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U.S. CARIBBEAN FISH TRAP FISHERY SOCIOECONOMIC STUDY

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ABSTRACT

Concerns over the potential impacts of trap fishing on coral reefs and associated habitats prompted a socioeconomic study to characterize the U.S. Caribbean fish trap fishery in anticipation of management actions. Stratified random interviews of one hundred fishermen revealed the presence of a diverse fishery, with appreciable inter-island differences in levels of fishing dependence, fishing practices, and capital investment. High levels of fishing dependence were observed among fishermen in the U.S. Virgin Islands, whereas Puerto Rican fishermen exhibited a more diversified livelihood strategy. Fishermen from St. Croix derived 62% of their household income from fish traps, significantly more than fishermen from St. Thomas/St. John and Puerto Rico, who derived 45% and 41%, respectively, of their household incomes from fish traps. The St. Thomas/St. John fleet was also larger and more capital-intensive than the Crucian and Puerto Rican fleets. This structural heterogeneity suggests that fishermen from the various islands may respond differently to the same regulatory constraint. Thus, targeted policies may be necessary to improve the socioeconomic performance of the fishery and the political acceptability of management actions.

The fish trap fishery is the quintessential U.S. Caribbean fishery. This long-established fishery has provided sustenance, income, and employment to many small-scale fishing communities in the Commonwealth of Puerto Rico and the Territory of the U.S. Virgin Islands (Fig. 1). The popularity of fish traps (or "pots" as they are known in the islands) lies in their ability to fish year-round with minimal supervision, which permits the simultaneous pursuit of other economic activities, as well as fishing with other gears. Moreover, traps can easily be set and hauled from small craft (Fiedler and Jarvis, 1932; Jarvis, 1932; Sylvester and Dammann, 1972).

During the past decade, the issue of gear-habitat interactions began attracting more scrutiny in fishery management circles. In the U.S. Caribbean, conservation groups, fishery managers, fishermen, and the general public became concerned over the potential damage caused by the haphazard setting and hauling of traps and the ensuing impacts on coral reef habitats and resource productivity and ecosystem resilience (Sheridan et al., 2003). The limited selectivity of fish traps was another source of concern. Pots are commonly used in coral reefs and related habitats, where they catch a variety of species including spiny lobsters, snappers, groupers, grunts, parrotfish, and surgeonfish. Many reef-fish species, especially groupers, are particularly vulnerable to overfishing due to their life history characteristics, which include slow growth, delayed reproduction, sedentary behavior, and highly aggregated spawning events. For example, Nassau and goliath groupers remain overexploited despite bans on commercial harvest activities since the early 1990s (Sadovy and Eklund, 1999).

Despite the controversies associated with trap fishing, few regulations are in place. These measures primarily rely on minimum mesh size and biodegradable panel and door fasteners. Additionally, the setting of traps, bottom longlines, and

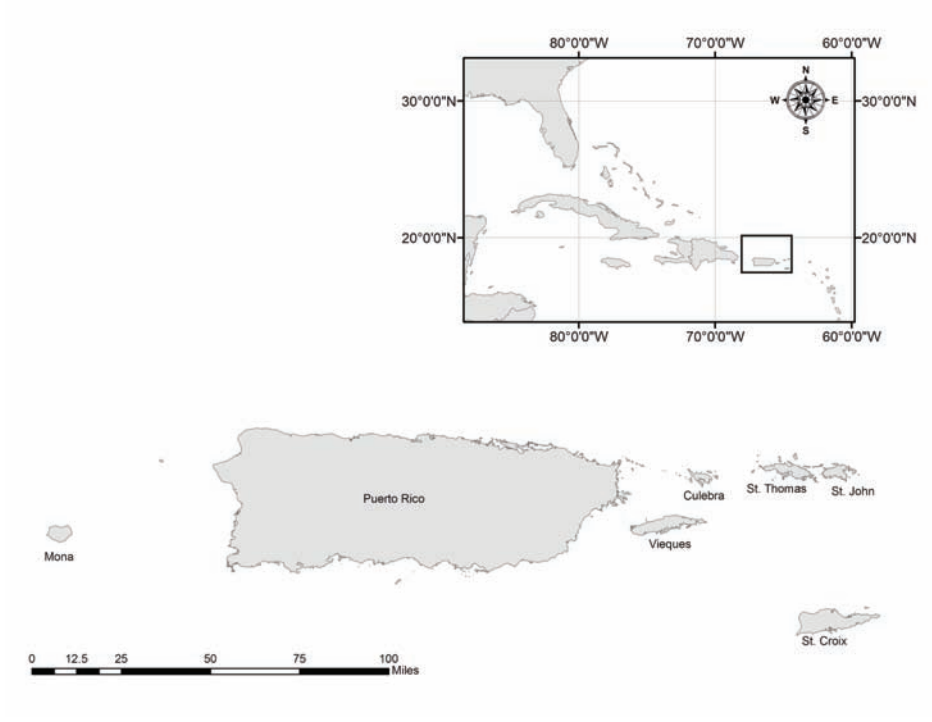

Figure 1. Map of Puerto Rico and the U.S. Virgin Islands.

gill and trammel nets on coral or hard bottom is prohibited year-round in seasonally-closed areas. There are no limits on the number of pots held by fishermen in federal, commonwealth, and territorial waters. Because existing management measures may be inadequate to protect sensitive habitats and rebuild overexploited stocks, federal and local fishery management agencies are interested in developing capacity, effort, and by-catch reduction proposals (Trumble et al., 2006). The paucity of socioeconomic data has been a major hurdle in the development and evaluation of regulatory proposals.

Most of the recent socioeconomic information is limited to the Puerto Rico and U.S. Virgin Islands fishermen censuses which primarily collect demographic and capital investment information (Kojis, 2004; Matos-Caraballo et al., 2005). None of these studies collected costs and earnings information. The few economic data collections were limited in geographic scope and are now outdated (Kahn, 1948; Abgrall, 1974; Olsen et al., 1982). In the wake of these information deficiencies, a socioeconomic study of the fish trap fishery in Puerto Rico and the U.S. Virgin Islands was undertaken.

Methods

Due to the absence of federal fishing licenses, we relied on the 2002 Puerto Rican fishermen census and U.S. Virgin Islands license registration databases to establish a sampling frame which identified the fishermen and the number of traps owned by each fisherman. These databases identified 324 fish trap fishermen in Puerto Rico and 97 fish trap fishermen in the U.S. Virgin Islands (Table 1).

Table 1. Sample size and interview response rates by trap tier and region of U.S. Caribbean fish trap fishermen.

Area	Trap tier (number of traps owned)	Fish trap fishermen population	Target number of interviews	Number of completed interviews	Number of non-responses	Number of contacts
Puerto Rico	1–40	258	30	30	27	57
	41–100	53	20	22	9	31
	≥ 101	13	10	8	5	13
Sub-total		324	60	60	41	101
St. Thomas/St. John	1–50	19	8	5	14	19
	51–150	20	7	10	7	17
	≥ 151	13	5	5	4	9
St. Croix	1–19	31	13	13	17	30
	≥ 20	14	7	7	5	12
Sub-total		97	40	40	47	87
Total		421	100	100	88	188

The study was designed to conduct in-person interviews with 100 fish trap fishermen, which is about 23% of the estimated total population of fish trap fishermen in the U.S. Caribbean. The questionnaire collected information about household demographics, annual catch and revenue, fishing practices, capital investment on vessels and equipment, fixed and variable costs, and the spatial distribution of traps. The survey also asked how fishermen would change their fishing practices in response to a hypothetical trap reduction program. To compare and contrast the fishery across islands, we stratified the interviews as follows: 60 in Puerto Rico, 20 in St. Thomas/St. John, and 20 in St. Croix. For each island, fishermen were divided into two or three strata (or tiers) to reflect the scale of operation, defined by the number of traps owned. The scale of operation tiers were determined in consultation with local fisheries experts from Puerto Rico's Department of Environmental and Natural Resources and U.S. Virgin Islands' Division of Fish and Wildlife.

The definition of fish trap tiers varied by island (Table 1). In Puerto Rico, tier I had fishermen who owned 1–40 fish traps, tier II had fishermen who held 41–100 fish traps, and tier III had fishermen who possessed in excess of 100 fish traps. In St. Thomas/St. John, tier I was composed of fishermen with 1–50 fish traps, tier II had fishermen with 51–150 fish traps, and tier III had fishermen who held in excess of 150 fish traps. In St. Croix, tier I was made up of fishermen who held < 20 fish traps, and tier II had fishermen who had 20 or more fish traps. The rationale for the stratification was to capture the heterogeneity of the fishery (i.e., small, medium, and large-scale operators) and to minimize the possibility of inadvertently marginalizing or excluding segments of the fishery. Thus, the stratification disproportionately sampled large-scale operators while broadly mirroring the universe of fish trap fishermen. In addition, the stratification made the survey more cost effective and convenient to administer.

After pre-testing the survey instrument, we conducted voluntary, in-person interviews from a randomized list of fish trap fishermen that contained their name, address, and telephone number.

To meet the requirements of the sampling protocol, interviewers were instructed to draw a replacement fisherman only if the randomly selected fisherman: (a) refused to participate in the survey; (b) was not available due to illness, death, or travel; or (c) could not be contacted after eight separate attempts. In some instances, the number of potential respondents in a stratum was exhausted due to the small number of operators, and interviewers conducted additional surveys in other strata. In Puerto Rico, interviewers conducted two additional interviews in the second tier stratum to compensate for a deficit in the third tier stratum, whereas in St. Thomas/St. John, interviewers conducted three additional interviews in the second tier stratum to offset a shortfall in the first tier stratum (Table 1).

Despite considerable effort and resources devoted to this survey, the unadjusted response rate was only 53.2%. The unadjusted response rate was obtained by dividing the total number of completed interviews by the total number of people contacted (Table 1). Reasons for nonresponse included the inability to locate 52 fishermen, 18 refusals to participate in the survey, 12 fishermen who no longer qualified for inclusion in the survey because they no longer fished with traps, and 6 fishermen who did not complete the survey for miscellaneous reasons. Disregarding those fishermen who either were unreachable or no longer qualified, the effective response rate increased to 80.6%. The survey took place from April to September, 2003.

Due to the high level of stratification of the study, we decided against making extensive statistical inter and intra-island comparisons. Instead we present aggregate summary statistics for selected demographics, capital investment on vessel and equipment, fishing practices, and revenue and cost structure of the fleet inbedded in a historical and ethnographic context. Unless otherwise noted, the tabulated numbers are sample means and the number in parentheses are the standard error of the mean. Readers interested in the frequency distributions, stratum-specific summary statistics, and accounts of other topics not covered in this article are referred to Agar et al. (2005).

Results and Discussion

Demographic Profile.—The survey revealed that the majority of the U.S. Caribbean fish trap fishermen were middle-aged men with considerable fishing experience, moderate levels of formal education, and small household sizes. On an island basis, fishermen from St. Croix tended to be older. The average age of Crucian fishermen was 57 yrs-old whereas Puerto Rican and St. Thomian/St. Johnian fishermen's average ages were 51 and 48 yrs-old, respectively (Table 2). The distribution of ages of fishermen who specialize in fish trap fishing was skewed towards middle-aged fishermen. Only 4% of the respondents were 30 yrs-old or younger (Agar et al., 2005).

Recent studies have documented that novice fishermen favor lucrative and physically-demanding gears such as SCUBA and nets (Matos-Caraballo et al., 2005 and unpubl. data; Tobias, 2004a). In Puerto Rico, about 90% of the new entrants are young divers who target high-value species such as lobsters, conch, and reef-fish species (Matos-Caraballo et al., unpubl. data). Fishermen's changing gear preferences are also evident in the landings statistics, which show a dramatic decrease in fish trap landings in the last two decades. In 1982, Puerto Rican fish trap catches accounted for 71.2% of the reported landings whereas in 2004–2006 their share declined to 18.6% of the reported landings, and nowadays, SCUBA accounts for 24.8% of the Puerto Rican landings (Matos-Caraballo et al., unpubl. data). Similarly, in the U.S. Virgin Islands, fishermen have gravitated towards gill and trammel nets in conjunction with SCUBA (Tobias, 2004a,b). Between 1991 and 2003, the share of reef-fish landings taken by traps decreased from 89% to 43%, whereas the proportion of reef-fish landings taken by nets increased from 11% to 57% (Tobias, 2004a). SCUBA is used to herd reef-fish species such as parrotfish and surgeonfish into the nets.

Most respondents were seasoned commercial fishermen. As a group, Puerto Rican and Crucian fishermen had 30 and 29 yrs of fishing experience, respectively. Fishermen from St. Thomas/St. John were less seasoned, averaging 25 yrs of fishing experience (Table 2). U.S. Caribbean fishermen did not operate fish traps for their entire commercial fishing history suggesting that they transitioned between gears over their lifetime. Fishermen from Puerto Rico, St. Croix, and St. Thomas/St. John stated having operated fish traps for 24, 23, and 21 yrs, respectively. Although the reasons for gear switching over time are not well understood, several studies have offered insight. In addition to declining catches and economic returns, trap losses due to adverse weather events (i.e., tropical storms and hurricanes) and theft, trap poaching, and large start-up investment and maintenance costs, modernization policies, technological advancements, and the evolving structure of social networks have influenced fishermen's gear choices (Valdés-Pizzini et al., 1992; Griffith and Valdés-Pizzini, 2002; Perez, 2005).

In Puerto Rico, modernization policies of the 1950s transformed the fishing sector by motorizing the fleet via the provision of low-interest governmental loans for the purchase and/or upgrade of vessels, engines, and fishing gears (Valdés-Pizzini, 1985; Perez, 2005). Between 1951 and 1964, the percentage of fishing vessels with engines grew from 3% to 65%, which permitted fishermen to fish in the outer reefs and insular shelf and increase the scale of their operations (Iñigo, 1968). These policies also led to a marked increase in the types and number of fishing gears employed. For example, the number of gill and trammel nets increased from 200 to 450 and turtle nets grew from 350 to 1000; the latter event leading to a sharp decrease in

Table 2. Demographic characteristics of U.S. Caribbean fish trap fishermen by region (values are means, with standard error in parentheses).

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Age of fish trap fisherman (yrs)	50.8	60	48.1	20	57.4	20
	(2.3)		(2.1)		(2.5)	
Formal education attainment (yrs)	9.7	58	10.2	18	8.9	18
	(0.5)		(0.6)		(0.6)	
Number of dependents (including self)	3.3	60	2.8	20	3.4	20
	(0.2)		(0.3)		(0.3)	
Commercial fishing experience (yrs)	30.1	60	24.9	20	28.9	20
	(2.3)		(2.0)		(2.5)	
Fish trap fishing experience (yrs)	23.5	60	23.3	20	21.4	20
	(2.1)		(2.0)		(2.7)	
Percentage of household income derived from commercial fishing	68.7	57	74.0	20	83.4	20
	(4.6)		(6.9)		(4.53)	
Percentage of commercial fishing income derived from fish trap fishing	59.4	56	61.0	19	74.9	18
	(4.5)		(6.5)		(5.8)	
Percentage of catch retained for personal or family use	2.9	51	3.8	19	2.5	19
	(0.6)		(1.2)		(0.4)	

the number of turtles in coastal waters and the eventual closure of the turtle fishery (Valdés-Pizzini et al., 1992). During the 1970s, innovations in outboard engine technologies, the replacement of wooden sloops by fiberglass boats, the adoption of iron rods and inexpensive chicken wire in the construction of traps, and the expanded use of winches further enhanced the scale and efficiency of the trap fleet. Collazo and Calderon (1988) reported that between 1975 and 1982 the number of traps increased from 8191 to 26,170. As inshore stocks dwindled, declining catches and increasing costs encouraged trap fishermen to switch to vertical lines to take advantage of the rich deepwater snapper and grouper stocks available at the shelf drop-offs and nearby islands (Valdés-Pizzini, 1985; Matos-Caraballo and Torres Rosado, 1989; Matos-Caraballo, 2000).

In the 1980s and 1990s, the growing demand for queen conch—considered a delicacy by local restaurants—led to a marked increase in the number of young SCUBA divers. These SCUBA divers also targeted other species traditionally caught in fish traps such as spiny lobster, snappers, and groupers. Declining trap catches, increased competition with divers and nets, alleged poaching and theft of traps by divers, and trap losses due entanglements by an expanding recreational boating sector contributed to the decline of fish traps in Puerto Rico (Matos-Caraballo, 2000; Griffith and Valdés-Pizzini, 2002).

In contrast to the Puerto Rican experience, the government of the U.S. Virgin Islands did not play an active role in the modernization of their local fisheries. The development of U.S. Virgin Islands fisheries was slow because of the prevailing belief that fishery resources have been over-exploited for several decades, the limited investment potential of local fishermen, and the minimal governmental assistance provided buying and/or upgrading vessels and equipment (Brownell, 1972; Brownell and Rainey, 1971; Olsen and LaPlace, 1981). Nevertheless, there were a small number of research efforts geared at diversifying landings by introducing new harvesting techniques (e.g., lines) and developing new fisheries (e.g., deep-water snapper and grouper and crab fisheries) (Olsen and Laplace, 1981). However, these attempts were unsuccessful because fishermen believed that larger fishing vessels and expensive gear were required to participate in these fisheries (Brownell and Rainey, 1972). Hill (1969) also noted that local fishermen were reluctant to adopt new technologies.

In the late 1980s and 1990s, U.S. Virgin Islands', particularly Crucian, fishermen, started moving away from traps because they were unable to obtain federal grants to replace large numbers of lost traps after hurricane events, most notably Hugo in 1989, Luis and Marilyn in 1995, Bertha and Hortense in 1996, Georges in 1998, and Lenny in 1999 (Tobias, 2004b). Unwilling to risk additional losses, many fishermen opted for gill and trammel nets instead, which afforded them higher catches and economic returns. Unlike fish traps, gill and trammel nets did not require extensive soak times (they are brought in after each trip), which spared fishermen from leaving the gear in the water to be subjected to storm events (Tobias, 2004b).

Another reason for trap fishermen's transition to other gears is the evolving structure of kinship relationships. Traditionally, kinship relations among father and sons, siblings, in-laws, and relatives were the main source of labor in the fishery. These extensive networks supported the efforts that households devoted to trap fishing by proving labor for trap building, maintenance, and storage, and boat repair and even hauling traps in extreme weather conditions. Nowadays, increased participation in wage labor in tandem with increased migration to the U.S. mainland, to seek low-

wage, unskilled, or semi-skilled employment, has weakened these kinship bonds. Hence, it has become harder for kinfolk to help with fishing activities or with the construction, maintenance, and storing of traps. Thus, novice fishermen favor individualist, socially less demanding harvesting practices such as SCUBA. Last, older fishermen tend to switch towards traps because traps are physically less demanding than other gears.

Most fish trap fishermen interviewed had moderate formal education levels and small household sizes. The average trap fisherman had only 9–10 yrs of formal education (Table 2), and 53% of the respondents did not complete high school (Agar et al., 2005). These findings are consistent with Kojis (2004) who showed that fishermen from St. Thomas/St. John had marginally higher formal education levels than those from St. Croix: 52% of the St. Thomian/St. Johnian fishermen had at least completed high school compared to 36% of the Crucian fishermen (Kojis, 2004). No comparable data on education are available for Puerto Rico. Of these households, 90% had at least one dependent. The average number of dependents across islands was fairly constant, ranging from 2.8 in St. Thomas/St. John to 3.4 in St. Croix (Table 2). Griffith et al. (2007) reports that fishermen from Puerto Rico have an average household size of 3.2 members.

Fishing Dependence.—U.S. Virgin Islands' fish trap fishermen were the most dependent on fishing, particularly Crucian fishermen. In St. Croix, the share of commercial fishing income to household income was 83% whereas in St. Thomas/St. John it was 74% (Table 2). The higher level of dependence for St. Croix fishermen was unexpected given their lower levels of capital investment relative to fishermen in St. Thomas/St. John (Table 3), perhaps reflecting the lower employment opportunities available to Crucian fishermen. St. Croix has consistently had higher unemployment rates than St. Thomas/St. John (U.S. Virgin Islands' Bureau of Labor Statistics, 2008). For example, in 2003, the unemployment rate was 12.5% in St. Croix and 7.2% in St. Thomas/St. John (U.S. Virgin Islands' Bureau of Labor Statistics, 2008). Crucian trap fishermen, particularly those with low educational attainment, may find it harder to participate in the local workforce since the two leading industries, manufacturing and construction, require specialized skills. St. Croix has a small leisure and hospitality industry relative to St. Thomas and St. John, which limits supply for low-skill jobs.

For the average Puerto Rican trap fisherman, we estimated that fishing income comprised 69% of their household income, representing a moderately high level of dependence on fishing. Overall, fishing income contributes 40%–45% to the average Puerto Rican commercial fisherman's household income (Griffith et al., 2007). Our higher estimate of dependence suggests that Puerto Rican trap fishermen have a comparatively higher degree of fidelity to the fishing profession relative to the average Puerto Rican commercial fishermen. The unemployment rate in Puerto Rico was 12.1% in 2003 (U.S. Census Bureau, 2008). Puerto Rican fishermen regularly engage in numerous temporary, low-skill employment opportunities (i.e., odd jobs or *chiripas* as they are known locally) to supplement their household incomes (Griffith and Valdés-Pizzini, 2002; Perez, 2005; Griffith et al., 2007). U.S. and Puerto Rican government transfer payments (i.e., Nutritional Assistance Program and Social Security) are important supplemental sources of household income, particularly to older commercial fishermen (Perez, 2005).

Table 3. Fish trap vessel characteristics by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Vessel length (ft)	20.8	60	27.9	20	21.2	20
	(0.5)		(1.2)		(0.9)	
Vessel age (yrs)	16.4	60	18.1	20	15.6	20
	(1.4)		(1.6)		(1.8)	
Engine power (hp)	76.7	57	208.4	19	108.2	20
	(9.8)		(14.0)		(18.1)	
Fully rigged vessel value ($)	8,652.4	58	58,518.0	19	19,831.0	19
	(1,034.0)		(8,762.0)		(4,332.4)	

Income derived from trap fishing accounted for a substantial share of fishermen's commercial fishing income. On an island basis, the contribution of fish traps to commercial fishing income was 75% in St. Croix, 61% in St. Thomas/St. John, and 59% in Puerto Rico (Table 2). These findings imply that St. Croix fish trap fishermen derived 62% of their household income from trap fishing. In St. Thomas/St. John and Puerto Rico, the contribution of fish traps to household income was moderately lower, averaging 45% and 41%, respectively. Fishermen also benefited from retaining the catch for household consumption: the percentage of the catch retained for personal or family use ranged from 2.5% in St. Thomas/St. John to 3.8% in St. Croix (Table 2).

Vessel and Equipment Characteristics.—The majority of the fishing vessels were small in size (14–40 ft) with moderate levels of mechanization. Remarkably, vessel sizes do not differ from those reported in the 1930s; however, vessel construction materials, propulsion methods, and fishing equipment have undergone significant changes (Kojis, 2004). Our survey shows that most vessels in the region were built with fiberglass and were outfitted with outboard engines rather than constructed with wood and propelled with sails and oars as in the 1930s.

The St. Thomas/St. John based fleet had the largest and more mechanized vessels in the region with sizable investments in trap gear and fishing equipment (Table 3). The representative St. Thomian/St. Johnian fish trap vessel was 28 ft long and had 208 hp engines whereas the typical Crucian vessel was 21 ft long and had 108 hp engines and the average Puerto Rican vessel was 21 ft long and had 77 hp engines (Table 3). Larger vessel sizes (and higher propulsion rates) are generally associated with larger trap endowments (Agar et al., 2005). Although Kojis (2004) reported average vessel length in St. Thomas/St. John and St. Croix to be 21.4 and 20.7 ft, respectively, had Kojis removed the dinghies from her sample, her estimates would be considerably closer to ours. In St. Thomas/St. John, many fishermen use dinghies to access their fishing vessels on moorings rather than trailering them to launching sites as is commonly done in St. Croix. Fishermen from St. Thomas/St. John also had marginally older and more valuable vessels relative to other islands and these vessels were almost three times more expensive than Crucian vessels and seven times more expensive than Puerto Rican vessels (Table 3).

Mechanical trap haulers and depth recorders were the most common on-board equipment used (Table 4). One hundred percent of the St. Thomian/St. Johnian fishermen had mechanical haulers compared with 52% in Puerto Rico and 20% in St. Croix. Regionally, the use of mechanical trap haulers was more common with larger levels of trap ownership (Agar et al., 2005). Depth recorders were more common in the St. Thomas/St. John fleet (80%) and least common in the Puerto Rican fleet (37%).

Table 4. Percent distribution of hull types, fishing equipment, and crew size by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Fishing equipment distribution (%)						
Mechanical hauler	51.7	31	100.0	20	20.0	4
Depth recorder	36.7	22	80.0	16	45.0	9
GPS	31.7	19	65.0	13	25.0	5
Radar	0	0	0	0	5.0	1
EPIRB	0	0	35.0	7	5.0	1
Hull type distribution (%)						
Fiberglass	86.7	52	100.0	20	95.0	19
Wood	11.7	7	0	0	5.0	1
Crew size distribution (%)						
0 crew	15.0	9	10.0	2	10.0	2
1 crew	70.0	42	75.0	15	75.0	15
2 crew	15.0	9	15.0	3	15.0	3

The limited presence of emergency position indication radio beacons (EPIRBS) was the norm for the fish trap fleet. Thirty-five percent of the St. Thomas/St. John fleet had an EPIRB whereas 5% of the St. Croix fleet had an EPIRB. None of the Puerto Rican fishermen interviewed had an EPIRB.

The existence of large differences in fishing capital between St. Thomas/St. John and St. Croix can be partially explained by the physical characteristics of the insular shelf, which favored the use of traps in the former island. The St. Thomian shelf is wider and deeper relative to the Crucian shelf. The St. Thomian and St. Johnian shelf is about 8 mi wide to the south of the islands and 20 mi wide to the north whereas most of the Crucian shelf, with the exception of Lang Bank, lies within the 3 nmi territorial jurisdiction (Kojis, 2004). Recent closures, particularly in St. Croix, have further reduced the amount of fishable area available to traps (Tobias, 2004b). In addition, the presence of dominant, long-established fishing communities such as the one of French descent in St. Thomas/St. John which date back to the 1800s, may have facilitated the accumulation and transfer of knowledge and fishing capital across generations. In contrast, most fishers in St. Croix are newcomers from different cultural and ethnic backgrounds: St. Lucia, St. Kitts, Trinidad and Tobago, and Puerto Rico. Puerto Ricans were the first to arrive in large numbers in the 1930s to work as sugarcane workers after the U.S. Navy took over the island of Vieques.

Fishing Practices.—Trap fishermen are experienced fishermen who rely on their extensive local environmental knowledge and skill to pursue fish across time and space (Schärer et al., 2004). A typical trip has the captain and his helper (or *proel* as they are known in Puerto Rico) leaving at dawn, steaming towards the fishing grounds. Depending on the productivity of the fishing grounds, traps may be emptied, baited, and set in the same location or moved to an alternative one (Schärer et al., 2004). Traps are set in a variety of habitats, which extend from a few fathoms deep in nearshore waters to > 100 fathoms along the edge of the insular shelf depending on the species sought. Fishermen usually return by afternoon or early evening.

Historically, Puerto Rican fishermen used fish traps mainly during the off-season of the sugar industry, which extended from June to February, whereas U.S. Virgin Island fishermen always fished their pots year-round (Jarvis, 1932). Nowadays, Puerto

Table 5. Fishing trip characteristics by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Number of weekly trips	2.1	46	1.4	20	2.5	19
	(0.2)		(0.1)		(0.2)	
Trip duration (hrs)	5.6	46	9.1	20	5.6	19
	(0.3)		(0.8)		(0.5)	
Number of fish traps fished last season	38.6	60	93.6	20	27.1	20
	(2.3)		(4.1)		(3.5)	
Number of traps hauled per trip	27.1	46	68.1	20	25.7	19
	(2.1)		(4.6)		(3.2)	
Soak time (d)	5.7	47	6.9	20	3.6	19
	(0.9)		(0.2)		(0.4)	
Number of traps per line	2.2	46	8.7	20	1.7	19
	(0.3)		(0.8)		(0.4)	
Average life of fish traps (yrs)	1.4	59	4.9	18	1.3	20
	(0.1)		(0.5)		(0.2)	

Rican and U.S. Virgin Islands fishermen fish year-round, making 2–3 trips per week. Fishermen from St. Thomas/St. John make fewer but longer trips than their Puerto Rican and Crucian counterparts (Table 5).

Fishermen from St. Thomas/St. John fished the largest number of fish traps in the region (Table 5). Because fishermen had different capital endowments, fishing practices varied across islands. For example, St. Thomian and St. Johnian fishermen fished for 9 hrs and hauled 68 fish traps per trip whereas Puerto Rican and Crucian fishermen fished for 6 hrs and hauled 27 and 26 fish traps per trip, respectively (Table 5). Longer trips were associated with higher number of traps hauled which explains the ubiquitous presence of mechanical trap haulers in St. Thomas/St. John (Table 4). St. Thomian/St. Johnian fishermen soaked their fish traps for 7 d while most Puerto Rican and Crucian fishermen soaked their fish traps for 6 and 4 d, respectively (Table 5). These findings are consistent with Sheridan et al. (2006), who observed that St. Thomas/St. John fishermen soaked their traps longer than St. Croix fishermen. We also found that fish traps were set with and without bait. Fishermen who baited their traps reported using a variety of baits including squid, cowhide, stale bread, dolphin-fish skin, papaya tree leaves, coconuts, and miscellaneous non-marketable fish caught in traps.

Most fishermen favored traps with the chevron or arrowhead design (Table 6). St. Thomian/St. Johnian fishermen owned the most with an average of 44 compared to the Crucian (15) and Puerto Rican (20) fisherman. The second most popular trap design was the square trap style, of which the St. Thomian/St. Johnian fishermen owned the most with an average of 33 compared to 9 and 2 for Puerto Rican and Crucian fishermen, respectively. Although Antillean Z (or S) traps are considered the most productive trap design, fishermen prefer the smaller-sized arrowhead and square traps because they are easier and less expensive to build and larger numbers of them can be safely deployed from small vessels. The cost of a fish trap, complete with rope and buoys, varied significantly due to the wide range of construction materials utilized (Table 6). Schärer et al. (2004) reported slightly higher prices ($100–$150) for fish traps in Puerto Rico.

Table 6. Design types and unit cost of fish traps by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Number of arrowhead traps owned	19.5	60	43.5	20	14.9	20
	(2.5)		(9.7)		(3.1)	
Number of square traps owned	8.6	60	33.2	20	2.2	20
	(2.1)		(9.4)		(0.8)	
Number of Antillean Z (or S) traps owned	2.7	60	0	20	4.4	20
	(0.9)		(0)		(2.3)	
Cost of arrowhead traps ($/unit)	94.3	31	251.1	9	118.8	11
	(11.3)		(15.6)		(13.9)	
Cost of square traps ($/unit)	86.7	15	252.1	8	93.4	4
	(11.1)		(17.1)		(29.8)	
Cost of Antillean Z (or S) traps ($/unit)	131.3	4	–	–	135.5	3
	(31.6)				(6.7)	

Revenue and Cost Structure.—Fishing operations from the U.S. Virgin Islands generated more revenue than operations in Puerto Rico (Table 7). Costs are usually divided into variable and fixed costs. Variable costs are those expenses incurred during the operation of the vessel and vary with the level of harvesting activity. Variable costs can be further categorized into running expenses (i.e., fuel, lubricants, bait, ice, food, and supplies) and labor expenses.

Annual running costs were higher in the U.S. Virgin Islands (Table 7), and fuel was the single most significant running cost expenditure (Table 8), accounting for 46%–55% of the running costs. Bait expenses were responsible for 23% of the running costs in the U.S. Virgin Islands and 14% in Puerto Rico (Table 8). These relative fuel and bait percentages are roughly consistent with earlier estimates of the Florida spiny lobster trap fishery (Milon et al., 1999).

Unlike other factors of production, labor typically receives a share of the trip's revenue after deducting operating expenses. Our study suggested that the annual crew compensation ranged from $3326 in Puerto Rico to $16,193 in St. Thomas/St. John.

Fishermen who get paid on a share system usually assist vessel owners in repairing the vessel and gear. This assistance is not remunerated since it is part of an understood system of obligations to the boat owner. They are part of a set of cultural values of mutual help. In a few instances, primarily in St. Thomas/St. John, we found that some large operators remunerate their crew on a traps-hauled basis rather than a share system. Under this alternative contractual agreement, crew members receive

Table 7. Annual gross revenue, running costs, crew payments, and fixed costs by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Annual gross revenue ($)	15,306.0	55	39,018.0	20	33,317.0	18
	(1,663.5)		(4,017.9)		(5,898.8)	
Annual running costs ($)	3,549.5	46	7,425.6	20	5,653.3	19
	(599.5)		(604.5)		(612.1)	
Annual crew payments ($)	3,326.4	42	16,193.0	20	14,961.0	18
	(544.7)		(3,242.5)		(4,910.8)	
Annual fixed costs ($)	2,347.5	60	9,813.2	20	4,201.9	20
	(528.5)		(1,586.0)		(815.5)	

Table 8. Description of trip-level variable costs by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Fuel expenditures ($/trip)	11.6	59	53.9	20	20.5	20
	(1.8)		(2.9)		(2.9)	
Oil expenditures ($/trip)	2.4	59	3.9	20	3.6	20
	(0.2)		(0.4)		(0.6)	
Ice expenditures ($/trip)	1.8	59	6.8	20	3.7	20
	(0.4)		(1.7)		(0.6)	
Bait expenditures ($/trip)	3.4	59	22.3	20	10.1	20
	(0.9)		(4.0)		(3.0)	
Supplies expenditures ($/trip)	0	59	0.9	20	0	20
	(0)		(0.6)		(0)	
Food/groceries expenditures ($/trip)	4.8	59	10.6	20	7.2	20
	(0.6)		(1.4)		(1.1)	
Other expenditures ($/trip)	0	59	0	20	0	20
	(0)		(0)		(0)	

between $1.00 and $1.50 per trap hauled. Crews paid under this alternative agreement do not assist vessel owners with maintenance chores.

Fixed costs are those expenses incurred regardless of whether the vessel operates or stays idle. In other words, they are independent of the level of fishing activity. Fixed costs include mooring fees, vessel, equipment, and gear maintenance and repair expenses, fishing permit and vessel registration fees, vessel and gear mortgage payments, and insurance payments. Annual fixed costs were highest in St. Thomas/St. John and lowest in Puerto Rico (Table 7). Maintenance expenses accounted for the largest share of the fixed costs. Over 50% of the total fixed costs in St. Thomas/St. John, and St. Croix were due to vessel, equipment, and gear maintenance (other than fish traps), whereas in Puerto Rico they accounted for 35% of such costs (Table 9). Fish trap maintenance costs were the highest in Puerto Rico, where they accounted for 52% of fixed costs. Fish trap maintenance was responsible for 28% of the fixed costs in St. Croix, and for 15% of the fixed costs in St. Thomas/St. John.

The low mooring expenses in Puerto Rico probably reflects the fact that the majority of the vessels are moored at makeshift piers, or at piers belonging to fish cooperatives (*villas pesqueras* as they are locally known) or coastal communities. Fishermen receive discounted mooring fees if they belong to a fish cooperative. A modest number of skiffs (*yolas*) are either tied to mangrove roots, or beached and tied to a permanent structure on the shoreline. In Puerto Rico, fish cooperatives also provide fish storage and marketing services. The miscellaneous category captures fish cooperative fees, which are mainly paid by Puerto Rican fishermen who belong to villas pesqueras. The low docking expenses in St. Croix reflect the fact that a majority of vessel owners trailer their vessels from their homes to the access ramps. In Puerto Rico, mostly line fishermen in the northwest and north coast trailer their vessels.

Conclusions

The development of sound policies to rebuild overexploited stocks, mitigate bycatch, and minimize the impact of fishing on sensitive habitats requires knowledge of the potential biological, ecological, and socio-economic consequences of the

Table 9. Description of annual fixed costs by region of U.S. Caribbean.

Variable	Puerto Rico	N	St. Thomas/St. John	N	St. Croix	N
Docking fees ($)	0	60	1,377.7	20	12.2	20
	(0)		(250.8)		(8.6)	
Loan payments on vessel(s) and gear ($)	149.1	60	1,290.7	20	0	20
	(54.2)		(571.4)		(0)	
Vessel(s) and gear maintenance ($)	879.8	60	5,648.1	20	2,139.3	20
	(130.1)		(1,372.3)		(531.8)	
Fish traps maintenance and repairs ($)	1,302.9	60	1,694.0	20	1,189.1	20
	(496.0)		(286.7)		(278.2)	
Lobster traps maintenance and repairs ($)	125.7	60	770.4	20	0	20
	(31.9)		(400.8)		(0)	
Supplies ($)	3.7	60	0	20	861.1	20
	(1.7)		(0)		(239.7)	
Other expenditures ($)	35.3	60	323.1	20	0.2	20
	(22.8)		(235.9)		(0.2)	

management proposals. The presence of a diverse fish trap fishery suggests that its participants may respond in different ways to the same regulatory proposals and constraints. Thus, failing to account for this structural heterogeneity may bring about unforeseen, unintended consequences. For example, in Maine's lobster fishery, regulations aimed at limiting the number of traps had the opposite effect, despite having wide industry support (Acheson, 2001; Acheson and Taylor, 2001). The existence of pointed regional differences in terms of commitment to the fishery and capital investment resulted in a net increase in the number of traps in the fishery (Acheson, 2001). Because the proposed caps primarily constrained large-scale operations, many medium- and small-scale operators were free to build their operations lured by plentiful stocks (Acheson and Taylor, 2001).

In the U.S. Caribbean, knowledge of demographic characteristics, livelihood strategies, fishing practices and capital investment may assist in the identification of effective management policies by anticipating the different incentives and constraints faced by the various segments of the industry. For example, management measures that would primarily rely on input controls, gear restrictions, and area or season closures to rebuild stocks and protect habitat will likely disproportionally impact those segments of the industry with high levels of fishing commitment particularly those with sizable, non-malleable capital investments such as the St. Thomas/St. John based fleet. This fleet will be the most prone to revise their annual and fishing practices to offset any forgone revenue brought about by these types of management measures. Adjustments to the annual round could be onerous because of the additional knowledge and skills required to operate new fishing gears and target new species (e.g., breeding patterns, feeding habits, migration patterns). In contrast, Puerto Rican fishermen, who have diverse livelihood strategies, will likely be better able to withstand fluctuations in fishing revenue because of their ability to straddle between fishing and non-fishing occupations. However, because previously non-remunerated household labor is increasingly participating in wage markets, Puerto Rican trap fishermen are becoming more vulnerable to resource and market fluctuations.

Socioeconomic assessments such as the present study can provide useful information for establishing benchmarks and developing economic models which identify

and analyze the benefits and costs of management proposals and provide insight into the distributional impacts of these proposals. Sound socioeconomic analyses can also help articulate policy decisions and potentially minimize objections to new policies based on political and equity grounds.

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Literature Cited

Abgrall, J. F. 1974. A cost-production analysis of the trap and hand line fishing in Puerto Rico. Ph.D. Dissertation. University of Rhode Island. Kingston, Rhode Island. 196 p.

Acheson, J. M. 2001. Confounding the goals of management: response of the Maine lobster industry to a trap limit. N. Am. J. Fish. Manage. 21: 404–416.

_____ and L. Taylor. 2001. The Anatomy of the Maine lobster comanagement Law. Soc. and Nat. Res. 14: 425–441.

Agar, J. J., M. Shivlani, J. R. Waters, M. Valdés-Pizzini, T. Murray, J. Kirkley, and D. Suman. 2005. U.S. Caribbean Fish Trap Fishery Costs and Earnings Study. NOAA Tech. Memo. NMFS-SEFSC- 534, 127 p.

Brownell, W. N. 1972. Fisheries of the Virgin Islands. Comm. Fish. Rev. 33: 15–22.

_____ and W. E. Rainey. 1971. Research and development of deep water commercial and sport fisheries around the Virgin Islands plateau. Contribution No. 3, Virgin Islands Ecological Research Station, Caribbean Research Institute, College of the Virgin Islands. St. Thomas, U.S.V.I. 88 p.

Collazo, J. and J. A. Calderon. 1988. Status of the Fisheries of Puerto Rico 1979-1982. CO-DREMAR Technical Report. 1: 1–30.

Fiedler, R. H. and N. D. Jarvis. 1932. Fisheries of the Virgin Islands of the United States. Bureau of Fisheries. Invest. Report No.14. 32 p. Washington, DC.

Griffith, D. C. and M. Valdés-Pizzini. 2002. Fishers at Work, Workers at Sea: A Puerto Rican Journey Through Labor and Refuge. Temple Univ. Press, Philadelphia. 256 p.

_____, M. Valdés-Pizzini, and C. García-Quijano. 2007. Entangled Communities: Socio- economic Profiles of Fishers, their Communities, and their responses to marine protected measures in Puerto Rico. NOAA Series on U.S. Caribbean Fishing Communities. NOAA Tech. Mem. NMFS-SEFSC-556, 524 p. Agar, J. J. and B. Stoffle (editors)

Hill, J. R. 1969. A Business Approach to Commercial Fishing in the U.S. Virgin Islands. M.S.Thesis. Inter-American University, San Juan, Puerto Rico.

Iñigo, F. 1968. El Fomento de la Industria Pesquera en Puerto Rico y sus Perspectivas. Agricultura al Día, Puerto Rico, 15: 116–119.

Jarvis, N. D. 1932. The Fisheries of Puerto Rico. Bureau of Fisheries. Inv. Report No. 13. 41 p. Washington, DC.

Kahn, R. A. 1948. Economics of Production in Puerto Rico. Proc. Gulf Carib. Fish. Inst. 1: 33–39.

Kojis, B. 2004. Census of the Marine Commercial Fishers of the U.S. Virgin Islands. Dept. of Planning and Natural Resources. U.S.V.I. Division of Fish and Wildlife. St. Thomas, U.S.V.I. 78 pp. Available from: http://www.vifishandwildlife.com/Fisheries/FisheriesReports/2004/CommFisherCensus004.pdf via the Internet. Accessed 15 January 2008.

Matos-Caraballo, D. 2000. Overview of Puerto Rico's Small-Scale Fisheries Statistics 1994–1997. Proc. Gulf Carib. Fish. Inst. 51: 215–231.

_____ and Z. Torres Rosado. 1989. Comprehensive Census of the Fishery of Puerto Rico. CODREMAR Technical Report. 1: 1–55.

_____, M. Cartagena-Haddock, and N. Peña-Alvarado. 2003. Comprehensive Census of the Marine Commercial Fishery of Puerto Rico 2002. Proc. Gulf Carib. Fish. Inst. 56: 97–110.

Milon, J. W., S. L. Larkin, D. J. Lee, and N. Ehrhardt. 1999. A Bioeconomic Analysis of the Florida Spiny Lobster Fishery. SGR 117, Gainesville: Florida Sea Grant College Program.

Olsen, D. A. and J. A. LaPlace. 1981. Demonstration of Advances in Virgin Islands Small Boat Fishing Techniques. Mar. Fish. Rev. 43: 11–15.

_____, R. S. Wood, W. Tobias. 1982. A Preliminary Economic Analysis of the Costs and Returns of Commercial Fishers Using Fish Traps Along the Insular Shelf of the U.S. Virgin Islands. Department of Conservation and Cultural Affairs, USVI Division of Fish and Wildlife. St. Thomas, U.S.V.I. 23 p.

Perez, R. 2005. The State and Small-Scale Fisheries in Puerto Rico. Univ. Press of Florida, Gainesville. 218 p.

Sadovy, Y. and A.-M. Eklund. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792) and the Jewfish, *E. itijara* (Lichtenstein, 1822). NOAA Technical Report NMFS No.146, and FAO Fisheries Synopsis 157 p.

Schärer, M. T., M. C. Prada, R. S. Appeldorn, R. Hill, P. Sheridan, and M. Valdés-Pizzini. 2004. The use of fish traps in Puerto Rico: current practice, long-term changes, and fishers' perceptions. Proc. Gulf Carib. Fish. Inst. 54: 744–756.

Sheridan, P., R. Hill, and B. Kojis. 2006. Trap Fishing in the U.S. Virgin Islands: How and where effort is exerted. Proc. Gulf Carib. Fish. Inst. 57: 175–188.

_____, R. Hill, G. Matthews, and R. Appeldoorn. 2003. The effects of trap fishing in coralline habitats: What do we know? How do we learn more? Proc. Gulf Carib. Fish. Inst. 54: 1–12.

Swingle, W. E., A. E. Dammann, and J. A. Yntema. 1970. Survey of the commercial fishery of the Virgin Islands of the United States. Proc. Gulf Carib. Fish. Inst. 20: 110–121.

Sylvester, J. R. and A. E. Dammann. 1972. Pot fishing in the Virgin Islands. Mar. Fish. Rev. 34: 33–35.

Tobias, W. 2004a. Netfishing Overview — St. Croix, U.S. Virgin Islands Management Implications for Restrictions on the Use of Gill and Trammel Nets. Division of Fish and Wildlife, Dept. of Planning and Natural Resources, U.S. Virgin Islands. 10 p.

_____. 2004b. Status of Reefs and Reef Resources. Division of Fish and Wildlife, Dept. of Planning and Natural Resources, U.S. Virgin Islands. 11 p.

Trumble, R., J. J. Agar, and W. Keithly. 2006. Workshops to Assess Fishers' Attitudes Toward Potential Capacity and Effort Reduction Programs in the U.S. Caribbean. Proc. Gulf Carib. Fish. Inst. 57: 149–159.

U.S. Census Bureau. 2008. Unemployment Statistics for Puerto Rico. Available from: http://www.census.gov/compendia/statab/tables/08s1290.pdf via the Internet. Accessed 15 January 2008.

U.S. Virgin Islands Bureau of Labor Statistics. 2008. Unemployment Statistics for St. Croix. Available:http://www.vidol.gov/Units/BLS/stxLabor.htm. via the Internet. Accessed 15 January 2008.

Valdés-Pizzini, M. 1985. Social Relations of Production in Puerto de La Corona: Capitalism and Development of Puerto Rican Fisheries. Ph.D. Diss. State University of New York at Stony Brook. 517 p.

_____, A. Acosta, D. C. Griffith, and M. Ruíz-Peréz. 1992. Assessment of the Socioeconomic Impact of Fishery Management Options Upon Gill Nets and Trammel Nets Fishermen in Puerto Rico: Interdisciplinary Approach (Anthropology and Fisheries Biology) For the Evaluation of Management Alternatives. S-K Final Report submitted to the National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Florida.

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