weak influence from differences in revenues on location choice, but the individual fisherman's choice history has a stronger influence (p. 148). The approach taken by Holland and Sutinen (2000) may be 'useful in predicting the redistribution of fishing effort as conditions and regulations in the fishery change' (p. 149).

Given more space and time, I would have liked to discuss the relationship between spatial behavior and risk preferences. In passing, I mention research carried out by Mistiaen and Strand (2000), who developed a model of location choice that allows for heterogeneous risk preferences, by Smith and Wilen (2005), who look at risk preferences among Californian sea urchin divers and find heterogeneous risk preferences and that preferences towards different types of risk (physical and financial) are correlated, and by Eggert and Tveterås (2004), who study heterogeneous risk preferences and gear choices among Swedish demersal trawl fishermen.

A prominent assumption among biologists and marine scientists modeling the spatial behavior of fishermen in response to spatial management measures is that displaced fishermen simply redistribute over the remaining fishable areas in the same pattern as fishermen were distributed prior to the spatial measures. Such assumptions can lead astray (Smith and Wilen, 2003, pp. 184, 200).

The analysis provided by Smith and Wilen (2003) has a new flavor to it. The analysis evolves in two steps. First, they estimate a model of fishermen (sea urchin divers) behavior that depends on a host of variables, among them wave period and height, wind speed, distance, and expected revenues. Next, they simulate a highly sophisticated metapopulation model that integrates biological, spatial features such as ocean currents and biomass migration with a calibrated model of fishermen behavior. In certain instances, the inclusion of spatial fisher behavior leads to opposite conclusions about the benefits from spatial closures (Smith and Wilen, 2003, p. 200). Ultimately, they raise questions 'about whether oceanographic dispersal is the key driver of spatial closure impacts, or whether harvester dispersal may be equally important' (Smith and Wilen, 2003, p. 204).

In a subsequent analysis, Smith and Wilen (2004) added another layer by allowing for endogenous port choice. They found little response in port choice to changes in expected revenues in the short term, but found large effects in the long term (p. 102). Again, they concluded that naïve assumptions regarding spatial behavior may lead to conclusions 'substantially at variance' with more reasonable assumptions (p. 109).

6. Experimental research

Although not experimental, Bockstael and Opaluch (1983) introduced uncertainty and risk preferences into fisheries economics. Since fishing is seemingly a risky profession, fishermen are perceived to be risk lovers (Smith and Wilen, 2005, p. 54). There is little evidence to support such a conjecture (Eggert and Martinsson, 2004, p. 550, Larson et al., 1999, p. 275).

The rational for using experiments to reveal preferences and agent characteristics is that the set of potential explanations for different outcomes is ideally small (see Camerer and Loewenstein, 2004, for a discussion of experimental versus behavioral economics). Perhaps the first to expose fishermen to experiments was Erling Moxnes (1998). In an article entitled 'Not Only the Tragedy of the Commons: Misperceptions of Bioeconomics,' he studied the ability of fishermen as well as scientists and bureaucrats from the fisheries sector and 'others' innocent of fisheries management to manage a renewable resource when the commons problem was absent (see Moxnes, 1998). Approximately three-fourths of the subjects overinvested in exploitation (p. 1239). More seriously perhaps, scientists and bureaucrats did not perform better than the other groups involved (p. 1241) (see Walker et al. (1990) for an experiment placing subjects in a limited-access common-pool resource setting; subjects were not fishermen, however).

The experiment by Moxnes (1998) was not ideal for revealing subject's preferences; whether overinvestments were intentional betting (risk-loving behavior) or 'misperceptions of bioeconomics' cannot be identified. Eggert and Martinsson (2004) were the first to investigate risk preferences among fishermen with a stated preference approach (p. 551). In their sample of Swedish commercial fishermen, approximately half were risk neutral, one-fourth were risk-averse, and one-fourth were strongly risk-averse. Surveying their subjects, they found that strongly risk-averse subjects earned 22% less than risk-neutral fishermen, a finding that was in agreement with theory predictions. Furthermore, risk preferences were explained by the proportion of household income from fishing, type of gear, political preferences, and attitudes towards introducing individual quotas (p. 559).

Turning to fisheries in developing economies, Eggert and Lokina (2007) found that artisanal fishermen on Lake Victoria have somewhat the same preferences as Swedish commercial fishermen. In the sample, subjects were distributed approximately evenly into characterizations as risk averse, risk neutral, and risk seekers (p. 49). However, the risk preferences were related to a set of other characteristics, regarding boat size, assets, and others (p. 61).

Anderson and Sutinen (2005) put non-fishermen (students) into experiments to investigate the equilibrium model supporting tradable fishing rights and found large price fluctuations during a protracted price formation period. In addition, average prices deviated from equilibrium prices. They also suggested improvements to the market institutions that could ameliorate the problems (Anderson and Sutinen, 2006).

Conclusion

While Gordon (1954) brought rigor to the study of fisheries economics, years would pass before fisheries economists started to carry out empirical research (Crutchfield and Zellner, 1962; Pontecorvo and Vartdal, 1967; Crutchfield and Pontecorvo, 1969). As the evidence began to mount, theories were built and extended. Particularly in the first period, theoretical progress seems to have followed suit with the realization of an inadequacy of policies (Crutchfield and Zellner, 1962; Christy, 1973; Christy, 1982; Squires, 1994; Smith and Wilen, 2003). That many of the groundbreaking ideas came from outside academia is telling of this trend (Squires, 2009).

The first empirical evidence on the behavior of fishermen was on fishermen under a lack of regulation or under very loose regulations. Economists have since found evidence on overcapitalization and rent dissipation in fisheries around the world. Soon, capital stuffing, input and output substitution, and efficiency were empirically investigated. The more recent developments point in several directions such as risk aversion, behavior under tradable quotas, and spatial behavior, while substitution effects and efficiency are still under investigation.

An exhaustive review of the empirical fisheries economics literature is beyond the scope of my work (Squires, 2009, recently reviewed the entire fisheries economics literature). A number of themes in the literature have gone unmentioned such as bycatch and endangered species issues, as well as buyback schemes. Social objectives in fishermen's behavior and regulations have also not been mentioned. Some experimental work has been mentioned, though behavioral field studies of entry and exit decisions and fleet capacity adjustments have not been mentioned (Bockstael and Opaluch (1983) serve as the exception). Another disregarded strand of the literature deals with technological change in fisheries.

I do not intend to dilate upon future avenues for fisheries economics research. I do however wish to encourage fisheries economists to embrace the multidisciplinarity of their field. See it as an advantage and an opportunity. Try new methods, challenge yourself. Be curious and brave, and the field will prosper.

References

1. Alder, J. and Sumaila, U.R. (2004). Western Africa: A fish basket of Europe past and present, *The Journal of Environment & Development*, 13 (2), pp. 156-178.
2. Andersen, P. (1983). 'On rent of fishing ground': a translation of Jens Warming's 1911 article, with an introduction, *History of Political Economy*, 15 (3), pp. 391-396.
3. Anderson C.M. and Sutinen, J.G. (2005). A Laboratory Assessment of Tradable Fishing Allowances, *Marine Resource Economics*, 20 (1), pp. 1-23.
4. Anderson C.M. and Sutinen, J.G. (2006). The effect of initial lease periods on price discovery in laboratory tradable fishing allowance markets, *Journal of Economic Behavior & Organization*, 61, pp. 164-180.
5. Bockstael, N.E. and Opaluch, J.J. (1983). Discrete modeling of supply response under uncertainty: The case of the fishery, *Journal of Environmental Economics and Management*, 10 (2), pp. 125-137.
6. Boyce, J.R. (1992). Individual transferable quotas and production externalities in a fishery, *Natural Resource Modeling*, 6 (4), pp. 385-408.
7. Branch, T.A. and Hilborn, R. (2008). Matching catches to quotas in a multispecies trawl fishery: targeting and avoidance behavior under individual transferable quotas, *Canadian Journal of Fisheries and Aquatic Sciences* 65 (7), pp. 1435-1446.
8. Branch, T.A., Hilborn, R., Haynie, A.C., Fay, G., Flynn, L., Griffiths, J., Marshall, K.N., Randall, J.K., Scheuerell, J.M., Ward, E.J., and Young, M. (2006). Fleet dynamics and fishermen behavior: Lessons for fisheries managers, *Canadian Journal of Fisheries and Aquatic Sciences*, 63 (7), pp. 1647-1668.
9. Camerer, C.F. and Loewenstein, G. (2004). Behavioral economics: Past, present, future, in C. F. Camerer, G. Loewenstein and M. Rabin (eds.), Advances in Behavioral Economics, Princeton University Press, Chapter 1, pp. 3-52.
10. Casey, K.E., Dewees, C.M., Turris, B.R. and Wilen, J.E. (1995). The effects of Individual Vessel Quotas in the British Columbia halibut fishery, *Marine Resource Economics*, 10 (3), pp. 211-230.
11. Christy, F.T. (1973). Fisherman quotas: A tentative suggestion for domestic management, *Occasional Paper*, 19, Law of the Sea Institute, Rhode Island.
12. Christy, F.T. (1982). Territorial use rights in marine fisheries: Definitions and conditions, *Technical Report*, 227, UN Food and Agricultural Organization, Rome.
13. Christy, F.T. and Scott, A. (1965). *The Common Wealth in Ocean Fisheries*, The Johns Hopkins Press.
14. Costello, C., Gaines, S.D. and Lynham, J. (2008). Can catch shares reverse fisheries collapse? *Science*, 321, pp. 1678-1681.
15. Crutchfield, J.A. and Pontecorvo, G. (1969). *The Pacific Salmon Fisheries: A Study of Irrational Conservation*, The Johns Hopkins Press.
16. Crutchfield, J.A. and Zellner, A. (1962). Economic aspects of the pacific halibut fishery, *Fishery Industrial Research*, 1 (1), U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington DC.
17. Eales, J. and Wilen, J.E. (1986). An examination of fishing location choice in the pink shrimp fishery, *Marine Resource Economics*, 2 (4), pp. 331-351.
18. Eggert, H. and Lokina, R.B. (2007). Small-scale fishermen and risk preferences, *Marine Resource Economics*, 22 (1), pp. 49-67.
19. Eggert, H. and Martinsson, P. (2004). Are commercial fishers risk-lovers? *Land Economics*, 80 (4), pp. 550-560.
20. Eggert, H. and Tveterås (2004). Stochastic production and hetereogeneous risk preferences: Commercial fishers' gear choices, *American Journal of Agricultural Economics*, 86 (1), pp. 199-212.
21. Gordon, H.S. (1954). The economic theory of a common-property resource: The fishery, *Journal of Political Economy*, 62 (2), pp. 124-142.
22. Grafton, R.Q., Squires, D., and Fox, K.J. (2000). Private property and economic efficiency: A study of a common-pool resource, *Journal of Law & Economics*, 43, pp. 679-713.
23. Grainger, C.A. and Costello, C. (2011). The value of secure property rights: Global evidence from fisheries, NBER Working Paper, w17019.
24. Hanna, S. (2011). Economics in the Service of Fisheries Policy and Practice, *Marine Resource Economics*, 26 (1), pp. 87-94.
25. Hannesson, R. (1983). Bioeconomic Production Function in Fisheries: Theoretical and Empirical Analysis, *Canadian Journal of Fisheries and Aquatic Sciences*, 40 (7), pp. 968-982.
26. Hannesson, R. (2000). A note on ITQs and optimal investment, *Journal of Environmental Economics and Management*, 40 (2), pp. 181-188.
27. Hannesson, R. (2004). *The Privatization of the Oceans*, The MIT Press, Cambridge, Massachusetts.

28. Hardin, G. (1968). The tragedy of the commons, *Science*, 162 (3859), pp. 1243-1248.
29. Hilborn, R., Branch, T.A., Ernst, B., Magnusson, A., Minte-Vera, C.V., Scheuerell, M.D. and Valero, J.L. (2003). State of the world's fisheries, *Annual Review of Environment and Resources*, 28, pp. 359-399.
30. Holland, D.S. and Sutinen, J.G. (2000). Location choice in New England trawl fisheries: Old habits die hard, *Land Economics*, 76 (1), pp. 133-149.
31. Homans, F.R. and Wilen, J.E. (1997). A model of regulated open access resource use, *Journal of Environmental Economics and Management*, 32 (1), pp. 1-21.
32. Kirkley, J., Squires, D., and Strand, I. (1995). Assessing technical efficiency in commercial fisheries: the mid-Atlantic sea scallop fishery, *American Journal of Agricultural Economics*, 77 (3), pp. 686-697.
33. Knapp, G. (1996). Alaska halibut captains' attitudes towards IFQs, *Marine Resource Economics*, 11 (1), 43-55.
34. Kompas, T., Che, T.N., and Grafton, R.Q. (2004). Technical efficiency effects of input controls: evidence from Australia's banana prawn fishery, *Applied Economics*, 36 (15), pp. 1631-1641.
35. Larson, D.M., Sutton, W.R., and Terry, J.M. (1999). Toward behavioral modeling of Alaska groundfish fisheries: A discrete choice approach to Bering Sea/Aleutian Islands trawl fisheries, *Contemporary Economic Policy*, 17 (2), pp. 267-277.
36. Marcoul, P. and Weninger, Q. (2008). Search and active learning with correlated information: Empirical evidence from mid-Atlantic clam fishermen, *Journal of Economic Dynamics & Control*, 32, pp. 1921-1948.
37. Mistiaen, J.A. and Strand, I.E. (2000). Location choice of commerical fishermen with heterogeneous risk preferences, *American Journal of Agricultural Economics*, 82 (5), pp. 1184-1190.
38. Moxnes, E. (1998). Not only the tragedy of the commons: Misperceptions of bioeconomics, *Management Science*, 44 (9), pp. 1234-1248.
39. Nøstbakken, L., Thébaud, O., and Sørensen, L.-C. (2011). Investment Behavior and Capacity Adjustment in Fisheries: A Survey of the Literature, *Marine Resource Economics*, 26 (2), pp. 95-117.
40. Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press.
41. Ostrom, E. (2006). The value-added of laboratory experiments for the study of institutions and common-pool resources, *Journal of Economic Behavior & Organization*, 61 (2), pp. 149-163.
42. Pearse, P.H. and Wilen, J.E. (1979). Impact of Canada's Pacific salmon fleet control program, *Journal of the Fisheries Research Board of Canada*, 36, pp. 764-769.
43. Pontecorvo, G. and Vartdal, K.J. (1967). Optimizing resource use: The Norwegian winter herring fishery, *Statsøkonomisk Tidsskrift*, 81, pp. 65-87.
44. Scott, A.D. (1962). The economics of regulating fisheries, in R. Hamlisch (ed.), *Economic Effects of Fishery Regulation*, UN Food and Agricultural Organization, Rome, pp. 25-61.
45. Scott, A. (2011). The Pedigree of Fishery Economics, *Marine Resource Economics*, 26 (1), pp. 75-85.
46. Smith, M.D. and Wilen, J.E. (2003). Economic impacts of marine reserves: The importance of spatial behavior, *Journal of Environmental Economics and Management*, 46 (2), pp. 183-206.
47. Smith, M.D. and Wilen, J.E. (2004). Marine reserves with endogenous ports: Empirical bioeconomics of the California sea urchin fishery, *Marine Resource Economics*, 19 (1), pp. 85-112.
48. Smith, M.D. and Wilen, J.E. (2005). Heterogeneous and correlated risk preferences in commercial fishermen: The Perfect Storm dilemma, *The Journal of Risk and Uncertainty*, 31 (1), pp. 53-71.
49. Squires, D. (1987). Public regulation and the structure of production multiproduct industries: An application to the New England otter trawl industry, *The RAND Journal of Economics*, 18 (2), pp. 232-247.
50. Squires, D. (1994). Firm behavior under input rationing, *Journal of Econometrics*, 61 (2), pp. 235-257.
51. Squires, D. (2009). Opportunities in social science research, in R.J. Beamish and B.J. Rothschild (eds.), *The Future of Fisheries Science in North America*, Vol. 31 of Fish & Fisheries Series, Springer, Chapter 32, pp. 637-696.
52. Squires, D., Kirkley, J. and Tisdell, C.A. (1995). Individual Transferable Quotas as a fisheries management tool, *Reviews in Fisheries Science*, 3 (2), pp. 141-169.
53. Townsend, R.E. (1985). On "Capital-Stuffing" in regulated fisheries, *Land Economics*, 61 (2), pp. 195-197.
54. Townsend, R.E. (1990). Entry Restrictions in the Fishery: A Survey of the Evidence, *Land Economics*, 66 (4), pp. 359-378.
55. Walker, J., Gardner, R. and Ostrom, E. (1990). Rent dissipation in a limited- access common-pool resource: Experimental evidence, *Journal of Environmental Economics and Management*, 19 (3), pp. 203-211.
56. Warming, J. (1911). Om grundrente af fiskegrunde (On rent of fishing ground), *Nationaløkonomisk Tidsskrift*, 49, pp. 499-505.
57. Wilen, J.E. (1979). Fisherman behavior and the design of efficient fisheries regulation programs, *Journal of the Fisheries Research Board of Canada*, 36, pp. 855-858.
58. Wilen, J.E. (1988). Limited entry licensing: A retrospective assessment, *Marine Resource Economics*, 5 (4), pp. 313-324.
59. Wilen, J.E. (2000). Renewable resource economists and policy: What differences have we made? *Journal of Environmental Economics and Management*, 39 (3), pp. 306-327.
60. Wilen, J.E. (2006). Why fisheries management fails: Treating symptoms rather than the cause, *Bulletin of Marine Science*, 78 (3), pp. 529-546.

61. Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J. and Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services, *Science*, 314 (5800) pp. 787-790.
62. Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R. and Zeller, D. (2009). Rebuilding global fisheries, *Science*, 325 (5940), pp. 578-585.
63. Zilberman, D. (2003). The Crutchfield and Zellner monograph and the evolution of environmental and resource economics, in J.A. Crutchfield and A. Zellner (eds.), *The Economics of Marine Resources and Conservation Policy: The Pacific Halibut Case Study with Commentary*, The University of Chicago Press, pp. 177-184.