Ecological Economics 100 (2014) 130–139

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Time preferences and the management of coral reef fisheries

Ayana Elizabeth Johnson [a,*], Daniel Kaiser Saunders [b]

[a] Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92083-0202, USA
[b] Department of Economics, University of California, Santa Barbara, 2127 North Hall, Santa Barbara, CA 93106-9210, USA

ARTICLE INFO

Article history:
Received 4 July 2011
Received in revised form 9 January 2014
Accepted 12 January 2014
Available online 26 February 2014

JEL classification:
C93
D91
Q22
Q56
Q58

Keywords:
Time preferences
Discount factors
Discounting
Present bias
Fisheries management
Artisanal fishing
SCUBA diving
Coral reefs

ABSTRACT

To investigate a potential relationship between financial and marine resource use decisions, we conducted a time preference experiment with 153 fishers and 197 SCUBA divers on Curaçao and Bonaire. The experiment was part of a socioeconomic survey wherein interviewees were asked about their fishing and diving practices, views on fish population and coral reef health, and preferred marine resource management approaches. We use a $\beta\delta$-model to identify discounting and present bias. Divers had a mean individual discount factor (IDF) of 0.91, significantly higher than fishers' mean of 0.82. Fishers and divers had similar distributions of IDFs and present bias; overall 66% of interviewees were non-biased, 22% future-biased, and 12% present-biased. IDFs and present bias were able to predict management preferences after controlling for demographic factors. However, the effect of discount factors is unique to divers, and the effect of present bias is concentrated among fishers on Curaçao. Differences in time preferences between fishers and divers should be considered when developing management strategies. Transfer payments from the dive industry could facilitate a transition to sustainable fishing practices. Establishing property rights alone may not be sufficient for ensuring sustainability if fishers are present-biased and greatly discount the future.

1. Introduction

Individuals' time preferences (here discounting and present bias) have been extensively researched as they pertain to demographic characteristics and financial decisions (Frederick et al., 2002). Recently, theories describing how individuals conceive of decisions and tradeoffs have begun to be applied more expansively, and research has considered the environmental implications of time preferences (Hardisty and Weber, 2009). Much of the environmental research to date has focused on how social discounting could influence policies for mitigating global warming (reviewed in Carson and Roth Tran, 2009). Less research has focused on the marine realm, although notable exceptions include applications of time preference concepts to marine protected area design (Grafton et al., 2005; Sanchirico et al., 2006) and to ecosystem restoration (Sumaila, 2004). Research on the relationship between the discount factors[2] of individuals and the management of marine resources is sparse.

Open access problems aside, we hypothesize that individuals with higher discount factors and less present bias with regard to financial decisions (i.e., those who value the future more highly) would also be more inclined towards resource conservation (i.e., marine reserves and less damaging types of fishing gear). Conversely, one might expect that individuals with lower discount factors and more present bias would be more inclined towards unsustainable levels of resource exploitation. Little empirical work has focused on this theory as pertains to fisheries management. Substantially more research has addressed the risk preferences of fishers (Bockstael and Opaluch, 1983; Eggert and Lokina, 2007; Eggert and Martinsson, 2004; Eggert and Tveteras, 2004; Mistiaen and Strand, 2000; Opaluch and Bockstael, 1984; Smith and Wilen, 2005) than the time preferences of fishers.

To our knowledge, only two published studies present fishers' discount factors. Both of those studies elicited individual discount factors (IDFs) using hypothetical choices between various fisheries management

* Corresponding author at. Waitt Institute, 1201 Connecticut Ave. NW, Floor 3, Washington, DC 20036, USA. Tel.: +1 202 652 2409.
E-mail address: ayanaelizabeth@gmail.com (A.E. Johnson).

[2] Throughout the paper, we refer to discount factors, not discount rates. For clarity, if ρ is the discount rate and δ is the discount factor, the two are related by the equation $\delta = (1+\rho)^{-1}$.

[2] Throughout the paper, we refer to discount factors, not discount rates. For clarity, if ρ is the discount rate and δ is the discount factor, the two are related by the equation $\delta = (1+\rho)^{-1}$.

http://dx.doi.org/10.1016/j.ecolecon.2014.01.004
0921-8009

regimes and the theoretical future income streams associated with those regimes (Akapalu, 2008; Curtis, 2002). There do not appear to be any published studies presenting time preferences elicited from SCUBA divers. Thus, the research presented here represents the first attempt to elicit fishers' and divers' time preferences using incentivized experiments (i.e., price lists associated with actual monetary payments), and further, to explore the relationships between experimentally-measured discount factors and stated resource management preferences.

We elicited time preferences from fishers and professional SCUBA divers on Curaçao and Bonaire, islands in the southeastern Caribbean. Those professions were targeted because both are financially dependent on the health of ocean resources — fishers for the abundance of their catches, and professional divers for attracting tourist clientele. These neighboring islands are former Dutch colonies with similar histories of resource exploitation and similar marine ecosystems. The time preference experiment was paired with a socioeconomic interview that included questions on fishing and diving practices, perceptions of fish population trends and coral reef health, and level of support for management options such as gear restrictions and marine reserves. Here, we evaluate time preferences, as well as demographic characteristics, to understand fishers' and divers' preferred strategies for managing coral reefs.

2. Methods

2.1. Socioeconomic Interviews

In fall of 2009 on Curaçao, and spring of 2010 on Bonaire, A.E.J. conducted in-person interviews with (full and part-time) fishers and professional SCUBA divers (i.e., dive instructors and divemasters). There are no records listing the fishers or divers on either island, so stratified random sampling of these groups was not possible. Instead, interviews were opportunistic, as exhaustive as possible, and as inclusive as possible of all demographic groups. Interviewees were identified via recommendations from local contacts, approaching individuals at fishing docks and in dive shops, and requesting the contact information for additional individuals at the end of each interview in what is termed a snowball sampling technique (Bernard, 1994). All divers were fluent or nearly fluent in English, and a Papiamento–Dutch–English translator was used for all fisher interviews.

A total of 388 interviews were conducted: 126 fishers on Curaçao, 51 fishers on Bonaire, 112 divers on Curaçao, and 99 divers on Bonaire. Based on the number of interviews, the number of potential interviewees identified but with whom it was not possible to schedule interviews, and general knowledge of the fishing and diving communities, we estimate that there are approximately 200 fishers on Curaçao, 80 fishers on Bonaire, 120 professional divers on Curaçao, and 130 professional divers on Bonaire as of 2010. Based on these estimates, our sample represented 63% and 65% of the fishers on Curaçao and Bonaire respectively, and 86% and 83% of the divers on Curaçao and Bonaire respectively.

Of the interviewees, eight fishers and five divers declined to participate in the time preference experiment because they refused to have their participation in the interview be at all associated with a monetary payment. Nine fishers and eleven divers had multiple switch points in one or more price lists. Because such responses imply either that this is an inappropriate approach for measuring IDFs for those interviewees, or that they did not properly understand the questions, those individuals are not included in this analysis. Five fishers did not provide full demographic information. Thus, here we only examine the responses of 153 fishers and 197 divers.

2.2. Eliciting Time Preferences

Methods for eliciting time preferences have become well-honed, and the research presented here utilizes the best techniques currently available in attempt to capture the most accurate responses (Coller and Williams, 1999). Price lists (sets of questions offering choices between receiving payments sooner and later) accompanied by real monetary payments were used to elicit time preferences. At the end of each socioeconomic interview, participants were asked twenty-one questions — three price lists were used, each with seven questions (Appendix A). All price lists presented choices between sooner, smaller payments, and later, larger payments. Payments ranged from twenty to fifty florins (Fl.; 1 USD = Fl. 1.75). This maximum payment of Fl. 50 was chosen because it is roughly equivalent to a fisher or diver's daily income, thus one would not expect participants to be indifferent between payment choices. Additionally, it is a denomination of the local currency, so participants should have been familiar with its purchasing power, yet the amount is not so high as to make the experiment cost prohibitive.

The quantities of money offered were consistent across price lists. All sooner payments ranged from Fl. 50 down to Fl. 20, while all later payments were held constant at Fl. 50. The sole difference among the price lists was the dates at which payments were to be distributed. The first price list contained choices between payments the upcoming Friday and payments two weeks from Friday. The second price list contained choices between payments Friday and one month from Friday. The third price list contained choices between payments two weeks from Friday and a month from Friday. The experiment instructions and all questions were read aloud to interviewees.

To encourage careful consideration of responses, each interviewee was offered a cash payment in accordance with their answer to one of the twenty-one time preference questions. After responding to all questions, participants pick a numbered chip from a sack, and the quantity of their payment was determined based on how they answered the question corresponding with the number on the chip. For example, an interviewee who chose the chip marked with number seven, and who in response to question seven chose to receive Fl. 50 two weeks from Friday over Fl. 20 on Friday, would then actually be given Fl. 50 two weeks from Friday.

We employed front end delays (i.e., no payments were made at the time of interview) to equate the transaction costs of choosing the sooner and later payments, and to reduce the dependence of responses on level of trust for the researcher (Cardenas and Carpenter, 2008). All interviewees were required to retrieve their payments at a specified future date, time, and location. On Curaçao, we distributed payments on Friday afternoons at Dienst Landbouw, Veeteelt & Visserij (LVV), where the fisheries department is located. On Bonaire, we distributed payments on Friday afternoons at the office of Stichting Nationale Parken (STINAPA), the headquarters of the island's marine park. Each interviewee was given a card stating the date and time that their payment could be picked up along with directions to the payment distribution location.

2.3. Calculating Discount Factors and Present Bias

For the point in each price list where the participant switched from preferring the sooner to preferring the later payment (i.e. the switch point), we took the mean between the sooner payment amounts in the question before the switch and in the question where the switch was made. The mean is used, as is common practice, because price list questions do not enable the determination of the exact switch point, rather the discrete range within which the switch occurs. We then divided that mean by Fl. 50, the highest payment option in each question, yielding discount factors from ≥ 1.0 down to 0.4 (Table 1). For example, a participant chooses sooner payments over later payments in response to all price list questions until asked to choose between Fl. 50 in two weeks from Friday and Fl. 20 on Friday, and at that point chooses to wait two weeks to receive Fl. 50. He would have a mean switch point of 25 (the mean of the Fl. 30 and Fl. 20 sooner payment amounts between which the switch was made), which when divided by 50 yields a discount factor of 0.5.

Table 1
Price list switch points with their associated midpoints, discount factors, and frequency of fisher and diver responses.

Interview responses elicited	Midpoint between switch questions	Discount Factor	# of fisher responses	# of diver responses
Prefers Fl. 50 later over Fl. 50 sooner	50	≥1.0	31	58
Prefers Fl. 50 sooner over Fl. 50 later	49	0.98	54	80
Prefers Fl. 48 sooner over Fl. 50 later	46	0.92	10	16
Prefers Fl. 44 sooner over Fl. 50 later	42	0.84	7	17
Prefers Fl. 40 sooner over Fl. 50 later	37.5	0.75	20	13
Prefers Fl. 35 sooner over Fl. 50 later	32.5	0.65	6	5
Prefers Fl. 30 sooner over Fl. 50 later	25	0.5	7	6
Prefers Fl. 20 sooner over Fl. 50 later	20	≤0.4	24	10

A participant who chose later payments in response to all questions, even when given the choice between Fl. 50 on Friday and Fl. 50 in 2 weeks, would have a discount factor of 50/50, which we notate as ≥1.0 because it cannot be assigned an upper bound. A participant who chose sooner payments in response to all questions would have a discount factor of 20/50, which we notate as ≤0.4 because it cannot be assigned a lower bound. These bounds cannot be determined because the price lists did not include enough questions to determine switch points for these participants.

We consider time preferences using a three period $\beta\delta$-model:

$$U_i(c_0, c_1, c_2) = u_i(c_0) + \beta\delta u_i(c_1) + \beta\delta^2 u_i(c_2).$$

In this model, $\beta = 1$ corresponds to the standard exponential discounting model, while $\beta \neq 1$ represents hyperbolic time preferences (i.e., changes in discount rates over time). Period zero refers to the upcoming Friday, while period one refers to two weeks from Friday, and period two refers to four weeks from Friday. Individual discount factors (IDF) were calculated based on participant responses to questions in the three price lists: IDF_1, IDF_2, and IDF_3 correspond with price lists one, two, and three, respectively. Within this context, our elicited discount factors relate to the model parameters as follows:

Discount factors	Model parameters
IDF_1	$\beta\delta$
IDF_2	$\beta\delta^2$
IDF_3	δ

Within the $\beta\delta$-framework, IDF_3 yields the most direct measure of the discount factor, δ, so we exclusively use IDF_3 when analyzing the effect of discount factors on management preferences. To examine the role of hyperbolic discounting, individuals were categorized as present-biased, future-biased, or non-biased (pure exponential) based on the definitions from the underlying model. Specifically, we use the relationship between IDF_1 and IDF_3 to impute β, since these are the IDFs calculated from price lists with two-week differences in payment dates, but with IDF_3 having an additional two-week front-end delay.

Time preferences	Value of β	Relation of IDFs
Present-biased	$\beta < 1$	$IDF_1 < IDF_3$
Non-biased (exponential)	$\beta = 1$	$IDF_1 = IDF_3$
Future-biased	$\beta > 1$	$IDF_1 > IDF_3$

Individuals for whom IDF_1 was smaller than IDF_3 are considered present-biased, since this implies hyperbolic discounting, i.e., $\beta < 1$. Individuals for whom IDF_1 was larger than IDF_3 are considered future-biased, i.e., $\beta > 1$. Individuals for whom IDF_1 is equal to IDF_3 are considered non-biased, corresponding to the standard model of exponential discounting.

2.4. Eliciting Management Preferences

As part of the larger interview, all participants were asked their opinions of a variety of marine resource management options (see Appendix B). Questions were focused on fishing gear restrictions (i.e., requiring modifications to certain types of fishing gear or banning gear types all together) and area restrictions (i.e., temporary or permanent no fishing or no diving reserves). Marine reserves, where fishing is prohibited, are a scientifically proven way to increase fish populations, restore habitat, and improve catches in surrounding areas (PISCO, 2007).

Using the nine gear questions and seven reserve questions, gear scores and reserves scores were calculated for each individual based on the percentage of gear restrictions and area restrictions that they supported. Using responses to gear and reserve questions and five additional miscellaneous management questions (i.e., restricting numbers of fishers and divers, and prohibitions on anchoring, catch of certain species, and catch of juvenile fish), an overall conservation score was calculated for each individual. The maximum value for each score is 100 (i.e., all responses favoring restrictions on use and increased resource protection) and the minimum value is zero.

2.5. Revealed Management Preferences

Questions on limiting the number of fishers and divers, closing areas to fishing or diving, and restrictions on types of fishing gear are used to explore interviewees willingness to have their own usage constrained, that is, their revealed management preferences. The most commonly used types of fishing gear on these islands are hook-and-line, trolling, fish traps, spearguns, gill nets, and beach seines. Hook-and-line and trolling generally cause less environmental harm (e.g., habitat damage, bycatch of juveniles and non-target species) than do fish traps, spearguns, gills nets, and beach seines. Thus, we term the former low-impact gears, and the latter high-impact gears. Low-impact gears have high risk of zero catch, but also a chance of valuable catch; they tend to catch low numbers of high-value species. High-impact gears have low risk of zero catch, are often less time intensive per kilogram caught (traps and nets need not be constantly attended while they are fishing), and have greater catch quantity, but with catch often (with the notable exception of spearguns) comprised of lower-value species.

2.6. Data Analysis

We conduct a variety of regressions in order to estimate the impact of time preferences on attitudes towards management. Our model for each management score (denoted *Score*) takes the form:

$$\begin{aligned} Score = {} & \alpha + \phi_1 IDF_3 + \phi_2 IDF_3 \cdot Fisher + \theta_1 Present + \theta_2 Present \cdot Fisher \\ & + \theta_3 Present \cdot Curaçao + \theta_4 Present \cdot Fisher \cdot Curaçao + x'\lambda + \epsilon \end{aligned}$$

where IDF_3 measures the exponential discount factor, δ; *Present* is a dummy variable denoting present-biased time preferences, $\beta < 1$; *Fisher* is a dummy variable denoting fishers; *Curaçao* is a dummy variable denoting residents of Curaçao; and x is a vector of demographic control variables. Within x are additional dummy variables, several continuous variables, and a few controls for interactions between variables. The dummy variables are for profession, location, marriage status, parenthood, possession of a bank account, access to credit, and employment status (i.e., full-time, part-time, hobby). The continuous variables are for age, years of experience, and a quadratic relation for the number of generations that one's family has fished/dived. Lastly, to add more flexibility to the model, we also control for interactions between profession and island, profession and marriage status, and profession and possession of bank account.

We employ one large model to allow the effects of discount factors and present bias to vary by group, and to avoid the loss of statistical power associated with reductions in sample size. We denote the effect of IDF as ϕ_1 for divers and $\phi_1 + \phi_2$ for fishers. Likewise, we denote the effect of present bias as θ_1 for divers on Bonaire, $\theta_1 + \theta_2$ for fishers on Bonaire, $\theta_1 + \theta_3$for divers on Curaçao, and $\theta_1 + \theta_2 + \theta_3 + \theta_4$ for fishers on Curaçao. For robustness, we estimate a few alternative restrictions to this flexible model, such as applying a uniform effect of discount factors ($\phi_2 = 0$) or present bias ($\theta_2 + \theta_3 + \theta_4 = 0$) on management preferences, or allowing the effect of present bias to vary by profession ($\theta_3 + \theta_4 = 0$), island ($\theta_2 + \theta_4 = 0$), or both ($\theta_4 = 0$). Under the full model, the effect of IDF varies by profession, while present bias has four, independent effects for each profession–island pairing.

2.7. Risk-aversion

Any experiment involving time preferences must take care to address uncertainty and risk aversion. Our use of a front-end delay for all payments controls for changes in risk preferences within an individual due to the certainty of payments in the current period versus the uncertainty of payments in future periods (Andreoni and Sprenger, 2012). However, theory posits that a longer length to maturity of any payment is inherently riskier, and the yield curve (i.e., the fact that interest rates tend to rise with the length to maturity) is often cited as an example of this effect. The future is deemed riskier because there is some increasing probability that the payment will not be received. This reflects increasing riskiness of the asset, not increasing risk aversion of the individual, over the length to maturity. Recent research on the U.S. treasuries (Startz and Tsang, 2012) suggests that the majority of the yield curve is explained by pure hyperbolic discounting, not risk. That is, what appears as an aversion to increasing risk over time-to-maturity is, in fact, increasing impatience with longer waiting periods. Hence, it may be sufficient to control for present bias, which we do, without also controlling for risk aversion.

Theory gives us further reason to believe that we have successfully identified the effect of present bias in particular. While heterogeneous risk preferences may affect observed discount factors (δ) and, hence, observed hyperbolic discount factors (β), it does not affect whether hyperbolic discounting is observed on the extensive margin, that is, whether our dummy variable *Present* equals zero or one. Additionally, the time to payment is quite short (four weeks at most), which explains the large proportion of discount factors observed between 0.98 and 1, and mitigates concern over payoff uncertainty. Thus, we are confident that our results identify individual discount factors and hyperbolic discounting separately from risk preferences.

3. Results and Discussion

3.1. Interviewee Demographics

The mean age of interviewed fishers was 48.0 years, significantly older than divers, for whom the mean age was 36.6 ($p < 0.001$, Table 2). Fishers were more likely than divers to be married ($p = 0.005$) and to have children ($p < 0.001$). Of the married interviewees, divers were more likely than fishers to have an employed spouse ($p < 0.001$). Proportions of fishers and of divers who were married, had children, and/or had an employed spouse did not differ significantly between islands. Fishers had more years of personal experience and more generations of family experience with fishing than divers had with diving (both $p < 0.001$).

Divers were significantly more financially secure than fishers, as measured by their greater likelihood of having a bank account, a credit card, and a friend who would loan them Fl. 50 (all $p < 0.001$). Of the participants who could borrow Fl. 50 from a friend, fishers were significantly more likely to have to pay interest on such a loan ($p < 0.001$). Professional divers frequently work in the dive industry to temporarily support themselves while living abroad, tend to be more educated than fishers, and often have higher-paying jobs that they can return to and/or family members (parents or spouses) to provide financial assistance while they pursue professional diving. Mean annual incomes of interviewees were approximately Fl. 22,100 ($12,486 USD), and not significantly different between professions or islands. However, because income data were self-reported and 125 interviewees (35%) chose not to respond to this question, income data are not used further in the present analysis to avoid potential effects such as sample selection bias.

To summarize the demographics, professional divers are generally younger, unmarried, without children, white, foreign (mostly Dutch), and more financially secure, with less personal and family history in their field than fishers. In contrast, fishers are generally older, married, parents, black, Antillean, less financially secure, and more experienced. Diver demographics likely remain fairly consistent over time despite high turnover within the professional diving community. Turnover of fishers is low, although the proportion of time that an individual allocates to fishing often varies seasonally and inter-annually based upon the catch and the availability of alternative employment opportunities.

3.2. Fisher and Diver IDFs

The majority of fishers and divers appear to have relatively high discount factors. However, fishers' discount factors were significantly lower than those of divers. Mean IDF_3 for fishers was 0.82 (SE 0.019) compared to 0.91 (SE 0.011) for divers (Table 2). Divers were significantly more likely than fishers to choose the later payment even when the sooner and later payment amounts were both Fl. 50, which results in some IDFs of ≥ 1.0 ($p < 0.05$ for all price lists; Fig. 1). Fishers were significantly more likely than divers to choose the sooner payment for all questions in a price list ($p < 0.002$ for all price lists). For fishers, IDF_3 was positively correlated with having a bank account ($p = 0.013$). Counter to our hypothesis, IDFs were not correlated with usage of high-impact gear.

Although evidence in the literature for the correlation between poverty and time preferences is mixed (Cardenas and Carpenter, 2008), some research has identified a positive relationship between discount factor and income (discussed in Carson and Roth Tran, 2009). Thus, the results here could reflect the fact that divers generally have higher expected lifetime incomes than fishers, and a lower level of financial constraint.

Individuals largely offered similar responses across price lists. 15% of fishers and 27% of divers had the same switch point in all three price lists. Consistency in switch points could be caused by individuals not perceiving these lists as presenting substantially different choices. Larger differences in days until payment (time periods on the order of six months or a year) might have produced greater differentiation in responses between price lists, but could also have exacerbated any effect of risk preferences.

3.3. Distribution of IDFs

The majority of both fishers and divers have discount factors ≥ 0.98, however, the distribution of diver IDFs exhibits an essentially monotonic decline from 1.0 down to ≤ 0.4 for all price lists, while that of fishers has a somewhat tri-modal distribution with additional peaks at 0.75,

Table 2
Mean demographic information, discount factors, present bias, and management scores for interviewed fishers and divers, with standard errors in parentheses. For "yes/no" categories, yes = 1, no = 0.

	Fishers			Divers		
Island	Curaçao	Bonaire	Overall	Curaçao	Bonaire	Overall
Number of interviewees	109	44	153	106	91	197
Age	47.9	48.5	48.0	34.2	39.3	36.6
	(1.23)	(2.89)	(1.20)	(0.89)	(1.31)	(0.79)
Years of experience	34.71	38.14	35.69	12.16	16.77	14.29
	(1.24)	(2.74)	(1.19)	(0.83)	(1.18)	(0.72)
Generations of family fishing/diving	3.14	3.41	3.22	1.34	1.37	1.36
	(0.14)	(0.18)	(0.12)	(0.06)	(0.06)	(0.04)
Married	0.55	0.43	0.52	0.36	0.39	0.37
	(0.05)	(0.08)	(0.04)	(0.05)	(0.05)	(0.03)
Children	0.80	0.71	0.77	0.26	0.26	0.26
	(3.86)	(6.93)	(0.03)	(0.04)	(0.05)	(0.03)
Bank account	0.72	0.66	0.70	1.00	0.98	0.99
	(0.04)	(0.07)	(0.04)	(0.00)	(0.02)	(0.01)
Credit card	0.50	0.41	0.48	0.66	0.70	0.68
	(0.05)	(0.07)	(0.04)	(0.05)	(0.05)	(0.03)
IDF_1	0.88	0.78	0.85	0.92	0.99	0.91
	(0.02)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)
IDF_2	0.83	0.69	0.79	0.90	0.89	0.90
	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)	(0.01)
IDF_3	0.86	0.71	0.82	0.92	0.89	0.91
	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)	(0.01)
Present bias	0.16	0.07	0.13	0.12	0.10	0.11
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)
Reserve score	28.90	52.04	35.77	64.80	74.65	69.35
	(3.36)	(4.12)	(2.80)	(2.17)	(2.17)	(1.57)
Gear score	51.92	57.24	53.45	75.00	75.63	75.29
	(1.87)	(3.91)	(1.75)	(1.98)	(2.52)	(1.57)
Conservation score	44.28	52.87	46.75	71.36	74.44	72.78
	(1.53)	(3.18)	(1.45)	(1.36)	(1.68)	(1.07)

and at ≤0.4 (Fig. 1). The cluster of fishers at IDF ≤ 0.4 represents 9.7% of participants in the sample. This cluster may be an artifact of the truncation of each price at the choice between Fl. 20 sooner and Fl. 50 later. If the range of sooner payments had included amounts less than Fl. 20, some participants may have chosen additional lower payments, resulting in discount factors lower than 0.4, thus dispersing that peak.

The cluster of fishers at an IDF of 0.75 represents approximately 10% of participants. This concentration of responses, which corresponds with a preference of Fl. 40 sooner over Fl. 50 later, but a preference of Fl. 50 later over Fl. 35 sooner and, may be meaningful and not an artifact of the experimental design. Currency quantities are often mentally compared against the value of oft purchased items, offering a potential explanation for this peak. Polar, the most popular beer on both islands, was priced from Fl. 36 to Fl. 38 per case at the time of this study, and is one likely candidate for such a calibration. Although anecdotal and inadequate to prove correlation, five fishers and one diver did explicitly mention this as the rationale for their switch point.

3.4. Comparison With Previous IDF Studies

Despite the array of literature on measuring time preferences, and due in part to widely varying elicitation methods, honing in on a "normal" range of discount factors has been elusive. As compiled by Frederick et al. (2002), seven studies published between 1978 and 2002 elicited discount factors using choice sets associated with real monetary payments. Those studies produced a range of annual discount factors from 0.0 to 1.01. The range of IDFs presented here, from ≤0.4 to ≥1.0, is truncated due to the experimental design, hindering a direct comparison with previous research.

The two previous studies that report experimentally measured discount factors of fishers found mean values substantially lower than those presented here. Fishers in the Irish Sea had a mean discount factor of ~0.7 (Curtis, 2002), and fishing boat skippers in Ghana had a mean discount factor of 0.43 (Akapalu, 2008). These studies measured IDF with questions about future profit scenarios that would result from different fishery management approaches. Because those two studies used different elicitation methods than the price list approach used here, unfortunately it cannot be determined whether the higher discount factors we measured are indicative of important differences in cultural, economic, or fisheries management contexts.

Another confounding factor when comparing discount rates is time period. Broadly, there is the question of determining the appropriate time horizon for considering the relationship of time preferences with ocean management decisions, given that costs are often incurred in the near-term, while benefits accrue at an unknown rate in the future. That said, we found sufficient variation in discount factors within our two-to-four week time period to explain management preferences (Table 3). The weak incentives implied by a short time horizon should only make significant results harder to find. Further, longer time periods to payment increase the potential for participants to factor uncertainty of payment into their decision-making, which could confound time preferences. Hence, we are satisfied that the time period we used is sufficient to meaningfully explain management preferences.

3.5. Present Bias

Distributions of hyperbolic discounting were not significantly different between professions or islands (Table 2). Contrary to our hypothesis, fishers who use high-impact gear did not exhibit a higher incidence of present bias. Two-thirds of both fishers and divers were non-biased. An additional 22% of participants were future-biased, and the remaining 12% were present-biased. As with IDF_3 (Section 3.2), the relatively low occurrence of present bias may represent consistency across price lists that individuals perceived as functionally equivalent. As for the large proportion of individuals exhibiting future bias, perhaps individuals were using the experimental payment as a commitment device for saving. For example, one interviewee explained that although he did not currently have a girlfriend, he might in two weeks, and if he waited for the payment then he would have money to take her out to dinner.

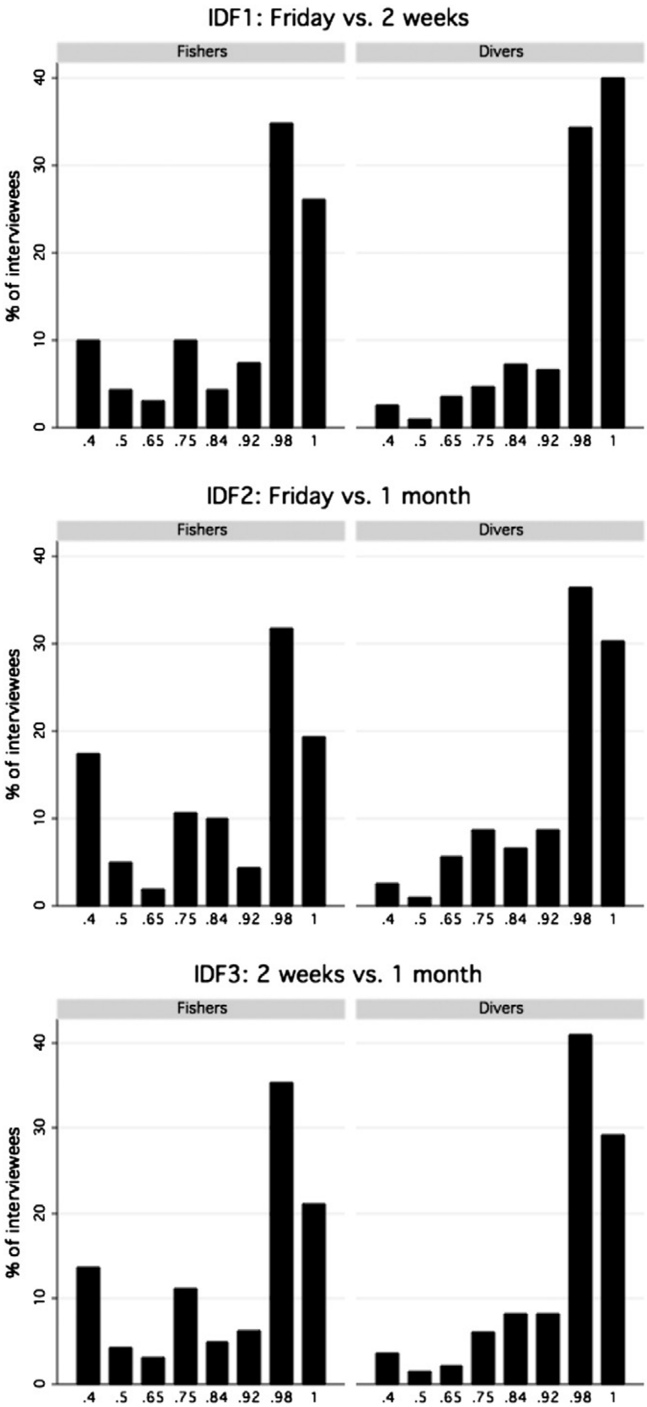

Fig. 1. Distributions of individual discount factors (IDFs) for fishers and divers as elicited via price lists with front-end delays and associated with real monetary payment. Price lists had identical payment amounts but different pairs of payment dates.

Alternatively, motivation to wait for payment could be related to the highly variable nature of fisher and diver incomes, with fishers depending on unpredictable catches and divers depending partly on tips. Future bias could be related to whether the interviewee had recently received a paycheck, whether divers had recently received a good tip, and whether fishers recently had a good catch. Interviewees may also have been hesitant to admit a preference for receiving money sooner, due to pride. This hesitation could have been exacerbated by the fact that the participants were mostly male and the interviewer was a young female. Indeed, decisions can be influenced by socio-cultural context, the desire to appear competent, and the interview process itself, and therefore may not solely reflect monetary preferences (e.g. Bowles, 1998; Levitt and List, 2007). Regardless, future bias has no measurable impact on management scores for any of the functional forms that we estimate. Thus, it is included within the reference category, along with exponential discounting, in order to increase the statistical power of our measurement of the effect of present bias.

3.6. Management Scores

Mean gear scores, reserve scores, and conservation scores were significantly higher for divers than for fishers (all $p < 0.001$, Table 2). This is not surprising, since divers benefit from restrictions on fishing, while fishers bear the bulk of costs for such restrictions. Without conditioning on any control variables, IDF_3 (Table 3) is positively correlated with reserve scores (R1, $p = 0.068$), gear scores (G1, $p = 0.023$), and conservation scores (C1, $p = 0.003$). This is consistent with our hypothesis that more patient individuals would show greater support for conservation efforts. Yet, when considering fishers and divers collectively, after controlling for other relevant factors by estimating our model with a uniform effect of discount factors and present bias, there are no significant relationships between these scores and individual discount factors (R2, G2, C2).

However, if we allow discount factors to have different effects for fishers and divers, but present bias is still restricted to one overall effect, for fishers there is still no effect, but we see that for divers (R3, G3, C3) discount factors are significant in explaining reserve scores ($p = 0.007$) and conservation scores ($p = 0.012$), though not gear scores. A 0.1 point increase in the discount factor leads to a 2.5 point increase in reserve scores for divers, or an almost 15 point increase over the range of observed discount factors. Similarly, for conservation scores a 0.1 increase in the discount factor leads to a 1.8 point increase in conservation scores for divers, or 10.8 points over the observed range. These results are robust to the restrictions that we place on the effect of present bias (R4, G4, C4). Since conservation scores are composed in part from reserve scores and gear scores, the smaller effect of discount factors on conservation scores is expected. The lack of an effect of discount factors on gear scores is also expected, since marine reserve restrictions directly affect inter-temporal decision-making while gear restrictions have only second-order inter-temporal effects (e.g., restricting high-impact gear leads to improved future catches).

Present bias (Table 4) reduces marine reserve scores by almost 14 points (P1, $p = 0.068$), 7.4 points (P2, $p = 0.040$) after controlling for demographic variables, but does not significantly reduce gear scores or conservation scores. That is, in support of our hypothesis, interviewees who were more present biased were less supportive of marine reserves. Gear scores are not responsive to present bias, thus washing out an effect for overall conservation scores, even after controlling for demographic variables. The effect of present bias on reserve scores is stronger for fishers than divers (P3, 9.7 versus 5.5), though not significant for either, and stronger on Curaçao than Bonaire (P4, 10.7 versus 0.26, $p = 0.016$). Model P5 estimates the effect of present bias across professions and islands simultaneously, though the model assumes that the difference between fishers and divers is the same for each island. The estimates suggest a combined effect that is significant for both fishers ($p = 0.049$) and divers ($p = 0.065$) on Curaçao; though present bias appears irrelevant on Bonaire. The final model (P6), which estimates a unique effect of present bias for each profession–island combination, suggests that present bias only applies to fishers on Curaçao ($p = 0.054$). Given the relatively low statistical power of these estimates (four parameters with 40 observations of present bias), it is not clear whether the effect applies only to Curaçao fishers, or whether we lack the sample size required to parse the effect of present bias across profession and location at the same time. Perhaps these inter-island differences could be explained by the greater industrialization and faster pace of life on Curaçao relative to Bonaire (Wang et al., 2009).

Table 3
Marginal effect of individual discount factors (IDF_3) on management scores by profession, with standard errors in parentheses.There are no significant differences between islands.

		All divers	All fishers
Reserve scores	R1: Unconditional difference-in-means	17.37*	17.37*
	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(9.50)	(9.50)
	R2: Uniform effect for IDF and present bias	7.09	7.09
	$\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(9.16)	(9.16)
	R3: Uniform effect for present bias	25.30*** (9.39)	−6.31
	$\theta_2 = \theta_3 = \theta_4 = 0$		(13.99)
	R4: Full model	24.81***	−6.43
		(9.52)	(14.17)
Gear scores	G1: Unconditional difference-in-means	14.87**	14.87**
	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(6.51)	(6.51)
	G2: Uniform effect for IDF and present bias	3.05	3.05
	$\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(6.55)	(6.55)
	G3: Uniform effect for present bias	15.09	−5.82
	$\theta_2 = \theta_3 = \theta_4 = 0$	(11.84)	(7.53)
	G4: Full model	15.09	−6.45
		(11.93)	(7.57)
Conservation Scores	C1: Unconditional difference-in-means	15.61***	15.61***
	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(5.29)	(5.29)
	C2: Uniform effect for IDF and present bias	4.06	4.06
	$\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(4.84)	(4.84)
	C3: Uniform effect for present bias	18.30**	−6.43
	$\theta_2 = \theta_3 = \theta_4 = 0$	(7.26)	(6.29)
	C4: Full model	18.05**	−6.70
		(7.33)	(6.33)

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

3.7. Principal Component Analysis of Management Scores

The design of the management scores was carefully tailored to best measure the conservation preferences of participants. That said, these key variables are constructed from survey responses; they are not naturally occurring and passively observable. This is true not only of conservation scores, which are composites of other created variables, but also, more subtly, of reserve scores and gear scores. Therefore, as a robustness check, we conduct a principal component analysis (PCA) on the management scores and repeat our regression analysis using the principal components as dependent variables.

We find that the effects of discount factors and present bias operate across distinct principal components. This result indicates that IDF_3 and *Present* are, indeed, measuring distinct aspects of time preferences. The first principal component is found to explain 76.9% of the variation across management scores, while the second and third components explain 20.8% and 2.3% of the remaining variation, respectively. While the units of the principal components, themselves, are not interpretable, the relative size of the estimated effects makes for useful comparisons.

The PCA results generally confirm our other findings. Only the first principal component is significantly affected by discount factors (Table 5). When allowing the effect of discount factors to vary across fishers and divers, we find that discount factors only impact the conservation attitudes of divers (PCA-R3, PCA-R4). In Section 3.6, we showed that discount factors impact both reserve scores and conservation scores for divers. Therefore, it appears that the measured effect for conservation scores merely represented the residual component of conservation scores attributed to reserve scores.

The third principal component is the only dimension significantly affected by present bias (Table 6). Since the third component is the weakest, this explains the difficulty in finding consistent results for the effect on reserve scores. By isolating this component, we obtain stronger results for present bias. Varying the effect of present bias by profession (PCA-P3), this component is reduced by 0.11 for divers ($p = 0.028$). Allowing the effect to differ across islands (PCA-P4), we estimate the reduction to be 0.12 on Bonaire ($p = 0.016$) and 0.10 on Curaçao ($p = 0.045$). Allowing each profession-island to have a unique present bias effect, we see that Curaçao fishers' scores are reduced by

Table 4
Marginal effect of present bias on marine reserve scores by profession and island, with standard errors in parentheses.

	Bonaire divers	Bonaire fishers	Curaçao divers	Curaçao fishers
P1: Unconditional correlation	−13.92***	−13.92***	−13.92***	−13.92***
$\phi_1 = \phi_2 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(5.26)	(5.26)	(5.26)	(5.26)
P2: Uniform effect	−7.43**	−7.43**	−7.43**	−7.43**
$\theta_2 = \theta_3 = \theta_4 = 0$	(3.60)	(3.60)	(3.60)	(3.60)
P3: Effect varies by profession	−5.55	−9.71	−5.55	−9.71
$\theta_3 = \theta_4 = 0$	(4.24)	(6.06)	(4.24)	(6.06)
P4: Effect varies by island	0.26	0.26	−10.73**	−10.73**
$\theta_2 = \theta_4 = 0$	(5.52)	(5.52)	(4.42)	(4.42)
P5: Effect varies by profession and island	0.63	−0.88	−9.91**	−11.43*
$\theta_4 = 0$	(5.97)	(7.46)	(5.02)	(6.18)
P6: Effect varies independently for each group	−2.12	7.17	−7.93	−13.11*
	(6.69)	(8.02)	(5.44)	(6.77)

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
Marginal effect of individual discount factor (IDF_3) on the principal components of the management scores, with standard errors in parentheses. There are no significant differences between islands.

		All divers	All fishers
Principal component 1	PCA-R1: Unconditional difference-in-means	1.10***	1.10***
76.9% of total variation	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(0.40)	(0.40)
	PCA-R2: Uniform effect for IDF and present	0.31	0.31
	bias $\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(0.35)	(0.35)
	PCA-R3: Uniform effect for present bias	1.31**	−0.43
	$\theta_2 = \theta_3 = \theta_4 = 0$	(0.53)	(0.46)
	PCA-R4: Full model	1.30**	−0.46
		(0.53)	(0.46)
Principal component 2	PCA-G1: Unconditional difference-in-means	−0.02	−0.02
20.9% of total variation	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(0.24)	(0.24)
	PCA-G2: Uniform effect for IDF and present	0.08	0.08
	bias $\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(0.27)	(0.27)
	PCA-G3: Uniform effect for present bias	0.16	0.02
	$\theta_2 = \theta_3 = \theta_4 = 0$	(0.39)	(0.38)
	PCA-G4: Full model	0.15	0.03
		(0.39)	(0.39)
Principal component 3	PCA-C1: Unconditional difference-in-means	−0.05	−0.05
2.2% of total variation	$\phi_2 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(0.07)	(0.07)
	PCA-C2: Uniform effect for IDF and present	−0.01	−0.01
	bias $\phi_2 = \theta_2 = \theta_3 = \theta_4 = 0$	(0.07)	(0.07)
	PCA-C3: Uniform effect for present bias	−0.06	0.04
	$\theta_2 = \theta_3 = \theta_4 = 0$	(0.10)	(0.11)
	PCA-C4: Full model	−0.06	0.03
		(0.10)	(0.11)

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

0.13 ($p < 0.001$). Surprisingly, with PCA we find that Bonaire divers' scores are reduced by 0.18 ($p < 0.001$), a far larger reduction than before. Thus, the PCA shows that our previous estimates lacked the statistical power necessary to separate out the effects of present bias on reserve scores across profession and island. We have confirmed a strong positive effect of discount factors, and a significant negative effect of present bias, on conservation attitudes. These effects are measured across different principal components, so we are confident that the elicitation experiment separately identifies these two dimensions of time preference.

3.8. Restricting Their Own Resource Use

We analyzed fishers' and divers' comparative willingness to put restrictions on their own resource use. 1% of fishers were willing to limit the number of fishers, whereas 34% of divers were willing to limit the number of divers ($p < 0.001$).[3] Fishers who used high-impact gears (traps, spearguns, gill nets, seines) had significantly lower marine reserve scores ($p = 0.044$), gear scores ($p = 0.014$), and conservation scores ($p = 0.037$) than those who use low-impact gears (hook and line, troll), reflecting reluctance not just on having restrictions placed on their use of these gears, but on conservation measures in general.

Fishers were more likely than divers to support no diving areas and vice versa for no fishing areas (both $p < 0.001$). 62% percent of divers supported no diving areas versus 37% of fishers who supported no fishing areas. On Bonaire, the same relationship holds as regards the existing no fishing and no diving areas, with fishers more likely than divers to support additional no diving areas ($p = 0.035$) and vice versa for no additional fishing areas ($p = 0.008$). Divers on Bonaire were significantly more likely to support additional no diving areas (51% support) than fishers were to support additional no fishing areas (32% support; $p < 0.05$). Taken together, this is evidence of divers' greater patience with resource use relative to fishers. To be fair, we are comparing a non-extractive, recent profession dominated by foreigners (diving) with a resource extractive profession with a long cultural history conducted by locals who feel displaced (fishing). There are likely complex socio-cultural factors at play here. Regardless, divers focus on observing marine life and therefore benefit from restrictions on fishing, so these differences in observed management preferences are to be expected to some degree.

[3] A restriction on the number of divers is likely to restrict the number of tourist divers, and thereby the number of potential customers, but not necessarily the number of professional divers. A restriction on the number of fishers could directly prevent interviewees from fishing.

3.9. Key Findings

Fishers and divers had relatively high discount factors; however, fishers' IDFs were significantly lower. The distribution of fishers' IDFs is somewhat trimodal (versus a monotonic decline for divers), perhaps related to the salient purchasing power of particular dollar amounts. Interestingly, divers' discount factors were positively related to their view of marine reserves, though not with their views of gear restrictions. Discount factors appear unrelated to management scores for fishers.

Fishers who use high-impact gear did not exhibit the higher incidence of present bias that we had anticipated. However, as expected, interviewees who were more present biased were less supportive of marine reserves, controlling for a host of demographic and economic factors. An explanation for the high proportion of present-biased interviewees cannot be determined from our data, but could be due to income variability or socio-cultural factors.

Divers are overall more supportive of management measures than fishers, and, divers' responses support our hypothesis that individuals who are more patient with money are more likely to support marine reserves. Also as expected, fishers who use high-impact gears are less supportive of marine reserves. Interestingly, divers on Bonaire, where there is a long history of marine protection, were the most supportive of conservation measures.

3.10. Policy Implications

Fishers' relatively lower levels of financial patience and support of management measures that would contribute to long-term resource

Table 6
Marginal effect of present bias on the third principal component by profession and island, with standard errors in parentheses.

	Bonaire divers	Bonaire fishers	Curaçao divers	Curaçao fishers
PCA-P1: Unconditional difference-in-means	-0.12^{***}	-0.12^{***}	-0.12^{***}	-0.12^{***}
$\phi_1 = \phi_2 = \theta_2 = \theta_3 = \theta_4 = \lambda = 0$	(0.01)	(0.01)	(0.01)	(0.01)
PCA-P2: Uniform effect	-0.10^{**}	-0.10^{**}	-0.10^{**}	-0.10^{**}
$\theta_2 = \theta_3 = \theta_4 = 0$	(0.04)	(0.04)	(0.04)	(0.04)
PCA-P3: Effect varies by profession	-0.11^{**}	-0.10	-0.11^{**}	-0.10
$\theta_3 = \theta_4 = 0$	(0.05)	(0.59)	(0.05)	(0.59)
PCA-P4: Effect varies by island	-0.12^{**}	-0.12^{**}	-0.10^{**}	-0.10^{**}
$\theta_2 = \theta_4 = 0$	(0.05)	(0.05)	(0.05)	(0.05)
PCA-P5: Effect varies by profession and island	-0.13^{**}	-0.12	-0.10	-0.09
$\theta_4 = 0$	(0.05)	(0.09)	(0.07)	(0.06)
PCA-P6: Effect varies independently for each group	-0.18^{***}	0.05	-0.06	-0.13^{**}
	(0.05)	(0.10)	(0.08)	(0.065)

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

conservation have implications for the effectiveness of various policy approaches. Perhaps management of fishing and diving should be approached differently, with consideration of these inter-group differences in time preferences.

Our research suggests two options for applying our behavioral economic results for increasing fishery sustainability. First, policy could attempt to shift fishers' incentives towards conservation — perhaps with transfer payments to offset the near-term expenses of switching to low-impact gears, reducing fishing effort, or adding marine reserves. Since dive industry employees are more patient financially, have greater access to credit, exhibit higher valuations of conservation, and would benefit from constraints on fishing, then perhaps they, or the dive industry more broadly, could offset the costs of altering fishing behaviors. Such an offset may be particularly needed because fishers who use high-impact gears are less supportive of conservation measures ($p = 0.037$).

The notion of offsets is timely in the context of the dive fee that exists on Bonaire and is being considered on Curaçao. Every individual who dives or snorkels on Bonaire is required to buy an annual marine park tag for 25 USD, the funds from which are used for marine park management. The idea for Curaçao is similar; an annual fee would be used to fund enforcement of marine regulations. Utilizing a portion of these funds to pay fishers to reduce or cease the use of high-impact gears could be a cost-effective conservation approach. For example, this might be a mechanism for a buyout of the fish traps and nets that inflict damage on shallow reef ecosystems, primarily catch herbivorous fish (i.e. parrotfish and surgeonfish) critical for controlling algal growth, and are deeply disliked by divers. Buyouts or other offsets, however, would require substantial community buy-in and enforcement capacity.

Regarding community buy-in, there is an effect we call conservation inertia. In addition to Bonaire having a dive fee, it also has no fishing and no diving areas, whereas Curaçao has none of these. These differences seem to be associated with a dramatic inter-island difference in level of support for marine reserves. No fishing areas receive 52% support on Curaçao versus 84% on Bonaire, and no diving areas receive 32% support on Curaçao versus 94% on Bonaire (both $p < 0.001$). Perhaps out of familiarity, people on Bonaire are more supportive of reserves, whereas people on Curaçao may resist reserve establishment because the consequences are unknown. Thus, gaining community support (especially from fishers) to put initial conservation measures in place may be a challenge, but conservationist views may grow after measures are put in place and benefits are seen.

Second, establishing property rights may not alone be sufficient for conservation. Ownership is presumed to lead to improved resource stewardship, and in recent years fisheries economists have examined the potential for property rights-based management approaches such as cooperatives, individual transferable quotas (ITQs), and territorial use rights in fisheries (TURFs). However, present bias can lead to over-consumption of resources in the present despite the incentive for sustainable use that is associated with ownership. For example, work by Hepburn et al. (2010) demonstrates how mechanisms that align incentives with resource-extraction externalities could still (though unlikely) leave the resource stock susceptible to inadvertent collapse in the presence of hyperbolic discounting. Therefore, even a property rights-based management scheme that addresses the common-pool resource problem may need to be paired with additional measures in order to prevent overfishing, if the fishers themselves are present-biased. Interestingly, fishers who more greatly discount the future have been shown to be more likely to violate fisheries regulations, especially if those regulations aren't perceived to be legitimate and the risk and severity of punishment are low (Akapalu, 2008).

This is not to say that management regimes involving property rights cannot be effective. In fact there is much evidence that the sustainability of fisheries can be improved by both individual transferable quotas (Costello et al., 2008) and territorial use rights fisheries (White and Costello, 2011), given certain ecological conditions and institutional structures. However, property rights should be implemented within an overall framework for sustainably managing resource use. When resource users are highly present-biased and financially constrained, the odds are stacked against sustainable use. Thus, to lower the chances of overexploitation, property rights could be paired with some mix of restrictions on effort and gears, near-term incentives for sustainable use, strong enforcement, and robust community buy-in. We suggest that future research into the most effective combinations of management tools would be an important contribution to the field.

Ineffective management of coral reef fisheries can result in overfishing, overcapitalization, and low profits (Munro and Scott, 1985); can facilitate a shift to an algal-dominated ecological state (Hughes, 1994; Knowlton, 2004); and can jeopardize food security (Pauly, 2006; Sadovy, 2006). It is therefore critical for coral reef management efforts and for fisheries research to consider how to address the myriad factors that influence individuals' resource use patterns, and apply economic research when endeavoring to better align financial incentives with sustainability. There is an important role for behavioral economics to play in developing strategies to sustainably manage ocean resources.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ecolecon.2014.01.004.

Acknowledgments

The largest part of our gratitude goes to the fishers and divers who participated in this project. AEJ is also deeply appreciative of the efforts of her primary translators: Kurt Brown, Jerry Vollebregt, Mark Brown, and Dustin Abraham. Faisal Dilrosun of Dienst Landbouw, Veeteelt & Visserij (LVV) and Ramon de Leon of Stichting Nationale Parken (STINAPA) offered key support. Charles Sprenger contributed to experimental design. Theodore Groves, James Andreoni, Richard Carson, Robert Deacon, and Rebecca Toseland offered valuable comments on previous drafts. AEJ's funding was provided by Scripps Institution of Oceanography, an AAUW Fellowship, a Switzer Environmental Fellowship, and NSF IGERT grant #0333444.

References

Akapalu, W., 2008. Fishing regulations, individual discount rate, and fisherman behaviour in a developing country fishery. Environ. Dev. Econ. 13, 591–606.
Andreoni, J., Sprenger, C., 2012. Risk preferences are not time preferences. Am. Econ. Rev. 102, 3357–3376.
Bernard, H.R., 1994. Research Methods in Anthropology: Qualitative and Quantitative Approaches. Sage Publications, Thousand Oaks, CA 585.
Bockstael, N.E., Opaluch, J.J., 1983. Discrete modelling of supply response under uncertainty: the case of the fishery. J. Environ. Econ. Manag. 10, 125–137.
Bowles, S., 1998. Endogenous preferences: the cultural consequences of markets and other economic institutions. J. Econ. Lit. 36, 75–111.
Cardenas, J.C., Carpenter, J., 2008. Behavioural development economics: lessons from field labs in the developing world. J. Dev. Econ. 44, 311–338.
Carson, R.T., Roth Tran, B., 2009. Discounting behavior and environmental economics. J. Neurosci. Psychol. Econ. 2, 112–130.
Coller, M., Williams, M.B., 1999. Eliciting individual discount rates. Exp. Econ. 2, 107–127.
Costello, C., Gaines, S.D., Lynham, J., 2008. Can catch shares prevent fisheries collapse? Science 321, 1678–1681.
Curtis, J., 2002. Estimates of fishermen's personal discount rate. Appl. Econ. Lett. 9, 775–778.
Eggert, H., Lokina, R.B., 2007. Small-scale fishermen and risk preferences. Mar. Resour. Econ. 22, 49–67.
Eggert, H., Martinsson, P., 2004. Are commercial fishers risk-lovers? Land Econ. 80, 550–560.
Eggert, H., Tveteras, R., 2004. Stochastic production and heterogeneous risk preferences: commercial fishers' gear choices. Am. J. Agric. Econ. 86, 199–212.
Frederick, S., Loewenstein, G., O'Donoghue, T., 2002. Time discounting and time preference: a critical review. J. Econ. Lit. XL, 351–401.
Grafton, R.Q., Kompas, T., Lindenmayer, D., 2005. Marine reserves with ecological uncertainty. Bull. Math. Biol. 67, 957–971.
Hardisty, D.J., Weber, E.U., 2009. Discounting future green: money versus the environment. J. Exp. Psychol. Gen. 138, 329–340.
Hepburn, C., Duncan, S., Papachristodoulou, A., 2010. Behavioral economics, hyperbolic discounting and environmental policy. Environ. Resour. Econ. 46, 189–206.
Hughes, T.P., 1994. Catastrophes, phase-shifts, and large-scale degradation of a Caribbean coral reef. Science 265, 1547–1551.
Knowlton, N., 2004. Multiple "stable" states and the conservation of marine ecosystems. Prog. Oceanogr. 60, 387–396.
Levitt, S.D., List, J.A., 2007. What do laboratory experiments measuring social preferences reveal about the real world? J. Econ. Perspect. 21, 153–174.
Mistiaen, J.A., Strand, I.E., 2000. Location choice of commercial fishermen with heterogeneous risk preferences. Am. J. Agric. Econ. 82, 1184–1190.
Munro, G.R., Scott, A.D., 1985. The economics of fisheries management. In: Kneese, A.V., Sweeney, J.L. (Eds.), Handbook of Natural Resource and Energy Economics. Elsevier Science Publishers.
Opaluch, J.J., Bockstael, N.E., 1984. Behavioral modeling and fisheries management. Mar. Resour. Econ. 1, 105–115.
Partnership for Interdisciplinary Studies of Coastal Oceans, 2007. The Science of Marine Reserves. (www.piscoweb.org. 22 pp.).
Pauly, D., 2006. Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. Marit. Stud. 4, 7–22.
Sadovy, Y., 2006. Trouble on the reef: the imperative for managing vulnerable and valuable fisheries. Fish Fish. 6, 167–185.
Sanchirico, J.N., Malvadkar, U., Hastings, A., Wilen, J.E., 2006. When are no-take zones an economically optimal fishery management strategy? Ecol. Appl. 1643–1659.
Smith, M.D., Wilen, J.E., 2005. Heterogeneous and correlated risk preferences in commercial fishermen: The Perfect Storm dilemma. J. Risk Uncertain. 31, 53–71.
Startz, R., Tsang, K.P., 2012. Nonexponential discounting: a direct test and perhaps a new puzzle. The B.E. J. Macroecon. 12, 31.
Sumaila, U.R., 2004. Intergenerational cost–benefit analysis and marine ecosystem restoration. Fish Fish. 5, 329–343.
White, C., Costello, C., 2011. Matching spatial property rights fishers with scales of fish dispersal. Ecol. Appl. 21, 350–362.
Wang, M., Rieger, M.O., Hens, T., 2009. An international survey on time discounting. Working Paper (http://www.socialpolitik.ovgu.de/sozialpolitik_media/paper_update/SSRN_id1481443.pdf).