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Are Fishermen Rational? A Fishing Expedition

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Abstract *Uncertainty is a defining characteristic of fisheries. Fishermen make decisions affecting their livelihood daily and even hourly, often with scant information on which to evaluate alternatives. Cognitive psychologists and behavioral economists have shown that decisions involving uncertainty often diverge substantially from what would be predicted by expected utility theory. I review relevant findings from the literature on decision making under uncertainty and previous empirical modeling of fishing decisions, and explore the implications of a number of different behavioral theories on fishing decisions of various types. Excerpts from ethnographic interviews of groundfish fishermen in New England are used to illustrate how these fishermen deal with uncertainty in decisions they make about when, where, how, and how long to fish. The interviews provide anecdotal evidence in support of prospect theory and other behavioral hypotheses that appear to contrast with what would be considered rational behavior from a neoclassical economics perspective.*

Key words Fisheries, risk aversion, prospect theory, uncertainty, heuristics and biases.

JEL Classification Codes D01, Q22.

Introduction

Uncertainty is a defining characteristic of fisheries. Fishermen make decisions affecting their livelihood and their lives daily and even hourly, often with scant information on which to evaluate alternatives. In modeling decisions of fishermen, economists typically assume that fishermen behave rationally, using what information is available to them to construct estimates of the expected utility of the choices they face and selecting the choice with the highest expected utility (Wilen *et al.* 2002). Cognitive psychologists and behavioral economists have demonstrated that actual decision making under uncertainty often diverges substantially from normative behavioral models based on expected utility theory (Camerer 2000). People have been shown to exhibit a number of decision-making behaviors that systematically violate normative theories of rational behavior, and the resulting choices of individuals, and on aggregate, can depart substantially from what models based on expected utility theory would predict.

Given the prevalence of decision making under uncertainty in fisheries, it is likely that these "non-rational" behaviors may have significant impacts on fishing behavior and should be given consideration when modeling fishing decisions such

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as location choice, targeting, exit and entry, and compliance with regulations. Group level decisions, such as support for increases or decreases in the total allowable catch, may also be affected by decision behaviors that depart from standard economic theory. Study of fishing decisions may provide validation or contradictions of behavioral theories of decision making under uncertainty, as well as important new insights that may have relevance beyond fisheries.

In this article I explain how insights from cognitive psychologists and behavioral economists on decision making under uncertainty can improve our understanding of and ability to predict behavior of fishermen. Following a review of the literatures on decision making under uncertainty and fishing decisions, I present excerpts from ethnographic interviews of groundfish fishermen in New England to illustrate how risk preferences and various decision making behaviors and biases affect the choices made by these fishermen. I then discuss the implications of prospect theory and related behavioral hypotheses for understanding the likely outcomes and impacts of various policies and exogenous changes in fisheries. I conclude with a summary of findings and suggestions for additional research on fishing decisions under uncertainty.

Behavioral Theories of Decision Making Under Uncertainty

Thaler (1985) notes that "the paradigm of economic theory is first to characterize the solution to some problem, and then assume that relevant agents (on average) act accordingly." In modeling decision making under uncertainty economists typically assume that individuals, on average, make decisions that maximize their expected utility. However, analytical, experimental, and empirical studies have shown inconsistencies between actual decision making and expected utility theory. This has motivated development and testing of behavioral decision theories that can better explain observed choice behavior under uncertainty (Camerer 2000).

Experiments proposed by Allais (1953) in which individuals first choose between a certain gain and a gamble and then between two gambles demonstrated a consistent violation of the substitution axiom of expected utility theory. Kahneman and Tversky (1979) developed prospect theory and later cumulative prospect theory (Tversky and Kahneman 1992) as a way to explain the Allais "paradox" and other apparent inconsistencies between choice behaviors and expected utility theory. In contrast to expected utility theory, prospect theory proposes that individuals assign value to potential gains or losses rather than to final wealth positions and substitute decision weights for probabilities. The value function used to evaluate choices is assumed to be concave for gains and convex for losses and generally steeper for losses than gains (individuals are roughly twice as sensitive to losses as gains). The theory predicts risk aversion when comparing uncertain gains and risk-seeking behavior when comparing uncertain losses, but also loss aversion due to the steep slope of the value function for losses. Much of the basis and support for prospect theory has been experimental, but a number of empirical studies have found evidence of behavior that supports prospect theory and conflicts with expected utility theory (see Camerer 2000 for a review).

Prospect theory provides an explanation for risk aversion even when the stakes of the individual decision are modest. Within the expected-utility framework, the only explanation for risk aversion is that the utility function is concave. However, Rabin (2000) shows analytically that expected-utility theory cannot explain appreciable risk aversion over modest stakes since for any concave utility function, even very little risk aversion over modest stakes implies an absurd degree of risk aversion over large stakes. In contrast, prospect theory proposes that people evaluate the probabilities of gains and losses relative to a reference point relevant for the indi-

vidual decision as opposed to considering how their overall wealth will be affected.

Prospect theory also hypothesizes that in formulating decision weights, individuals tend to overweight very low probabilities, which can lead to apparent reversals of risk preferences (*e.g.*, risk seeking for gains and risk aversion for losses). Kahneman and Tversky (1979) suggest that overweighting of low probability outcomes is an explanation for the purchase of actuarially overpriced insurance and for gambling. Studies of betting behavior at horse tracks lend support to prospect theory's conclusions relating to evaluation of low probability gains. In a study of bettors in British horse races, Jullien and Salanie (2000) find that rank-dependent utility models do not fit the data noticeably better than expected utility models, but that cumulative prospect theory has higher explanatory power. Golec and Tamarkin (1998) investigate the favorite-longshot bias in horserace betting where bettors tend to bet on low return, high variance bets when favorites are both lower variance and higher expected return. Their analysis suggests that bettors are in fact risk averse, but are skewness loving. These findings are also consistent with prospect theory's supposition that individuals tend to overweight low probability outcomes and thus overvalue longshots.

The initial work of Kahneman and Tversky (1979) was followed by a substantial amount of experimental and empirical work exploring a variety of other decision making heuristics and biases that may explain how and why actual decision making under uncertainty often leads to choices at odds with expected utility theory. Work by Thaler (1985) supports the idea that people often bracket decisions narrowly, considering the effect of a decision on their income or loss over a short period, rather than how it may effect their overall wealth. As a result, they may fail to consider opportunities to diversify risk over repeated similar decisions and thereby reap the gains of choices with higher expected value without incurring the level of risk apparent when considering each choice independently. A study of taxicab drivers (Camerer *et al.* 1997) suggests that drivers tended to work longer hours on days when hourly income was low in order to reach an income target and tended to quit early on days when hourly income was high.[1] Narrow bracketing also provides an explanation for the tendency of people not to disregard sunk costs when making decisions. Individuals tend to consider the net outcome including the sunk cost but do not consider the longer outlook (Garland and Newport 1991).

A number of studies has shown that when faced with complex decisions with limited information, people do not make choices consistent with Bayesian probability estimates and expected utility theory, but instead tend to resort to simple decision heuristics or rule-based behavior relying on principles, analogies, and exemplars rather than utilitarian calculus (McFadden 1999, 2006). Camerer (1998) argues that experimental and empirical evidence has shown that most people do not follow Bayesian decision making and that there is little directed evidence of Bayesian updating that cannot be explained with much simpler theories, such as anchoring and adjustment. Experiments with a two-armed Bernoulli bandit problem (Gans, Knox, and Crosson 2004) have shown that normative theories of decision making do not describe or predict behavior as well as simpler myopic models such as exponential smoothing or a simple "satisficing" model. Rather than seeking the arm that maximizes expected rewards, the subject is satisfied with any arm that meets some target level of average reward per trial.

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[1] A follow-up study by Farber (2005) raised questions about the validity of Camerer's results, suggesting that the negative labor elasticity estimates could be the result of biased estimator. In particular, because the dependent variable (hours worked) also appears in the denominator of the explanatory variable (revenue per hour), it can produce a negative bias in the parameter estimate if there is observation error in the number of hours worked.

There is substantial evidence that, to the extent individuals are evaluating conditional probabilities, they often do a poor job of it. Examples include: the gambler's fallacy, a belief that an event that has just happened is unlikely to reoccur (Tversky and Kahneman 1974); the *hot hand* effect, the belief that a recent trend is an indicator of future events (Gilovich, Vallone, and Tversky1985); and the *law of small numbers*, the belief that a small sample is highly representative (Tversky and Kahneman 1971). Tversky and Kahneman (1971) observed excessive reliance on readily retrieved information and a tendency to interpret supporting information as confirming a prior hypothesis while discounting information that contradicts that hypothesis. Psychological research indicates that people have a cognitive bias that leads them to misinterpret new information as supporting previously held hypotheses (Rabin and Schrag 1999). Experiments have also shown that people often fail to sufficiently adjust expectations from an initial *anchor* in the light of new evidence (Tversky and Kahneman 1974).

Experimental evidence also suggests the people are averse to uncertainty itself as distinct from the risk associated with uncertainty. Camerer (1998) notes that this provides an explanation for the Ellsberg paradox whereby many people prefer to bid on either color of balls for an urn with known 50-50 ratio of balls rather than either color from an urn with unknown ratio. This is particularly pertinent for understanding fishing decisions where fishermen may not have sufficient information, or predilection, to effectively evaluate the expected value of the alternatives they face.

Previous Studies of Uncertainty and Risk in Fishing Decisions

There is a substantial and growing literature devoted to understanding and modeling fishing decisions, primarily fishery and location choice and entry-exit decisions. These decisions are taken in a climate of considerable uncertainty, and several of these studies have addressed issues of uncertainty and risk by examining the information structure that supports decision making (*e.g.*, Curtis and McConnell 2004; Dupont 1993; Eales and Wilen 1986; Holland and Sutinen 2000; Salas and Gaertner 2004; Smith 2005; Wilen *et al.* 2002), by quantifying risk preferences (*e.g.*, Bockstael and Opaluch 1983; Curtis and Hicks 2000,; Eggert and Martinsson 2004; Eggert and Tveterås 2004; Holland and Sutinen 2000; Mistiaen and Strand 2000; Smith and Wilen 2005; Strand 2004) and by identifying risk-coping strategies (Salas 2000; Salas and Gaertner 2004; Hilborn *et al.* 2001).

Most economists working on modeling fishing decisions have used random utility models that assume we observe decisions that, on average, reflect utility maximizing choices. This allows us to estimate an approximation of the utility function, which can be used to make predictions about how policies and other factors may affect future decisions and what welfare impacts they may have. Most of these studies have modeled expected utility as a function of either expected profit or expected final wealth given some initial endowment generally based on vessel value. Expected revenue or profit is typically modeled as a weighted average of lagged revenue or profit rates reported by vessels from a discrete fleet for specific locations or fisheries over a discrete period of time. Several papers allow utility to be affected by risk preferences by including the variance of expected revenue, profit, or final wealth in the model specification. Most of these studies report negative signs on these variables, which are interpreted as risk aversion. An exception is Holland and Sutinen (2000), who report a positive sign on the coefficient of variation (CV) of expected revenue. While this could be interpreted as risk-seeking behavior, they suggest that it may simply reflect a failure to model the information structure correctly (fishermen may respond to reports of particularly high catches and these

locations tend to have high CV in revenue). This may be skewness-loving rather than risk-loving behavior as has been observed in racetrack bettors (*e.g.*, Goleck and Tamarkin 1998).

To be consistent with expected utility theory, risk preferences must be assessed by evaluating choice behavior in terms of the utility of the final wealth position and probability of each alternative. Bockstael and Opaluch (1983) take this approach by estimating a truncated Taylor-series expansion of an explicitly specified (log) utility function. Risk preferences are evaluated with the parameter on the second moment of the utility function. In practice, many empirical studies of fishing behavior that have explored risk aversion in fishing decisions have not included initial wealth in the utility function and only examine variability in expected profits or revenue. For example Strand (2004) excludes initial wealth from the expected utility specification noting that determining the initial wealth of agents is nearly impossible and can create severe statistical problems by introducing error into the highly correlated terms in the utility function. Strand also cites Kahneman and Tversky (1984) findings that choices in lotteries are independent of initial wealth. Clearly exclusion or inclusion of wealth can yield different estimates of relative risk aversion that can, in turn, lead to different behavioral predictions and welfare estimates.

Eggert and Martinsson (2004) attempt to directly test whether risk preferences of fishermen are consistent with prospect theory or expected utility theory using a stated preference study administered to Swedish fishermen. Each fisherman evaluated six pairs of alternative fishing trips with different means and ranges of possible income. The authors note that risk-averse behavior for repeated stakes will lead to substantial income reduction in the long run. Since the individual trips being evaluated in each choice set involve relatively modest stakes in terms of their impact on the fishers total lifetime wealth, expected utility theory would predict risk neutrality in these decisions, while prospect theory would predict risk aversion. Eggert and Martinsson found substantial heterogeneity in risk preferences in their sample with 48% characterized as risk neutral, 26% modestly risk averse, and 26% strongly risk averse. They argue that these results are inconsistent with expected utility theory and that research on fishing behavior should give more consideration to behavioral theories of decision making under uncertainty (*e.g.*, prospect theory).

None of the fishing decision studies that evaluate risk preferences explicitly consider the potential effects of loss aversion on decisions where fishermen face the possibility of a loss. However the possibility of not covering expenses and suffering a net loss on a fishing trip is real. A key proposition from prospect theory, which has been demonstrated repeatedly in experiments and several empirical studies, is that individuals are loss averse. It is consequently important to understand whether individuals view uncertain outcomes as gains or losses. Loss aversion may be difficult to distinguish from risk aversion, though it may manifest itself through avoidance of fishing alternatives that pose significant risk of a loss. Furthermore, loss aversion may relate not only to an absolute financial loss but also to failure to meet an income target. Salas (2000) notes that some fishermen in the Yucatan who fish independently and competitively in the part of the year when fishing is most lucrative, pool their catch at other times of year when fishing is poor. Hilborn *et al.* (2001) note that some risk-averse fishermen in a very short, intense, and volatile spawn-herring purse seine fishery pool their catch, while other more risk-prone fishermen fish independently.

A few studies of fishing decisions have shown that fishers may be slow to switch to more profitable fisheries or fishing locations, preferring to continue with familiar ones. Bockstael and Opaluch included a dummy variable for prior fishery choice in their fishery choice model and found this variable to have a strong effect on choices. They suggest that this "bias" in favor of past choices might partially re-

flect conversion costs for switching, but that it might also reflect non-monetary values, such as a desire to stick with family traditions or pure inertia. In their model of fishery and location choice for trawlers in New England, Holland and Sutinen (2000) also include dummy variables for prior choices both in the recent past and the previous year. Like Bockstael and Opaluch, they find past behavior to have a positive impact on future choices, creating a strong bias against what appear to be more profitable, but less familiar, fishing alternatives. They suggest that fisher's experience in particular areas, or lack of it in others, may affect the true profitability they would realize in those areas (or at least their expectations of profitability) and thus influence choices. However they suggest that simple habit may lead fishers to maintain traditional fishing patterns despite potential gains that might be derived from changing these patterns. They, too, are unable to differentiate inertia from heterogeneity in profit expectations. In a study of gear choice of Swedish fishers, Eggert and Tveteras (2004) find that the majority of fishers respond positively (negatively) to increased mean (variability) of expected landings values for alternative gears, but that there is a strong tendency to chose the same gear used on the previous trip. They also find substantial heterogeneity in risk preferences, that when not accounted for explicitly in the modeling, can provide misleading results about risk preferences. They find continued inertia in decision making remains even allowing for heterogeneity in expectations and risk preferences. Using a mixed logit model of repeated location choice decisions by California urchin divers, Smith (2005) is able to differentiate state dependence from heterogeneity (which might reflect rational expectations of higher profits in areas where the individual has experience). He finds that true state dependence (*i.e.*, inertia) is an important determinant of location choice. These studies suggest that modeling fishers as maximizing expected utility, where the expected revenue or profit is modeled on the basis or activities of other vessels, may sometimes lead to biased predictions of location or fishery choices, specifically to predictions that fishers will be more responsive to economic incentives to shift behavior than they actually will be.

While profitability is probably an objective of most fishermen, other factors may be important as well. Personal risk associated with weather is a major determinant of when fishermen make trips in the California urchin fishery (Wilen *et al.* 2002; Smith and Wilen 2005). Salas (2000) notes that fishermen in San Felipe, Mexico, concentrate on meeting a quota of 300 kilos of catch per month in order to maintain membership in a fishing cooperative. Roy (1998) reports that fishermen in Newfoundland, Canada, have to fish a certain number of days per year to be able to claim unemployment insurance. The interviews of fishermen in New England, discussed below, also find evidence of goal-oriented behavior and a variety of factors (beyond profit maximization) that affect fishing decisions.

Self-described Responses to Uncertainty by New England Groundfish Fishermen

I conducted ethnographic interviews with a number of fishermen that participate in the New England multispecies groundfish fishery.[2] The interviewees included captains of large and small trawlers and gillnetters fishing from ports in Maine and Massachusetts. The primary focus of the interviews was the decision-making pro-

[2] Ethnographic interviewing is an interviewing technique developed to allow researchers to describe other cultures, while minimizing the bias introduced by the researcher's preconceived notions and unfamiliar wording of questions (Spradley 1979).

cess these individuals use when making decisions about when and where to fish, and particularly how they deal with uncertainty and risk in that decision-making process. The interviews were recorded and transcribed. Excerpts from these interviews that relate to decision making under uncertainty are discussed below.[3]

The interviews provide anecdotal support for risk aversion in decision making and illustrate a variety of ways that fisherman cope with and reduce risk. While many of the responses to risk discussed do not necessarily indicate behavior that is inconsistent with expected utility theory, they make clear that fishermen deal with uncertainty and risk in a variety of decisions and seek to avoid or mitigate risk in most cases. The fact that risk aversion appears to influence repeated decisions for modest stakes would appear to conflict with expected utility theory. The interviews provide some support for loss aversion and narrow bracketing predicted by prospect theory, as well as some other behavioral hypotheses of decision making under uncertainty.

General Risk Aversion

The Northeast multispecies groundfish fishery underwent a substantial decline in the mid 1990s and has yet to fully recover from the depletion of several key stocks. The fishery, which is managed with a combination of individual effort limits, closed areas, and trip limits, has gone through a continuing series of effort reductions coupled with additional area closures and trip limits designed to reduce fishing mortality on key stocks. The reductions in the stocks together with reductions in available fishing time, and more recently increasing fuel prices, have increased the risks of incurring losses both on the fishing trip and annual levels. While fishermen are by choice in a profession that is risky both in a physical and financial sense, most of those interviewed made clear statements suggesting they were generally risk averse and gave examples of ways that they attempt to mitigate risk and uncertainty in fishing decisions.

For example, a captain of a small trawler in Portland, ME, when asked to compare some fishing alternatives with different potential payoffs and risk stated:

> I'd go for the sure bet. I'd go for less, guaranteed. I would make the safe play. One thing that my father always told me was that what makes you in the fish business is a consistent day's pay, not the lucky strike or the big strike. I always find the worst thing that happens to me is when I get a big set of fish someplace that it's not a high production area, you just stumble across them, big accident. And it happens, doesn't happen often but it happens. It's usually the worst thing that happens because you continually go back looking for them and waste time instead of the constant production. I guess I'm not a gambler.

A captain of a small gillnetter in southern Maine made these observations:

> I'm a consistency person. I'd rather come in with a little bit less and have it every day than go for the risky, pound your chest, I caught 'em all. I've been doing this a fairly long time. I'm fairly successful at it, so I must be making the right decisions. I will always take my $2,000 a day even though I know that at that particular time of year I ran off one time and I stocked $8,000 in one day. You're thinking in the back of your head that you can do

[3] Names of the interviewees are withheld for confidentiality reasons.

> better, but the bottom line is you have a commitment for surety in this business because there is so much uncertainty. You have a commitment to make sure that you produce, and if you can produce at a moderate level, you are much better off than jumping around trying to catch the million dollars. I don't know anybody that's gotten really fantastically rich in this business.

Similar sentiments were expressed by a Portuguese captain of a large trawler out of New Bedford, MA, in explaining how he decided whether to leave an area with moderate catches when a cousin he sometimes fishes with let him know he'd found a particularly good area several hours steam away. "Sometimes I go steady. Sometimes I go on my own. If I got a place steady, I prefer to go steady than to go to get a jackpot. If I (after moving to the new location) don't do well, I lost a day or two. I don't like that. I go steady. At the end of the day I make my numbers. Next day is another good day."

Wealth Effects

A number of the fishermen interviewed indicated that their relative wealth affects their attitudes toward risk though opinions on the direction of the effect differed amongst them. A midcoast Maine captain illustrates this by comparing his decision not to reconfigure his trawler as a gillnetter when his friend, who was financially secure, did so:

> The richer the fisherman the more willing they are to risk usually. One spring, gill netting was just starting to look good in our area and I added up what I had and I figured it was going to take all the money I had in my savings account to rig over from being a dragger to a being a gillnetter. And I didn't do it because I thought, well, if I spend all this money to rig over and I don't catch anything, then I'm screwed. I was pretty sure I could make more money as a gillnetter and for a few years I could have. He (the friend that was financially independent) on the other hand looked at that and he rigged over as a gillnetter and he did a lot better. He had been a lobster fisherman. He went from lobster to gillnetting. But that was a risk. If he'd spent that money, he might have had to sell off a CD or a property or something but wasn't going out of business. Where if I'd spent all the money I had and hadn't made any money I'd been a lot deeper in debt. The poorer you are the less risk you are likely to take; even though there might be a bigger return.

When asked if that attitude toward risk applied for shorter term decisions such a location choice he confirmed this: "Yeah it still holds true. If you've been going along pretty steady for a few weeks and making a little money, you don't mind going some place and trying to make a little more money. But if you've just been scratching getting by then you are less likely to go looking. Because you've still got to get by."

A gillnetter from southern Maine expressed a nearly opposite view:

> The more money I have, the less risk I take. I make sure that I am profitable, but I'm not interested in going to Parker Ridge looking for pollock in the middle of February any more. I don't like the beating I took out there. I don't like the chances. Your tolerance to risk is directly related to your bank account. When I was younger and I was looking at all the stuff

> I had to do and all the bills were coming in, I was banging the risk all the time looking for that cash out. Now that I've built up a portfolio [of stock], I'm comfortable, I can go awhile.

Coping with Price Risk

Price volatility adds significant extra risk on top of the risk associated with volatile catch rates. Some fishermen actively try to manage this risk by targeting a mixture of species or species with less volatile price:

> You try to get a mixture of species if you can. You try to work on species whose price is less volatile. Monks go up and down now, but for the whole 80's monks were $2.50 a pound winter, summer, spring, or fall. You always knew if you had 1,000 pounds of monks it was $2,500. Something like redfish goes up and down like a yo-yo. They might be no value one day and 75 cents the next, so usually you won't try to load your boat up with redfish because you don't know what you're going to get out of them. If you are working on flats and there's the chance to get a few cod it's a good bet because they (the flats) may or may not be worth a lot. The species that are more price stable are better to go after in general. If you've got that choice.

A Maine gillnetter expresses as similar opinion: "You tend to mix your species. It goes back to putting all your eggs in one basket. If you can mix your species you're guaranteed you will hit on one and you'll do well."

Coping with Gear Risk

Fishermen also face the risk of losing gear, and that risk is influenced by the areas fished. In some cases gear risk relates to the type of bottom or the presence of wrecks, but ghost gear can also be a problem. A midcoast Maine fisherman talks about a place he used to fish but doesn't anymore because it has been popular with offshore lobstering, and the large draggers (80-90 foot boats) have gotten into their gear and spread it around:

> If I get a stringer of them it stops me. If I get more than 4 or 5 of them in my net I can't lift it, and it's a real bummer. Every time I fish out here, the last five or six times, I lose about 25% of my time in interaction with fixed gear. The volume of fish hasn't been good enough to make up for the 25% loss. I can fish somewhere else and catch less fish, but at the end of 24 hours I got the same amount with no hassle and no strain on the gear.

Willingness to fish in areas that might damage gear (*e.g.*, rip nets) is affected by weather as a captain of a midsize trawler out of Portland explains. "If I know there is a piece of bottom where the fishing might be good but there is risk of net damage, I won't go there if the weather is cucky. The cuckier the weather the more likelihood of doing net damage. And net damage is lost time and lost time is dollars per hour." Bad weather also increases the cost of dealing with gear loss. "It's ten degrees and light freezing spray. I am not going to go near any bottom that has a potential of net damage because you got your men bare handed (trying to mend nets) and that's just brutal." This captain is much more willing to take gear risks if the weather is fine. "That's the easiest one to make. If I thought I could move on riskier bottom and

double the $400 a tow I've been making, I'm gone. I'd even sacrifice a tow. I'd move 42 miles if I thought I could double my productivity even if the bottom is a little risky." He shows me an area on a nautical chart with some peaks marked with colors and explains:

> The green ones are the ones I know I can get over, the yellow ones have a little more risk. The orange ones, you just completely avoid those unless you have the tide and the wind and everything going with you and then you risk going. I will go on some orange ones. Because I put them there I know them. I know what the risk is. And if the weather conditions are perfect and I see fish on the machine. Sometimes I'll circumnavigate them and then tow them the last 20 or 30 minutes of the tow.

For fixed gear fishermen the risk to gear may come from interactions with mobile gear. A Maine gillnetter notes that there are areas you avoid because your gear may get hit by trawlers. There are some small areas where your gear can get caught up with coral, but he avoids those areas now. "It's no decision for me; you don't trade gear for fish."

Willingness to take risks with gear seems to have declined for some fishermen as they have aged. A trawler captain in his 50s from New Bedford explained, "No, I go for safe. All my guys are tired. My guys work for me for 20 years. My back is not good. No more." He explains that he used to do that when he was younger. "When I started this life, I'm a tough captain. I put the net in the rocks to look for cod."

Nevertheless many fishermen are willing to take a risk with gear at least some of the time if the reward is high enough:

> We know where the bad spots are, bad bottom. And usually sometimes there's fish over there. If you get 1,000 pounds and the next tow you get 200 pounds because your net ripped, but then you might get another 2,000 pounds your next tow, you can take a chance. But now if you keep tearing up, you're wasting a lot of time. And then you have to make a move. There has to be fish for you to set on the hard bottom, enough to cover the expense and the waste of the time…I'll make an example. I go in the bad bottom. I know if I go in the smooth bottom I can get 4,000 pounds a day. But I'm going to take a chance on the hard bottom. If I get 8,000 or 9,000 pounds in 24 hours I might stay there because there's more fish. At the end of the day I see what I did for the 24 hours. If it works I'll stay even if I damage the gear. If there's fish I'll set out. I got gear for working hard bottom.

A few trawler captains from New Bedford mentioned that they are less likely to fish in areas where there is risk of tearing up nets, partly because they don't have as many or as experienced crew to mend them. This apparently relates to the fact that overall profitability is down due to resource conditions and increased costs (fuel and insurance), so they are working with smaller crews. In essence, lower profitability is reinforcing risk aversion in keeping them away from hard bottom that might have bigger payoffs but more risk. One captain explains, "You've only got four guys; years ago it was six guys, seven guys. And they lose sleep, everyone gets tired, because you rip one net and then you got to set the other net, and that one gets ripped up and then you got nothing." Another New Bedford captain notes that years ago he used to fish more in the shoal [shallow] water because he needed more money to pay for the boat, but now the boat is paid for. He thinks even now that he could make more money fishing there, but the risk of gear damage is a deterrent. "We don't have

the men. You have broken nets all the time. You have to have guys fast at mending the nets. All the good guys have moved to the scallopers. The scallops are the ones who make money. You got old guys like me. A long time ago we used to have six guys on the boat. Now you got four. If we go in this water and break the net we're going to be stuck."

Diversification of Risk Over Time and Across Activities

Although catch rates and income from tow-to-tow and day-to-day can be highly volatile, it will tend to even out over the length of a multiday trip and even more so over an entire season. To the extent that the risk associated with individual fishing trips is independent, one from the next, fishermen could diversify risk over time and thus pursue relatively risky strategies on a trip-by-trip basis if those strategies had a higher expected value without incurring substantial risk in annual earnings. The interviews suggest that these fishermen prefer consistent landings over the course of the year, often bracket their decisions over relatively short time frames (a day or a multiday trip), and may not take advantage of their ability to diversify risk over a larger number of production decisions (*e.g.*, a fishing season). A captain of a small dayboat trawler in Maine notes, "A season is never made in a week and a week is never made in one day. So I like to look for consistent production over a long period of time rather than a day or a week. But in order to have that consistent production you have to take chances although they are calculated chances. You cannot just continue to go back to the same area and expect that production." One New Bedford captain explained that he thinks about performance on a trip basis and doesn't get too worried on the tow-by-tow basis. However, he does say that, "After two or three (bad) tows, yeah it messes you up. You need to make money. You got four people with you. You got mortgage, rent, it's not easy, kids in college." He says he is worried more about his crew than himself when things are not going well. This may not be just concern for their welfare; finding and keeping good crew has become increasingly difficult.

One reason that captains may have become more concerned with short-term performance is that the overall number of fishing days is strictly limited by regulation now and the number has been declining with tightening regulations. Another New Bedford, MA, captain notes, "If you lose three trips in a year, you're in big trouble. You go out there, you got to try to make a trip." The restriction on total fishing time makes it increasingly critical for fishermen to choose the right times to take trips. As another Maine trawler captain explains:

> Years ago we used to just go out and grind. Sometimes you wouldn't catch any fish for a week. If you didn't catch anything you jumped around and jumped around and jumped around. Eventually you found something. You didn't pay too much attention to the prices because, you know, some people might say the prices are low and I'm not going but by the time you got your fish to market they might be back up again. Used to be we just went out and put our time in and did the best we could do and it all evened out at the end of the year. Nowadays you have to think about whether you are burning a day up for nothing, or should I save this day for May or save it till July when I can make more money.

The ability of captains to fish only in the most profitable times of year may be limited; several captains of larger vessels mentioned that they need to provide crew with a reasonably steady income throughout the year to keep them on.

Many fishermen do diversify risk by participating in more than one fishery. A captain of a small trawler in Maine has held on to a lobster license he doesn't use in case of further declines of groundfish. "I consider my lobster license an insurance policy." Another trawler captain from midcoast Maine who fishes for lobster, groundfish, and shrimp at different times of year explains, "I'd be money ahead the last ten years if all I did was go lobstering. But I kind of like to keep diversified although that's cost me in a way. It's cost me in days at sea because of going shrimping and going lobstering" [meaning his individual allocation of days at sea for groundfish was reduced because he had logged fewer groundfishing days during the qualifying period]. He notes, however, that part of the reason for being diversified is not just money; he likes groundfishing and shrimping better than lobstering, he likes the hunt.

Loss Aversion and Target Income

Several fishermen indicated that they have income targets that influence their decisions. These targets are related to operating costs, but may include opportunity costs of labor as well. Failure to meet these targets may be thought of as a loss, and might be avoided in favor of another strategy with a lower expected value, but less probability of failing to meet an income target. A captain of a gillnetter based in Portland, ME, notes:

> I have numbers I like to meet and it depends on what we've done previously as to how long I can stay in an area and keep looking. If you had a big week there and it starts to taper off, you can go on a little while and keep the crew happy not making a lot of money if you already put some money in the bank for them. But after a while if a guy is going out and only making $50 a day, they are going to want to make more money.

A captain of a midsize trawler fishing out of Portland, ME, also indicates he has an income target. "We have a nut. I got my fuel costs, grub costs, ice costs, and so forth, so I got a nut. It takes about 3 or 4 days to break the nut. And the next two days; that's our profit. The goal for these boats is to stock $3,000 to $4,000 a day." Income targets are clearly adjusted over time in response to fishing conditions as well as price, as comments by another fisherman illustrate, "Yeah. That changes a lot. Used to be shrimping I'd like to stock a couple thousand dollars a day back when shrimp were a $1 pound. This year I'm happy to stock $1,000 although my expenses are higher. It's unrealistic to think I'm going to stock $2,000."

If fishermen set an income target, and perceive not making that target as a loss, prospect theory would suggest that they may tend to fish longer when catch rates are poor and go home early when they are good, but the responses in interviews were mixed. One fisherman suggests he may fish longer when conditions are particularly good, but sometimes may go home early.

> When you're not making anything you got to fish hard because you're not making anything. When you're making money you want to fish hard because you're making money. Occasionally if you've been working hard and you make unexpected money early you might quit early, especially if you don't think it's going to hold up all day. If you've had a couple of really good tows in the morning and then you drop off, then you are more likely to go home early. If it's stayed steady all day, then you are more likely to stay and get what you can out of it. Because you never know what's going to be there the next day.

Another fisherman explains, "I'll put a good faith effort into going to other spots. I won't just go out and say there's nothing here, I'm going home and be a lazy guy. I will go and I'll do a progression and look for some fish. If it ends up that I'm like a cat chasing my tail and there's nothing there, I'll put the full day in and I'll go home." When asked what he would do if the fishing is better than expected he responded that it depends whether he is going to be constrained by trip limits on some species (that might require discarding), and what the outlook is for fishing the next day. "If I know I can get out the next day I'll just put my day in, which is basically to be back in by 6:00, so that I can get back out and do it again the next day. I don't fish at night."

A few captains of large trawlers that make multiday trips suggested that they would tend to shorten (lengthen) trips when fishing had been particularly good (poor). Cutting a trip short may be quite rational to increase the chance of landing when there is less fish being landed and the price is higher. For example, if all the boats left port on the same day after a storm, heading home early might mean getting a better price. "After six days you look at what fish you have in the hold, you look at the price in the market. Sometimes, especially in the winter time, if all boats left on the same day (after a storm), you need to pay attention to price. If the market has no fish, sometimes the fish is so high. If you have 40,000 (pounds), 50,000, it's better for me if I come sell those fish for a high price." The same captain explained that he may lengthen a trip when fishing has been poor and may stay out a few more days, "Sometimes if I don't make enough money to pay my crew, I make one or two days more. If I can get $5,000 or $10,000 more it's OK."

It should be noted that in some fisheries what might appear to be income targets may actually result from marketing arrangements. For example, in both the mahogany quahog and shrimp fisheries in Maine, many fishermen are fishing to fill explicit orders from dealers.[4] If fishing is good they may return home early simply because they have no market for any additional catch.

If fisherman are bracketing risk at the level of the trip and are generally risk averse but are also loss averse, we might expect to see different kinds of behavior toward the end of the trip depending on whether they are above or below their income target. If they are well below the target they may actually be willing to explore some risky options if they have a chance of bringing the trip revenue above the target. On the other hand, if they are above the target they may be unwilling to take risks. Again, the insights from interviews show some support for this, but also suggest that fishermen may pursue riskier alternatives toward the end of a trip even on good trips. A captain of a small trawler from Maine states, "Usually you are more likely to take more risks later in the day, whether it's been a good day or a poor one. If it's been a poor day you'll take the risk because you want to salvage the day. If it's a good day you'll take the risk because you've already made a day's pay and you're not out as much. Especially if you know the next day is going to be a bad day weather wise." The captain quoted in the previous paragraph who may lengthen trips that have had poor fishing suggests he is risk averse in choosing fishing locations for these last days. "If there are no fish around, it's better to go for the safe most of the time." He explains that if he has been out there that long and hasn't found fish, there are probably not good places to go to find a lot of fish, "it's better to just stick with it."

In some cases the decision to pursue more uncertain alternatives toward the end of a trip appear to be related to the value of the information generated for future trips, as a captain of a small trawler in Maine explains.

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[4] I observed this firsthand as an observer on trips in each of these fisheries and have been told this by a number of fishermen in the Maine shrimp fishery.

> Eight out of ten times I would go for something different. Now it may be a big score for that day. But really the determining factor would have nothing to do with that day, but it would be where I'm going to approach the next week or the next day. I might even just make a short sample just to see if that's the direction these fish are going. Whether they are going deep, whether they are going shoal. If things are drying up I want to broaden my horizons. I want to know what direction I'm going to go with my fishing practices next week. Because I don't live from day to day. I'm looking for long-term production. I'm looking for options down the road.

Uncertainty Aversion

In some cases, it may be aversion to uncertainty rather than risk aversion that may be driving behavior, though the two may be difficult to distinguish since individuals have generally lower profit expectations for unfamiliar areas. One fisherman noted, "If I'm fishing here and I'm getting 600 pounds a tow, I'm going to stay. Because I don't know what's over there, I know what's over here."

Fishermen may have a legitimate reason to expect they will do better in an area they are more familiar with, even if other fishermen appear to be doing better elsewhere and they are aware of that. A fisherman explains:

> If there are two tows where you think you are going to catch an equal amount of fish, most likely you'll go to the one you are more familiar with because you are less likely to rip up and you are more familiar with it. You've got the home court advantage. So Fred might be more likely to fish over there because he's fished there more in the past and I'm more likely to fish here because I've fished here more. All things being equal he'll go there and I'll go here. But if I talk to him and he's doing twice what I'm doing, I'll go over there where he is. I usually figure I'm not going to do quite as good as he will because he knows his way around there better and it's the same when he comes over my way. You have a better idea of which part of the tows the fish are usually in. Usually the fish aren't spread evenly over the tow. You have a better idea of where the nooks and corners and hangs are.

In both cases, it may be that the individuals are choosing the more certain alternative because it is less risky or because they simply hold a higher profit expectation for the area that is familiar. However, there appears to be a component of uncertainty aversion as well.

Rule-based Behavior, Qualitative Categorization, and Non-monetary Objectives

Individuals faced with complex decisions involving uncertainty have been observed to follow rules of thumb or decision-making heuristics that work for them, but that are not really an attempt to maximize utility, at least at the level of the individual decision. This was described quite well by the captain of a small trawler fishing out of Portland, ME:

> I have an almost instinctive thought process every time I leave the dock and I don't even realize I'm doing it. Say it's for groundfish in July. There are four or five key areas that I would like to hit, that are historically very productive. I'll have about four or five options in my head before I even

> step aboard the boat. When I get aboard the boat the second factor will be the weather. Why the weather is important is that each one of those areas have better performance characteristics to the weather. It is a safety issue, but, to a degree, comfort is an issue. Let's say I can get my 800 pounds of codfish (the trip limit on cod); it's blowing southwest 20, they are giving it to blow 30 the rest of the day, the tide's coming. I'm going to steam down to the Southwest, into it, so the tide's not stacking them up, it's going to be a comfort issue. I'm going to hit a hump that I'm pretty sure I can get my cod within one tow, maybe two, and then when the tide turns and the wind really starts stacking them up, all I have to do is just ride it right home. Get a day's pay and ride it right home.

Comments in a number of interviews suggest that fishermen tend to evaluate alternatives qualitatively rather than developing a numerical estimation of the expected value to be used in comparing alternatives. For example, one fisherman explained he chose to fish in an area because, "I got a good sign of haddock, good sign of cod."

When alternatives are evaluated qualitatively it is much easier for a fisherman to consider factors that may not affect the expected profit of a choice alternative. Several comments by fishery demonstrate that there are non-monetary factors that influence their decisions both in terms of a long term fishing strategy and on a daily basis. A captain of an small, and quite old, trawler in Portland, ME, said that he has chosen an older small boat so he has low costs and can afford to fish close to home and be home at night. "It's a lifestyle choice." Another fisherman notes that there may be a sort of labor-leisure trade-off even during a trip. "I like the most value for the least amount of work I have to do. That's why I prefer flatfish over roundfish (since it does not have to be gutted) and monks over groundfish" (often only the tails of monkfish are landed). The same fisherman also expresses concern about catching small fish, partly because of the extra work of handling more, less valuable fish, but also because of conservation concerns:

> I guess I'm not in it for the money. I mean I do it to make my living. But, I'm not always out to make the maximum amount of money I can. A few years ago those small dabs were down there in the deep water. Some fellows I know were down there catching 10,000 pounds a day at 35 cents. That's a lot of work and you're killing all these small fish. I could fish up inside there and catch a few codfish and few monkfish and make two-thirds as much money and not have to handle that volume of fish. And I just didn't like the idea of working on fish that are just barely legal size.

Discussion

The way that fishermen deal with uncertainty in decision making has important implications for understanding and predicting fishing behavior and for designing policies intended to influence behavior. While it would be useful to undertake a rigorous analysis, a simple conceptual discussion serves to highlight some potentially important policy implications of prospect theory (and other behavioral hypotheses) for understanding fishing decisions under uncertainty.

In contrast to expected utility theory, prospect theory predicts risk aversion (risk-seeking) for decisions involving modest gains (losses) and a tendency to bracket decisions narrowly rather than consider expected value and risk over repeated decisions. In general, this would suggest that fishermen tend to gravitate

toward fishing locations and strategies with lower variability in earnings on a trip-by-trip or perhaps even a tow-by-tow basis. The impact of risk preferences on fishing decisions should be considered when designing policy measures that are meant to influence behavior by altering the relative profitability of fishing locations or strategies. Risk preferences may substantially alter the level of economic incentives required to influence behavior. As the interviews with trawler captains demonstrate, the effects of risk aversion on fishing location choices may have important implications for the species composition of catch at the fleet level. In fisheries managed with input controls, this could lead to over harvest of species that are more evenly distributed (*i.e.*, with lower variability in catch rates) and of species with more consistent prices.

Heterogeneity in risk aversion across sectors or the industry may have important consequences for how industry structure is affected by alternative management systems. For example, Bergland and Pederson (2006) show analytically that if one group (a coastal fleet) has strongly decreasing absolute risk aversion and the other (offshore fleet) is risk neutral, the original quota allocation will affect the equilibrium quota price, as well as the final distribution of quota between the groups. Assuming increasing marginal costs, they argue that a redistribution of initial quotas from the ocean fleet to the coastal fleet leads to higher economic efficiency in the case of strongly decreasing absolute risk aversion in the fishing industry. Under the same assumption, an increase in the TAC level will lead to the highest total expected profit in the fishing industry if the additional quota units are distributed to the coastal fleet.

Loss aversion could affect a variety of fishing decisions. As Camerer *et al.* (1997) argue, loss aversion, together with narrow bracketing, could lead to short-term negative labor supply elasticity. This effectively undermines the economic efficiency of the fleet and, potentially, its total catch when regulated with effort controls (though some might consider this a positive outcome). Loss aversion may also aggravate physical risk by causing individuals to continue fishing rather than return to port when bad weather is approaching. This may be accentuated by convexity in the value function for losses, which motivates risk-seeking choice behavior in evaluating losses.

Loss aversion and risk preferences may be quite important to understanding how fishers will respond to economic penalties, such as fines for infractions of regulations, though it is not at all clear what those effects might be. On the one hand, prospect theory would suggest that because of the convexity of the value function below the reference point, individuals may be risk-seeking in losses, which would tend to increase the fine needed to assure a given level of compliance. This would seem to apply if a fisherman was considering an action that would avoid a sure loss (*e.g.*, fishing in a closed area to avoid a money losing trip) against the potential fine if caught. On the other hand, a decision with both the potential for a loss and a gain can create the opposite effect. A potential loss from a fine may outweigh a probable gain from an illegal action due to the greater steepness of the value function below the reference point. Also, if the probability of being caught is very small but the penalty is high, individuals may tend to overweight these low probabilities which, like loss aversion, would tend to create a stronger compliance response to a given level of fine. In sum, while it seems likely that insights from prospect theory would be useful in designing a compliance system, it is difficult to generalize how those insights might affect optimal design. A key factor may be whether the compliance strategy relies on high fines and a low probability of detection or lower fines with a moderately high probability of detection. The former may motivate risk-averse behavior while the latter may motivate risk-seeking behavior.

A recent experimental study on compliance with a tradable permit system found that subjects that were predicted to buy permits had higher levels of violation than those who were predicted to be sellers (Murphy and Strandlund 2007). The authors suggested that this could be due to an endowment effect for holders of permits (whereby, all else equal, those that already hold permits would value them more than those considering buying them). The kinked value function proposed by prospect theory might also explain this behavior. A holder of permits is comparing a risky gain from selling the permit to a potential loss associated with getting caught not complying (having sold their permit). A buyer, on the other hand, faces a choice between a certain loss from having to buy the permit and a gamble from buying one that might not be needed.

As noted earlier, a few studies have documented a tendency of fishermen to avoid, and apparently undervalue, relatively unfamiliar fishing options in favor of more familiar ones. While some of this may be explained by heterogeneity in preferences or the lack of specialized information or skills that reduce the expected utility of these unfamiliar options, simple inertia appears to be a major factor. One explanation for that inertia is uncertainty aversion. Individuals avoid these areas not because their expected value is necessarily lower, but simply because their estimate of expected value is much less certain. This would be consistent with empirical results from fishery and location choice studies, though it may be difficult to demonstrate the causality. When considering how to design economic incentives meant to influence fishing behavior, such as bycatch fees or fines for various regulatory infractions, it may be important to explicitly consider the information available to fishers. In some cases it may be possible to increase the effectiveness and response to economic incentives by improving the quality of information available to fishers (though there could be cases where the converse is true).

Most of the examples discussed in this article relate to decisions of independent operators. It may be that behavior in large industrial fisheries, with fleets of vessels operated by large firms, may be less prone to some of the choice heuristics and biases discussed here. Also, in rights-based fishery management systems, markets (for quota) may tend to force out operators that are less efficient, which may move average behavior closer to normative predictions based on expected utility theory.

Loss aversion and risk preferences toward potential losses may also have interesting implications for evaluating how groups of stakeholders may consider management decisions. Consider, for example, how a group of stakeholders would evaluate the relative benefits of accepting a cut in their total allowable catch (TAC) in response to a stock assessment that suggests the stock has declined and that a failure to reduce the TAC may result in a further decline or collapse of the fishery. If stakeholders are risk-seeking in losses and loss averse, they may be reluctant to take a cut in the TAC, which represents a certain loss in the upcoming year, even when the discounted expected value of the income stream that would result from taking the cut exceeds that of not doing so. Whether group decision making tends to be more "rational" than individual decision making is a question that has received little attention to date.

Conclusions

Choice behavior that is consistent with prospect theory may differ substantially from what would be predicted by expected utility theory. Various choice heuristics and biases in formulating value expectations may result in decisions that, even on average, depart from what standard economic theory would predict. There is, up to now, little

in the way of empirical studies that document whether choice behavior in fisheries is consistent with prospect theory or inconsistent with expected utility theory and "rational" behavior. Although a number studies of fishing behavior reveal risk preferences and choice behaviors that appear inconsistent with expected utility theory, the stated preference study by Eggert and Martinsson (2004) provides the only direct test of this question. The ethnographic interviews of New England fishermen discussed herein provide some anecdotal evidence in support of prospect theory and other behavioral hypotheses (*e.g.*, rule-based behavior, uncertainty aversion, qualitative categorization, *etc.*) that appear to contrast with what would be considered rational behavior from a neoclassical economics perspective, However, an empirical analysis is needed to confirm whether these behaviors are widespread.

The discussion in the previous section illustrates a number of ways in which behavioral theories of decision making under uncertainty can lead to different conclusions about the expected outcomes of policies and environmental and economic changes in fisheries. The importance of accounting for these behaviors in modeling fishing behavior and in designing fishery policy will vary from case to case, but there is clearly a need for more consideration of these theories in the context of understanding fishing decisions. There has been almost no empirical research on fisheries that attempts to directly test the validity of expected utility theory vs. prospect theory, or for the use of various other decision-making heuristics and biases by fishermen in making decisions under uncertainty. In addition to empirical studies, experimental economics may be a useful way to improve our understanding of how these decision-making behaviors will influence the outcomes and impacts of policies or exogenous changes in fisheries.

When modeling fishing decisions, there should be more explicit consideration given to how fishermen incorporate information into complex decisions, what information they actually use, how they formulate expectations, and how they actually make decisions. Are fishermen truly formulating accurate conditional probability expectations and making dynamically optimal decisions or are they following simple decision strategies? Are they gathering and acting on information from a network or just relying on their own information? Are there consistent biases in how they formulate expectations of expected profit? Are there non-monetary factors influencing choices? Over what time frame are fishermen evaluating fishing strategy choices? How are decisions impacted by risk preferences, and are those risk preferences more consistent with prospect theory than expected utility theory? If our goal is to understand and predict fishing behavior and design more effective fishery management tools, it is critical to understand how fishermen actually make decisions, not how economic theory suggests they should make them. There is growing evidence that the two may be quite different and that predicted outcomes, even at the aggregate level, may diverge substantially from expectations as a result.

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